ROADMAP

Rethinking of antimicrobial decision-systems in the management of animal production

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Report about socio-technical solutions to reduce AMU at farm level

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About the ROADMAP research project

The overall aim of ROADMAP is to foster transitions towards prudent use of antimicrobials (AMs) in animal production in different contexts to manage antimicrobial resistance (AMR). Prudent antimicrobial use (AMU) will be achieved by enhancing antimicrobial decision-systems along the food and drug supply chains. ROADMAP will focus on supporting animal health and welfare through prevention and health promotion actions.

AMR is recognized as a significant threat to global public health and food security. Overuse and improper use of AMs in many parts of the world contribute to the emergence and spread of AMR. Although human and animal health require AMs, it has been estimated that two thirds of the future AMU growth worldwide will be in animal production. Improving the management of AMU in farm animals is therefore a critical component of dealing with AMR and optimizing production in the livestock sector. Nevertheless, the variety of contexts of AMU in the livestock sector is a major challenge to managing AMR. **There is no "one-size-fits-all" solution to improve AMU and strategies must be contextually developed** (for instance, strategies used in the Danish pig industry are difficult to adapt and adopt in the French free-range poultry farming). Successful solutions must be combined and tailored to the production systems and the social and economic context in which they operate.

ROADMAP will meet three general objectives, in line with the EU AMR Action plan: i) Rethink AM decision-systems and animal health management; ii) Develop options for encouraging prudent AMU in animal production; iii) Engage all actors in the food and drug supply chains in fostering a more prudent use of AMs.

Project consortium

Part. N°	Participant organisation name (acronym)	Country
1	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE) **	France
2	Association de coordination technique agricole (ACTA) ***	France
3	Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) **	France
4	University of Liverpool (ULIV) *	United Kingdom
5	Cardiff University (CU) *	United Kingdom
6	James Hutton Institute (HUT) **	United Kingdom
7	Alma Mater Studiorum - Università di Bologna (UNIBO) *	Italy
8	Aarhus Universitet (AU) *	Denmark
9	Eigen Vermogen van het Instituut voor Landbouw en Visserijonderzoek (EV-ILVO) **	Belgium
10	Research Institute of Organic Agriculture (FiBL) **	Switzerland
11	Stichting Wageningen Research (WR) *	Netherlands
12	Swedish University of Agricultural Sciences (SLU) *	Sweden
13	Southern Agriculture and Horticulture Organization (ZLTO) ***	Netherlands
14	European Forum of Farm Animal Breeders (EFFAB) ****	Netherlands
15	Fundacion Empresa Universidad Gallega (FEUGA) ****	Spain
16	Dierengezondheidszorg Vlaanderen (DGZ) ***	Belgium
17	INRAE Transfert (IT) ****	France

** Universities/veterinary schools*
*** Research institutes specialized in both fundamental and applied agricultural and veterinary sciences*
**** Public and private advisory services Organisations*
***** Knowledge transfer and Innovation organisations*

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List of acronyms and abbreviations

AIA ANAS	Associazione Italian Allevatory – Italian Association of Pig Breedes
ADKAR Model	ADKAR is an acronym that represents the five building blocks of successful change for an individual: Awareness of the need for change; Desire to participate and support in the change; Knowledge of what to do during and after the change; Ability to realize or implement the change as required; Reinforcement to ensure the results of a change continue.
AIFA	Agenzia Italiana del Farmaco
AM	Antimicrobial/Antibiotic
AMU	Antimicrobial us/Antibiotic use
AMR	Antimicrobial resistance
copa-cogeca	Copa (Committee of Professional Agricultural Organisations) and Cogeca (General Confederation of Agricultural Cooperatives) are the united voice of farmers and agri-cooperatives in the EU.
DISARM	It is a project launched in January 2019 and funded by the EU Horizon 2020 research and innovation programme. DISARM stands for Disseminating Innovative Solutions for Antibiotic Resistance Management
Ecoanti-bio	Plan national de réduction des risques d'antibiorésistance en médecine vétérinaire (2017 – 2021) – National plan to reduce the risk of antibiotic resistance in veterinary medicine
EFSA	European Food Safety Authority
EMA	European Medicines Agency
ESVAC	European Surveillance of Veterinary Antimicrobial Consumption. It collects information on how antimicrobial medicines are used in animals across the European Union (EU).
FNOVI	Federazione Naziolale Ordine Veterinary Italiani
HPCIA	Highest Priority Critically Important Antimicrobials
ISS	Istituto Superiore di Sanità
IZSLER - CRENBA	Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna - Centro di Referenza Nazionale per il Benessere Animale
IZS	Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "Giuseppe Caporale" is a **public health institute** with administrative and managerial autonomy, **which operates as a technical and scientific arm of the state and the Abruzzo and Molise Regions**
PCU	PCU refers to the 'Population Correction Unit' and takes into account the animal population as well as the estimated weight of each particular animal at the time of treatment with antibiotics.

SIVAR	Società Italiana Veterinari per Animal da -reddito
SBV	Stichting Brancheorganisatie Kalversector -Branch Organisation Calf Sectors
Svarm-Pat	Samarbetsprogram för antibiotikaresistensövervakning - focus on antimicrobial resistance in animal pathogens
UN-AITALIA	Unione Nazionale Filiere Agroalimentari is the trade association that promotes and represents the Italian agri-food supply chains for meat and eggs and represents over 90% of the entire national poultry chain and a very large slice of the swine sector.

1 Summary

In this deliverable report we collected different strategies to reduce AMU in countries across Europe and beyond. We planned to collect mainly social or economic approaches. In the countries investigated, we found rarely participatory or multi-actor approaches. Since many technical approaches are implemented, some examples are also included in this compilation.

In most of the countries investigated, the main driver for change is policy. Often, the implemented policies involve surveillance, replacing AM with different approaches but also by investing in training and education.

In Sweden a national strategy, increased surveillance, a contract between the veterinarian and the farmer, import requirements and strict disease control are part of their strategy regarding AMR. In Italy the strategy is mainly focused on education of veterinarians and farmers. In 2016, also in Switzerland, a national strategy for a more prudent AMU is implemented. The same counts for the UK, who on top of that also pays attention to the rules for suppliers and promotion of vaccinations. France has a national program and retailers and private brands are developing their own labels. The Netherlands also has their national strategy to register the Animal Daily Doses used, but most of the strategies are organized from the private sector on a project basis in different sectors, but with an obligation from government on monitoring the antibiotic use. The same counts for Switzerland, there are for example a project about a preventive concept on dairy farms to strengthen young calves for their live on veal calf farms. The strategy of Denmark is mainly government-led, including reinforcements and restrictions. In Mozambique, only a best practice guide is developed by the government.

As described above, there is a variation in the level of influence found amongst the national strategies: this ranges from an impact on the whole livestock production system e.g. when data about AMU is needed or vets are not allowed to sell AM based on the introduction of a new regulation. And some government made changes at a very specific level, such as an agreement between the veterinarian and the farmer.

But there are also examples, where alternative systems are developed outside the existing system (mother-calf systems) or inside the existing production system (e.g. labelling AM-free meat for the consumer segment interested in such products).

We observed, that countries invest in research to improve the use of AM and explore different strategies for a transition to a more prudent use. However, we see rarely, that the outcome of the projects is translated into an improved practice, specifically, if there is a need to re-think the existing livestock-system.

Beyond the case study countries, strategies to reduce AMU were identified in Canada, the US, New Zealand, Australia, Iran, India, China, Poland, Hungary, Ireland and Germany. We found similar patterns: Implementation of new policies (e.g. Germany, Canada, or Australia) and, connected to the strategy improvement of monitoring, data collection about AMU and AMR, technical changes to improve biosecurity and replacement of existing AM with plant products. In almost all countries, information, education, training and coaching of livestock farmers and vets play a relevant role.

In some countries, there are consumer labels established, that inform about the non-use of AM in the production. Depending on the actors, who implements the AM-free label, these strategies impact a whole value chain. For this transition, farmers need support, which is not always provided.

2 Introduction

In 2017, experts from the European Food Safety Authority (EFSA) and the European Medicines Agency reviewed the antimicrobials use in animals. In their analysis, they concluded, that successful strategies follow an integrated, multifaceted approach which consider the local livestock production system and involves all relevant stakeholders - from governments to farmers. Moreover, they stated, that there is a need to re-think the livestock system by implementing farming practices that prevent the introduction and spread of the disease into farms and by considering alternative farming systems which are viable with reduced use of antimicrobials (EFSA 2017).

The objective of ROADMAP is to foster transitions towards prudent use of antimicrobials (AMs) in livestock production. For this transition to occur, different developments have to take place, from new practices and technologies up to guiding principles and values (Sutherland et al. 2017). A transition towards more prudent use of AM need a societal, ecological, economic, cultural, technological and institutional co-evolution (Loorbach et al. 2009) and would affect the whole sector of agricultural production.

This perspective framed this compilation. In the context of ROADMAP and this deliverable D4.2, we explored and collected socio-technical strategies are on the livestock production in Europe and the connected use of AM. Regarding socio-technical strategies to reduce AMU, it was assumed, that such strategies may have started in niches and, in some cases, are now supported by "a cluster of elements, including technology, regulations, user practices and markets, cultural meanings, infrastructure, maintenance networks and supply networks" (Geels et al. 2004).

In this deliverable, we compiled technical, social and economic strategies implemented to improve the use of antimicrobials in different livestock species across Europe and beyond. We specifically wanted to identify *socio-technical approaches* to reduce AMU. According to Smith (2007) there are 7 dimensions to characterize the concept of *socio-technical:*

- Guiding principles;
- Technologies and infrastructures;
- Industrial structure;
- User relations and markets;
- Policy and regulations;
- The knowledge base for the regime;
- Cultural, symbolic meanings underpinning practices.

Socio-technical stands for the interaction between individuals or groups, their behaviour and technical improvement or changed practices. We specifically aimed at identifying, examples, where different actors jointly *experiment* with technologies and strategies to improve animal health and welfare and in parallel, reduce the AMU.

3 Method

3.1 Selection of countries

We assumed that countries with a low use and a high use of AM are relevant for this study. The European Medicines Agency (EMA) has been conducting and collecting data on sales of antimicrobials for veterinary use (ESVAC - European Surveillance of Veterinary Antimicrobial Consumption) since 2010.

Figure 1: Spatial distribution of overall sales of all antimicrobials for food-producing animals, in mg/PCU, for 31 countries, for 2018 (ESVAC 2020).

31 European countries participate in the survey voluntarily. Based on the actual data about overall antimicrobial sales for veterinary for food-producing animals use published by ESVAC in 2018 and 2020 (Figure 1), we selected European countries with very diverse scores and tried to find information about implemented strategies to reduce AMU.

Based on the information given in Figure 1, we selected the following countries in Europe:

- Low use of AM: Sweden, Denmark
- Due to a reduced use of AM: Germany, Austria, France, the Netherlands, Belgium
- Due to a high use of AM: Italy, Hungary, Poland.

To select countries beyond Europe, we used the same approach but focussed on countries which are above or below a target value of 50 mg antibiotic use per kg of meat production (50mg/PCU). PCU

refers to the 'Population Correction Unit' and considers the animal population as well as the estimated weight of each particular animal at the time of treatment with antibiotics.

This selection of the countries was done based on information from the website www.our-worldindata.org (Figure 2)

- Countries above 50 mg/PCU are USA, Iran, China, Canada
- Countries below 50 mg/PCU are Australia, New Zealand, Mozambique, Ethiopia

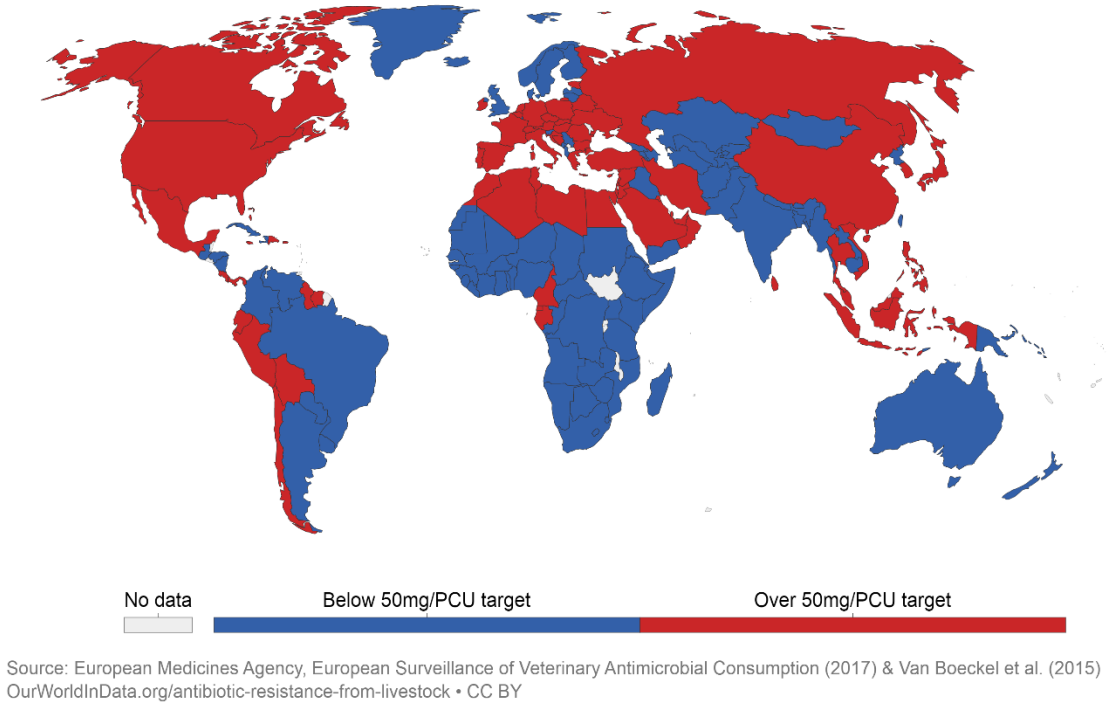

Figure 2: Antibiotics used in livestock production above or over a potential target value of 50 mg/ kg meat (50 mg/PCU)

The selected countries were looked for a governmental strategy and the implemented measures, for economic incentives to reduce AMU or research programmes.

3.2 Data collection

The compilation was done based on desk research, questionnaires and expert interviews conducted in 2020 (Table 1). We excluded approaches that focused on improving animal welfare without giving information on AMU, but approaches in animal welfare implement or improve disease-prevention were include e.g. mother-calf-systems. We also could not go in depth in collecting innovations by farmers. But if in the documents or conversations of innovations by farmers were mentioned, they were included in this compilation.

The document aims at giving a comparative and comprehensive overview of strategies at different levels: farm, value chain, policies. In addition, we conducted questionnaires and supplementary exchanges with all 10 ROADMAP Country Leaders and we conducted expert interviews. The aim of this compilation is to inspire the co-creation of strategies in the Living labs in WP3 and WP4.

The collected information was screened for concrete measures and structured them based on the approached used e.g. technical improvement, social approaches including animal welfare, economic incentives and combinations of them.

Moreover, Deliverable D4.2 adds to the research done in WP 1 of ROADMAP, where policies implemented in the different countries that are represented in ROADMAP, are compiled. Therefore, in this document, information about the policies is not given in details.

We started with a desk study to identify specifically socio-technical strategies to reduce AMU in the selected countries. The following questions where relevant

- Are there policies implemented about AMU?
- What kind of policy instruments are implemented (e.g. surveillance, monitoring, prohibition, education, research).
- Are there examples of socio-technical solutions implemented by the government?
- Are there examples of socio-technical solutions implemented by market actors to reduce AMU?
- Are there other examples of socio-technical solutions implemented by other actors e.g. farmers organisations, vets, research programmes?

In addition, questionnaires were completed by the 10 ROADMAP Country Leaders in order to collect information about the strategies to reduce AMU in their countries. There were additional email conversations to ask for additional information. In the cases of Switzerland, Belgium, UK, Germany, Iran, USA, Hungary, Ethiopia, we could conduct additionally expert interviews. For the interviews, the following questions were relevant

- Are you working on Antimicrobial Resistance (AMR) or/and reducing Antimicrobial Use (AMU)?
- Which kind of programs / strategies did you implement? Surveillance, awareness raising / training of farmers or vets / supply chain approaches e.g. labelling for AM-free production?
- How successful were these strategies?

The collected information was structed using the 7 dimensions of socio-technical identified by Smith (2007).

Table 1: Desk research and expert interviews took place in 22 countries. The compilation of data was not aimed to be complete in the countries. But we aimed at collecting ideas from different contexts.

Country		**Desk research**	**Expert Interviews**
Roadmap Partners		Data provided by LL -Leaders	
Sweden	SE	X	
Italy	IT	X	
UK	UK	X	X
France	FR	X	
The Netherlands	NL	X	X
Denmark	DK	X	
Switzerland	CH	X	X
Belgium	BE	X	X
Other European countries			
Austria	AT	X	
Germany	DE	X	X
Hungary	HU	X	X
Ireland	IE		
Poland	PL	X	
Beyond Europe			
Australia	AU	X	
Canada	CA	X	
China	CN	X	
Ethiopia	ET	X	x
Iran	IR	X	X
India	IN	X	
Mozambique	MZ	X	
New Zealand	NZ	X	
USA	US	X	X

4 Results Part I – Country Reports from Europe - What socio-technical strategies are in place to facilitate AMU reduction

4.1 Sweden

Sweden[1] has been gathering data on sales of antimicrobials for the use in animals since 1980. The gathered data includes sales from pharmacies to animal owners (prescription dispensed) and to veterinarians (requisition based). Pharmacies are compelled to report their sales to the e-Health Agency who maintain a database. Furthermore, veterinarians are required to report their use of medicinal products (including antimicrobials) to the Swedish Board of Agriculture. Principles for use of AM in Sweden are

- Antibiotics should only be used to treat diseases with bacterial etiology or when a bacterial etiology is strongly suspected;
- Diagnosis of bacterial infection accompanied by sensitivity testing should precede treatment whenever possible
- When treating bacterial infections in production animals the ambition should always be to use products with a narrow antibiotic spectrum
- When treating group of animals an etiological diagnosis should be obtained and a treatment plan established
- When high treatment rates are discovered, the underlying reasons/predisposing factors should be investigated and corrected by means of preventive measures whenever possible

When implementing the policy, also the market actors changed their attitude towards a restrictive use of antibiotics, dealing with the transition from a closed agricultural market to a free one with the entry into the EU in 1995. To specialize in providing the country's own citizens with safe and healthy foods was seen as a way for the industry to assert itself on this new competitive market.
Thanks to national control programs, organized health surveillance and comprehensive import control, Sweden has managed to eradicate or prevent introduction of several serious diseases causing animal suffering, economic losses or that poses a potential risk for human health. Health controls of imported animals are long-standing. In addition to strict health controls during import Sweden also has national control programs for *Salmonella* and *Campylobacter* as well as for other diseases/infectious agents such as Maedi Visna (MV) in sheep and Caprine Arthritis Encephalitis Virus (CAE) in goats, Porcine Reproductive and Respiratory Syndrome (PRRS) in pigs. Strict import conditions together with control and surveillance programs have contributed to the fact that Sweden today is free of many devastating conditions in farm animals.

Further information about the AM policy and legal background for the use of AM is available in June 20210 based on a compilation done in Work Package (WP) 1, Deliverable D1.3 "The regulatory framework of AMU in livestock farming and its evolution" from the Roadmap website www.roadmap-h2020.eu

[1] The information compiled in this chapter is based on the Study from Grudin et al. 2020.

4.1.1 Selected socio-technical strategies to reduce AMU in Sweden

Targeted species	Strategy	Socio-technical dimensions identified
Cattle Sheep Pigs General	Svarm-PAT: One Health national strategy led by the Swedish board of agriculture with seven objectives: (1) increased knowledge through enhanced surveillance, (2) continuous strong preventive measures, (3) responsible use of antibiotics, (4) increased knowledge for preventing and managing bacterial infections and antibiotic resistance with new methods, (5) improved awareness and understanding in society about antibiotic resistance and countermeasures, (6) supporting structures and systems and (7) leadership within the EU and at the international cooperation.	Implementation of guiding principles and policies for prevention and surveillance of AMR; Increase the knowledge base by monitoring of pathogens and AMU. New practices / techniques
General	Farmers working with certain species of animals (i.e. dairy or beef cattle, pigs, sheep, goats, poultry or fur animals) can choose to sign a contract with a veterinarian for "conditional use of veterinary medicinal products". This contract enables them to identify and treat specified clinical conditions with a limited range of veterinary medicinal products. Farmers wishing to enter such a contract need to take an educational course approved by the Swedish Board of Agriculture and the veterinarian must perform regular control visits on the farm (about every 5 weeks). Certain criteria must be met at farm level with regards to animal health and welfare and the use of medicinal products if the contract is to be valid. These criteria and regular on-farm visits from the veterinarian motivate a focus on preventive work.	Improved practices e.g. targeted and informed collaboration between farmers and vets. Changing relations between vets and farmers. Changing the culture between vets / farmers.
General	Swedish Farmer´s Disease Control Program (SFD) is a producer-owned import control. They have established additional voluntary import requirements, consequently demanded by the importing farmer or company, in addition to the official requirements set by the Swedish Board of Agriculture. These import requirements must be followed in order to be allowed to send animals to the slaughterhouses and to deliver milk to the dairy plant.	Changing markets e.g. imports.
General	If salmonella is detected in a farm level, several various measures are initiated[33]. How this is done depends on animal species, type of production, salmonella type etc.	Policy and regulations e.g. Restrictions on facility, blocking all movements, Eradication plan Changing practices by enforcing hygiene- and management routines

4.1.2 References

Grundin, J., Blanco Penedo, I., Fall, N., & Sternberg Lewerin, S. (2020). ” The Swedish experience”–a summary on the Swedish efforts towards a low and prudent use of antibiotics in animal production. Uppsala, SLU Framtidens djur, natru och hälsa, ISB978-91-576-9745-5 (elektronisk), 978-91-576-9746-2 (tryckt)

4.2 Italy

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.2.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Dimensions identified
General, poultry, dairy, pigs, rabbits	Research projects and education, trainings of veterinarians regarding proper use of antibiotics about: • The interpretation of in vitro chemo-antibiotic sensitivity tests for use in clinical therapy • Responsible use of the veterinary drug and for the fight against antibiotic resistance in poultry farming • Prudent use of veterinary medicines and for the fight against AMR in rabbit breeding • Prudent and rational use of antibiotics in livestock production • Diagnostics and sensitivity testing to detect bovine mastitis • "Wisdom pills for the veterinary practitioner": Guidance for the veterinary practitioner on key aspects concerning some antimicrobial classes • Antimicrobial resistance, prudent use of antimicrobials and 'One Health' • Brochures and posters • "Assessing of AM use in veterinary medicine to prevent AMR" • Prudent use of antimicrobials in livestock farms to prevent AMR and alternative solutions; prudent use of antimicrobials in dairy cattle breeding, swine breeding and in pets • "From the choice to the responsible use of medicines in bovine breeding" • "AMR: current issues and commitment for the future" Driven by IZSLT-CRAB, UNAITALIA, SIVAR, FNOVI, Ministry of Health, ISS, AIFA, Regional Veterinary Service of Emilia Romanga, University of Milan, IZS.	Implementation of guiding principles and policies for prudent use; Improvement in technologies and infrastructure Increase the knowledge base by monitoring of pathogens and AMU. Training and education for new practices / techniques Changing the culture of AMU Awareness raising
General, pigs, dairy, poultry, buffalos, rabbits	• Education of farmers and veterinarians on the prevention on the use of antibiotics (biosecurity, additives, vaccination) about: • "Biosecurity and proper and rational use of antibiotics in livestock production"	

	• Good practice for swine breeding, dairy cattle breeding, buffalo breeding, rabbit breeding • Welfare of animals reared (laying hens, broilers) • Manual of good hygiene practice for the prevention and control of pathogenic microorganisms with particular reference to salmonella in the Gallus gallus species (broilers) bred to obtain poultry meat - on farms, and during capture, loading and transport • "Technological innovation in poultry farming as a tool to improve animal health and welfare and reduce the use of antimicrobials" Driven by IZSLT-CRAB, Ministry of health, IZS, AIA-ANAS, Regional Veterinary Service of Piemonte, AVEC, COPA-COGECA.	
Pigs, poultry, dairy, beef cattle	Education of farmers and veterinarians on animal welfare, with special attention to prevention on aggressive behaviour in animals about: • The evaluation of animal-based parameters related to pig welfare • Feeding and welfare of pregnant sows: the promotion of interventions aimed at improving the welfare of sows through a correct feeding regime • Downer cow syndrome • Technical certification of poultry meat producer • Evaluation of welfare and biosecurity in dairy cattle breeding, veal production and beef production • Prevention of tail cutting in pig breeding from weaning to fattening, categorizing risks in breeding pig breeding and in fattening pigs Driven by IZSLER-CRENBA and UNAITALIA.	
General	Introduction of e-prescription and electronic traceability of vet AM use	
General	Introduction of a farm classification system based on risk for AMR.	

4.3 The UK

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.3.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimensions identified
General	Government-driven education provided to veterinarians and farmers	General principles for prudent use New practices / techniques Awareness raising
General	Rules for suppliers (farmers) imposed by retailers regarding their use of antimicrobials (eliminating routine, ban of particular type of antimicrobials, issuing protocols, providing education). Example: Red Tractor food standards scheme (Traceable, Safe and Farmed with Care).	User relations and markets
General	Government-driven promotion of vaccination against certain diseases	General principles for disease prevention New practices / techniques
Pigs	An alliance of farmers and industry called the Agriculture and Horticulture Development Board (AHDB) developed an interactive disease management app for pig farms (AHDB, 2020). The Think Bio Risk App aims to inform farm workers about good practice and common mistakes on pig farms regarding disease prevention. By using interactive video scenarios and quizzes, the tool trains good disease management on pig farms.	New practices / techniques
Calves	As part of the DISARM project, a farmer in Dorset UK adapted her calf pens. The design features include ventilation tubes, a cambered central area and sloped calf pens. In general, the design was oriented in order to be easily cleaned. Among the benefits of the stable redesign were cut mortality rates and less medical treatments. (see also: https://www.youtube.com/watch?v=nq733Iw54P8).	New practices / techniques Cultural change towards animal health and care
Dairy cows	The Welsh government support programme called "Farming Connect" offers business support to farms in order to improve their management systems and business case. Among these projects is the "Antibiotic awareness project" on dairy farms. The project included dairy farmers, scientists and vets. Core of the project were data collection of AMU on farm. By analysing the AMU data, measures to improve management and herd	Increase knowledge base New practices / techniques Changing the culture between farmers / vets

	health were developed. The exchange between the vet, scientists and farmer proved to be very important. The programme supported one focus dairy farmer to reduce her AMU by 30%.	

4.3.2 References

AHDB. (2020). Home Think BioRisk website. Retrieved from http://thinkbiorisk.pork.ahdb.org.uk/

Business Wales. (2020). Focus Site Project: Antibiotic Awareness Project. Retrieved from https://businesswales.gov.wales/farmingconnect/our-farms/projects/goldsland-farm

Innovation for Agriculture (Producer). (2020). Designing Buildings to Improve Calf Health. Retrieved from https://www.youtube.com/watch?v=nq733Iw54P8

4.4 France

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.4.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimension identified
General	Government-led Ecoantibio program, which focuses on: • Fostering preventive measures and alternative medicines • Communication and awareness about AMR, prudent use of antimicrobials and alternatives • Steering • European and international governance and control in France Stakeholders of each value chain are voluntary involved. There is a strong involvement in research and the development of new alternative for antibiotics on the one hand and on training of farmers and advisors on the other hand.	New guiding principles e.g. prevention and alternative medicines Increase knowledge base Changing policies and regulations Improved culture of collaboration
General	Private brands and retailers are showing their effort in AMR by labelling of products (antibiotic free, health specifications to farmers)	Changing user relations and markets
Dairy cows	The French Higher Education establishment for training, research and support for agricultural education (ENSFEA) developed an interactive documentary around the problem of AMU and AMR in dairy cow systems. The objective is to provide teaching material for zootechnics teachers at agricultural education institutions. The material gives a broad perspective on the topic of AM in society and in dairy cattle systems.	Guiding principles for the use of AM.

4.4.2 References

ENSFEA. (2020). Nouvelle ressource numérique en ligne. Retrieved from http://www.ensfea.fr/2019/05/22/nouvelle-ressource-numerique-en-ligne/

4.5 The Netherlands

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.5.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy / Research	Measures
Pigs	The initiative of ZLTO called "Optimaliseren Diergezondheid varkenshouderij" (Optimizing Animal Health in Pig Industyy) supports farmers in reducing their antibiotic use with the aid of a multi-actor coaching method. The farmer, veterinarian and feed advisor work together on an action plan under the supervision of a coach.	Changing the culture between vets / farmers New practices / techniques
Veal calves	With the 'Ontvangst Kalveren' (Receiving Calves) project, the veal calf sector wants to improve the reception of sober calves at the veal calf farm. The project focuses on the management of the veal calf farmer during the first four weeks of the newborn calves in the barn, including releasing the calves in groups. In order to support veal farmers in their efforts to improve the reception of new calves, SBK, the project's implementer, is expanding the Farm Health Plan (BGP) for veal farmers with a separate chapter on calf reception.	New practices / techniques A culture of joint learning
Veal calves	The dairy companies introduced the KalfOK initiative at the beginning of 2018 to further improve the health and welfare of calves. Around 13,775 dairy companies have now authorised their dairies to collect the necessary data for this purpose. Twelve key indicators come together in the KalfOK score. Each farm can score a maximum of 100 points. Dairy farmers can compare the results with each other, with averages and with target values. In this way KalfOK stimulates the improvement of the health and welfare of the calves.	Introduction of calf health as guiding principle in the dairy sector. Increase knowledge base
Broilers, Pigs, Dairy	Hycare is a hygiene management method of the company MS Schippers aiming at improving biosecurity. Reducing antibiotic use is the main goal of this approach. Measures are carried out with regard to barn design as well as in farm management. E.g Pore-free surfaces, thorough cleaning and disinfection process of living environment, cleaning drinking water, pest prevention, facilitating optimal working method	Introduction of biosecurity as guiding principle in the dairy sector. New practices / techniques
Dairy	Since 2012 it is compulsory to register the use of antibiotics on every cattle farm in the national database MediRund. This allows to calculate the Defined Daily Dose Animal (DDDA) per animal per year (DD/DJ) at farm level. These levels are used for benchmarking. For the thresholds a traffic light coding system is implemented (green: ok, orange: requires attention, red: requiring immediate action). If the DD/DJ remains too high, milk will no longer be collected.	Introduction of a prudent AMU as guiding principle in the dairy sector.

4.6 Denmark

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.6.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy / Research	Measures
Pigs	Government-led research plan in the veterinary field 2018-2021. All studies are expected to support a continued reduction in antibiotic consumption in Danish pig production. Examples: Raising pigs with reduced use of antibiotics, optimal use and alternatives for antibiotics, use op probiotics.	Increase the knowledge base by monitoring of pathogens and AMU. Research
Pigs	With the initiative of Danish Crown, called OUA (Opdrættet uden AB – Raised without antibiotics), Farmers are given a higher price for pigs if they can guarantee that the pigs never have never been treated with AM.	User relations and markets
Pigs	Restriction on having an advisory agreement with a veterinarian, who regularly visits him and gives advise how to prevent disease	Policy and regulations
General	Government penalizes farmers who use more antibiotics than a defined level	Guiding principles for a prudent use of AM Policy and regulations

4.7 Switzerland

The StAr (Strategies to reduce Antobiotic Resistance Switzerland) initiative, led by the government, has developed various strategies in monitoring, prevention, appropriate use of antibiotics, resistance control, research and development, cooperation, information and education, and general conditions in antibiotic use. In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.7.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimension
All	STAR Strategie Antibiotikaresistenz - Strategy on Antibiotic Resistance. The aim is to ensure that antibiotics remain effective in the long term and to curb the development of resistance. This strategy approved by the Federal Council to combat antibiotic resistance is being pursued in the areas of human and animal health and the environment.	Implementation of guiding principles of maintaining the effectiveness of antibiotics for humans and animals, and combating resistance. Increase the knowledge base by monitoring of AMR, AMU and specific research programmes.
Veal calves	Initiative ImproCalf tests a preventive concept on dairy farms to strengthen young calves for their live on veal calf farms covering mineral supply, vaccination, shelter and access to unlimited feed/milk (Rell et al. 2019). The project is driven by VetSuisse faculties, HAFL, Agroscope and FiBL. The approach was partly implemented by a supermarket	Increase the knowledge base about calf health and connected practices
Veal calves	In an initiative of the Swiss calf health service, Swiss organic farmers association, Bio Suisse and FiBL, farms will be visited by a veterinarian to assess antimicrobial consumption as well as the living conditions (including feeding, housing, health management) and will provide advice (www.kometian.ch)	Guiding principle for calf health and welfare New practices / techniques Private sector initiatives provide farm visits, advice
Veal calves	A broad technical multi-center on farm trial is testing a preventive concept on dairy farms to strengthen young calves for their live on veal calf farms (results are under analysis). The project is driven by VetSuisse faculties, HAFL, Agroscope and FiBL. (Walkenhorst pers. Comunication)	Increase the knowledge base about calf health and connected practices
Veal calves	Some farmers improve animal welfare and health and develop “mother-calf” systems (FiBL 2018)	Guiding principle of calf welfare and health New practices / techniques

		New culture of calf rearing
Dairy calves	Freiluftkalb "out-door calf" (NFP 72) In calf fattening operations, young animals from several herds of origin are often gathered to large groups. As a result, they pass on germs to each other that cause a large number of diseases, resulting in the use of large quantities of antimicrobial drugs. We are developing a new management concept for calves called the "outdoor calf". The animals live outdoors, initially in individual igloos that enable them to be quarantined on arrival at the fattening centre. They are later kept in small groups with igloos and a bedded and sheltered outdoor area. This exposes them to fewer pathogens and they fall ill less often. The concept was successfully tested on 20 farms.	Increasing knowledge base
Organic sector	The organic sector (Bio Suisse) informed all farmers about their strategy to reduce AM. They limit critical antibiotic active substances may now only be used on organic farms in exceptional cases for initial treatment: • Only if an antibiogram shows an antibiotic of a critical active ingredient group as the only effective antibiotic. • Only if only one antibiotic of the critical groups of active substances is effective for the disease in question and the animal species to be treated.	Guiding principles for farmers in the organic sector based on preventive measures and animal welfare Policy / regulation e.g. private standard
All	During the project KOMETIAN, advised farms should reduce their AMU by 50% within six years. The offer extension services (Hotline, farm visits) with a focus on alternative treatments. The project aims at the development of knowledge and experience with complementary medicine alternatives to antibiotic treatments	Increasing knowledge base New culture of collaboration between vets and farmers. New practices / techniques

4.7.2 References

FiBL 2018. Mother-bonded and fostered Calf Rearing n Dairy Farming. www.fibl.org

KOMETIAN 2020: Kometian - Verein

NFP 72: The "outdoor" calf – a new concept for calf fattening (nfp72.ch)

Rell, J., Wunsch, N., Home, R., Kaske, M., Walkenhorst, M., & Vaarst, M. (2020). Stakeholders' perceptions of the challenges to improving calf health and reducing antimicrobial use in Swiss veal production. *Preventive Veterinary Medicine*, 104970.

4.8 Belgium

In this paragraph we compiled an overview of the different strategies gathered from a questionnaire, desk research and interviews.

4.8.1 Selected strategies to reduce AMU

Targeted species	Strategy	Scoio-technical dimension
All sectors	Belgium is continuously committed to preventive veterinary medicine and is committed within the new action plan to coach companies towards reduced use of antibiotics	Guiding principles for a prudent use of AM
Pigs, poultry, dairy	DGZ is developing a company health plan application, which allows the company veterinarian and the livestock farmer to take targeted actions together for a step-by-step improvement of company health. If necessary, the veterinarian and the farmer can develop a targeted action plan to reduce and minimize the use of antibiotics in a sustainable way. Discussion of the results from the periodic antibiotic benchmark reports is essential for the elaboration of this action plan.	Guiding principles for animal health New practices / techniques New culture of collaboration along the value chain and between farmers and vets.
Pigs, poultry dairy	Every year the DGZ laboratory reports the results of antibiograms. Veterinarians can consult these results if the layout of a company-specific antibiogram is not possible.	Increase the knowledge base by monitoring of pathogens and AMU.
Pigs and poultry	i. Within the i-4-1-Health project, hospitals, public health services (GGD's and the Agency for Care and Health), knowledge institutions (Utrecht University, Ghent University, University of Antwerp, the Health Service for Animals, UHasselt and Avans) and two SMEs (CIDER and Applied Maths) have worked together by conducting research and comparing (local) policies and protocols for the development and validation of the Infection RIsico Scan (IRIS).In this project they tested *ADKAR model* and *Theory of situational leadership* for behavioural change to lower the antibiotic use	Increase the knowledge base by monitoring of pathogens and AMU. New practices / techniques

4.8.2 References

https://www.dgz.be/nieuwsbericht/dgz-werkt-volop-mee-aan-one-health-strategie-die-strijdt-tegen-antibioticaresistentie-

i-4-1-Health project: https://www.grensregio.eu/projecten/i-4-1-health

https://www.boerenbond.be/kenniscentrum/boer-in-de-kijker/minder-antibiotica-betere-resultaten

4.9 Hungary

According to the ESVAC-report, in 2016, Hungary us be the 5th largest consumer of AM in Europe, after Cyprus, Italy, Portugal and Spain. Between 2011 and 2016, there was only a 2.8% decrease in antibiotic use in Hungary, while total use in the EU fell by 20%.

Compared to other governmental websites (https://meddighat.hu/) visited for this study, the information about AMU or strategies to reduce AMU is very limited. It is focussing on the information, when antibiotics should not be used or could be replaced e.g.

- Minor injuries and infections can heal without antibiotics. With careful care and regular veterinary check-ups, we can help our animals recover.
- Vaccinate your animals to reduce antibiotic use, as preventing a disease saves animals from unnecessary suffering and increases costs.
- Use antibiotics only if prescribed by a veterinarian and follow the medical instructions.

Otherwise, there are many approaches to reducing or eliminating antibiotics in animal feed. The expert interviewed mentioned following approaches that are recommended:

- Raising vitamin levels (especially vitamin E) may be beneficial in some respects, but this alone may not be enough.
- Favourable production results using various organically bound microelements have attracted attention for the formulations.
- Different enzyme preparations can have a positive effect on the digestibility of certain nutrients, so they should not be forgotten as a potential option.
- Probiotics are bacterial preparations used to balance the intestinal flora, which seek to shift the pH of the intestine in an acidic direction, making the living conditions of pathogenic bacteria more difficult. These formulations may also be considered as possible alternatives, but may be sensitive to heat treatment, so this should be considered in the case of granular feeds.
- Prebiotics are products that promote the growth of beneficial bacteria and thus support the development of a favorable intestinal microbial composition. Thus, they may have a role in fighting bacteria and inducing antibiotics.
- Organic acids in the gut can shift the pH in the acidic direction and thus have a beneficial effect on the prevention of bacteria in the gut.
- Essential oils try to improve production results by stimulating the production of salivary and digestive enzymes and having a certain bactericidal effect.
- The development of herbal extracts (flavors and aromas) has recently received a great deal of energy, resulting in the emergence of numerous such preparations on the market.
- Immune stimulants can achieve an improvement in production results by strengthening and enhancing the immune system of animals.

No information is available about the fact, if thees measures are implemented by the livestock producers. The company MCS Vágóhíd Zrt has implemented the production line with reduces AMU (https://pick.hu/hu/premium/). It was jointly developed between the pig sector of the Bonafarm Group and the MCS and covered

- Pigs fattened with 100% antibiotic-free feed during fattening.
- No routine uses of growth-promoting antibiotic use.
- Responsible use of antibiotics.
- Earmark pigs treated with AM and separate them at the slaughterhouse.
- No use of antimicrobials listed by the WHO as critical with priority for humans.

Figure 3: The products of one Hungarian pork producers are labelled as AM-free. The program covers e.g. 100% AM-free fed during fattening and responsible use of AM.: https://pick.hu/hu/premium/

The socio-technical dimensions identified in Hungary cover the implementation of guiding principles and policies for a more prudent use of AM and explore alternative treatments and new practices / techniques up to the introduction of a label for AM-free products.

4.10 Germany

In Germany, the DART 2020 Strategy Deutsche Antibiotika-Resistenzstrategie (German Antibiotic Resistance Strategy) is implemented (DART 2020). It covers several livestock categories (veal calves, beef cattle, piglets, growing-finishing pigs, broiler, turkey).

The measures of the antibiotic minimization concept of the 16th amendment of the German Medicines Act include the obligation of the affected livestock farmers to provide information about their livestock and their use of antibiotics as well as the obligation for the competent authorities to calculate the operational half-yearly therapy frequency from these notifications and to submit them to the Federal Office of Consumer Protection and food safety (BVL) and the animal owner. From all the individual farm therapy frequencies determined in a half-year period, the BVL calculates the median (key figure 1) and the third quartile (key figure 2) of farm therapy frequencies every six months for each of the six types of use of the 16th AMG amendment (piglets for fattening, pigs for fattening, calves for fattening, cattle for fattening, chickens for fattening, turkeys for fattening) and publishes these nationwide key figures in the Federal Gazette at the end of March and the end of September. The comparison of the individual farm therapy frequency with the nationwide key figures published by the BVL forms the basis for further action.

The total use of antibiotics for all six types of animals decreased from 298 tons to 204 tons in the period under investigation, a decrease of 31.6 percent.

The largest reductions were achieved with pigs: fattening piglets down 46 percent (from 87.5 tons to 47.2 tons); fattening pigs down 43 percent (from 115 tons to 65.2 tons).

Fattening turkeys down 4 per cent (from 38.1 tonnes to 36.7 tonnes); broilers down 1 per cent (from 29.7 tonnes to 29.5 tonnes); veal calves down 4 per cent (from 26 tonnes to 25 tonnes).

The calculated reduction for cattle for fattening was minus 76 per cent. The quantities used in absolute terms were very low overall, at 1.7 tonnes at the beginning and 0.4 tonnes at the end of the observation period.

Reserve antibiotics were used to a small extent in pigs and cattle (each less than 10 percent of the respective quantities used). For chickens for fattening and turkeys for fattening, they accounted for about 40 percent of the respective consumption volume.

4.10.1 Selected socio-technical strategies to reduce AMU

There are several research programmes and also private initiatives to reduces AMU.

Targeted species	Strategy	Socio-technical dimension
General	In Germany, the DART 2020 Strategy Deutsche Antibiotika-Resistenzstrategie (German Antibiotic Resistance Strategy) is implemented (DART 2020). It covers several livestock categories (veal calves, beef cattle, piglets, growing-finishing pigs, broiler, turkey).	Guiding principle to contain AMR and develop a one-health perspective.

General	Time- and location-independent professional training for veterinarians working in the livestock sector (currently about 6,000) Knowledge about antibiotics, resistances and the potential for improving housing and feeding conditions and alternative management structures - preferably prepared individually for each target group www.vetmab.de	Guiding principles of hygiene, housing and management improvements in the barn.
Dairy cattle	Antibiotic treatment in animal husbandry is under discussion. In dairy farming treatment of cows at drying off is an important application of antibiotics. The study investigated whether a quarter-selective antibiotic treatment causes results comparable to blank dry cow therapy. The study was done in two research herds which differed in prevalence of major and minor mastitis pathogens. The quarter-selective dry cow therapy with antibiotics revealed no disadvantages as long as hygienic standards were kept high. www.thuenen.de	Knowledge base on new practices / techniques e.g. selective drying of udder quarters - an approach to the targeted use of antibiotics
Dairy cattle	The RAST project aimed at a selective and thus reduced use of antibiotics for drying. On the basis of different information, an individual decision was made for each animal at the time of drying, according to which method (with or without antibiotics) was used. The aim of a selective decision was, on the one hand, to protect the animals from disease and, on the other hand, to ensure a reduction in the use of antibiotics. The project drew on the experience of previous studies and on relevant practical experience. In the project, the use of antibiotics for drying was reduced by about 40%. https://www.lfl.bayern.de/RAST	Knowledge based about new practices / techniques with a reduction of antibiotic use in dairy cattle through selective dry period)
Dairy cattle	The aim is to identify difficulties and uncertainties that may arise when implementing the project [RAST] in practice without intensive supervision and support, and to revise or supplement the recommendations for the general public. At the same time, the experience and knowledge will be conveyed in numerous lectures and workshops. https://www.lfl.bayern.de/RAST	New practices / techniques and training material Culture of joint learning

Dairy cattle	Develop data-based strategies to reduce the use of antibiotics and implement quality assurance programmes DDairy (2020)	New practices / techniques Improved technologies and infrastructure based on digitalisation, data integration and detection and decision support. -
sDairy cattle	Collaborative project: Reduction of multi-resistant, pathogenic bacteria in milk production: Use of antimicrobial peptides (AMP) to combat bacterial infectious agents in biofilms and development of a rapid test for the detection of pathogens (Wieland 2020)	New practices / techniques - development of biological disinfectants in combination with AMPs.
Dairy cattle	Minimization of antibiotic use at the beginning of the dry period through automated drying in the last lactation period – AutoDry (Müller 2020).	New practices / techniques - software module for automation of the drying process
Dairy cattle	On behalf of the BMEL, the Federal Agency for Agriculture and Food (BLE 2020) is looking for project participants with ideas/concepts to identify possible alternatives with the aim of minimising the use of antibacterially effective drugs in the treatment of mastitis as well as the drying out of dairy cows, to prepare the current state of knowledge based on scientific studies and practical experience, and to demonstrate and demonstrate practical approaches.	Increase the Knowledge transfer for the reduction of antibiotics in dairy cows
Pig	A group of 16 farm managers of pig farms in Schleswig-Holstein were able to take advantage of intensive advice between June 2014 and May 2016 to reduce the use of medication in piglet rearing. After a status quo analysis of the farms, the participants worked continuously on the problems identified. Every six to eight weeks, advisors moderated group advisory seminars in which the farmers themselves developed reduction strategies. The advisor's main function here was to act as a moderator. In addition, the advisors also carried out intensive individual consultations based on performance, management and husbandry data. LWK Schleswig-Holstein 2020	Increase the knowledge base by model and demonstration project: "Implementation of measures to reduce the use of drugs in piglet rearing through innovative extension services".
Pig	Within the framework of a comparative nutrigenomic study on German Landrace pigs (DL X DL 2020), the influence of a commercially available premix (supplementary feed) of natural oregano oil on the health of the pig is to be analysed. The aim of this study is to prove a positive effect of a feed additive on the health of the animals on the genetic and cellular level in order to produce more vital and	New practices / techniques to Reduced use of antibiotics and the modulation of the microbiome by feeding a supplementary feed in piglet fattening (intestinal health)

	robust animals in the future and thus improve animal welfare and reduce the use of drugs, such as antibiotics.	
Pig	For the project, the scientists select pig farms whose animals have problems with respiratory diseases. In the course of the project, the project partners visit these farms regularly and assess the clinical and hygienic condition of the pigs. They also take various samples, such as blood, water and dust samples. They then examine the samples for bacterial resistance and create resistance profiles. Based on these results, they evaluate the use of antibiotics on the individual farms. The scientists also look at the development of resistance to bacterial respiratory pathogens in the pigs examined as a function of the antibiotic use on the farms. All information on clinical and laboratory findings, antibiotic use and resistance testing is collected in a database. The data compiled in this way should serve as an evidence-based decision-making aid for veterinarians.	Knowledge based about new practices / techniques to reduce the use of antibiotics in pig farming by integrating epidemiological information from clinical, hygienic, microbiological and pharmacological veterinary.
Pig	For artificial insemination of sows, boar semen with antibiotic supplementation has so far been used. This is required by law and serves to reduce the germ load. An interdisciplinary research project is now to investigate whether the same result can also be achieved with alternative antimicrobial concepts. Low-temperature preservation is intended to reduce the germ content in the sperm portion in such a way that the addition of antibiotics can be dispensed completely or in part. Together with the market leader in reproductive technology Minitüb and the partners of the Förderverein Bioökonomieforschung e.V. (FBF) from Germany, Austria and Switzerland, a practicable concept is to be developed.	New practices / techniques e.g.antimicrobial concepts in pig insemination (AMIKOS 2020)
Pig	Starting in July 2018, the Westphalian private butcher Reinert will for the first time launch a product line on the German market with meat that comes from 100 percent antibiotic-free pig rearing. The meat comes from pigs from Denmark that have been reared without antibiotics since birth. Reinert (2020)	New guiding principles with a focus on improved animal welfare. New culture in pig production
Broiler	In Germany there is a special rearing programme for broilers, the "Kikok programme", under whose framework conditions antibiotic-free fattening of poultry is possible. Kikok (2020)	New guiding principles with a focus on improved animal welfare

Broiler and pig	Strategy to control Campylobacter without the use of antibiotics using bacteriophages (Campy-Präv) The project objective is to develop a strategy to control Campylobacter ssp. as an alternative to the use of antibiotics in animal housing. Bio-Security Management GmBH (2020)	New practices / techniques
Broiler	Esram serves the Zentralverband der Deutschen Geflügelwirtschaft as the basis for a strategy / demands: - Reserve antibiotic colistin should not be used in chicken and turkey houses from the end of 2023 - reduce fluoroquinolones by 20 % by the end of 2023 - Requirement: Use formaldehyde as disinfectant and use CE cultures Development of cross-stage reduction measures for antibiotic-resistant pathogens in fattening poultry (EsRAM) Other EsRAM subprojects dealt with, among other things, hatching egg disinfection, the use of probiotics and other measures at the level of fattening, slaughtering and processing.	New guiding principles of a main market actor e.g. limited used of reserve AM

4.10.2 References

BLE (2020). https://mud-tierschutz.de/wissen-dialog-praxis/antibiotikareduzierung-milchkuehe/

AMIKOS (2020). https://www.fbf-forschung.de/reproduktion/aktuelle-projekte-reproduktion-schwein.html .

Bio-Security Management GmBH (2020). https://www.bio-security.de/campy-praev/DART 2020. Deutsche Antibiotika-Resistenzstrategie https://www.bundesgesundheitsministerium.de/themen/praevention/antibiotika-resistenzen/antibiotika-resistenzstrategie.html

D4Dairy 2020. Develop data-based strategies to reduce the use of antibiotics and implement quality assurance programmes. https://www.lfl.bayern.de/ite/rind/206144/index.php

DL X DL (2020). https://www.fisaonline.de/projekte-finden/details/?tx_fisaresearch_projects%5Bp_id%5D=12264&tx_fisaresearch_projects%5Baction%5D=projectDetails&tx_fisaresearch_projects%5Bcontroller%5D=Projects&cHash=1ad7a104df2c8a17ab7e6904fbec8898#more

ESRaM (2020): https://www.bfr.bund.de/cm/343/esram-abschluss-symposium-programm.pdf

Lieke F. (2020). Personal communication https://www.tiho-hannover.de/aktuelles-presse/pressemitteilungen/pressemitteilungen-2015/pressemitteilungen-2015/article/weniger-ist-mehr/

Kikok (2020). https://www.kikok.de/kikok/verantwortung/qualitaet.php

LWK Schleswig-Holstein 2020. https://mud-tierschutz.de/wissen-dialog-praxis/antibiotikareduzierung-milchkuehe/

Müller U. (2020). Personal communication. https://www.landtechnik.uni-bonn.de/forschung/tierhaltungstechnik-1/sammelordner_projekte/2015-03-01_autodry

Reinert (2020). https://www.agrarheute.com/tier/schwein/erste-wurst-100-prozent-antibiotikafreier-schweinezucht-541950

Wieland T. (2020). Personal communication. http://www.imtek.uni-freiburg.de/professuren/sensoren/projekte/projekte?projectId=10960

4.11 Ireland

Ireland ranked 17th highest of 30 EU/EEA member states for antimicrobial use in animals (mg/kg biomass) in 2016. Based on sales data, most animal AMU in Ireland (66.6%) is formulated as premixes or oral remedies, presumed to be predominantly used as in-feed or in-water medication for the intensive pig and poultry sectors. The implementation of strict biosecurity policies combined with a big increase in recent years in vaccination of pigs and poultry to protect against the major disease threats required less antibiotic intervention.

In 2017, Ireland published its first "One Health" National Action Plan on Antimicrobial Resistance (iNAP). The purpose of iNAP is to tackle the serious and increasing threat of AMR in Ireland. The "One Health" strategy recognises that the health of humans, the health of animals and the health of the environment are all interconnected and are all, in some ways, contributing to AMR. Given the serious health threat posed by AMR, a common understanding of AMR, and the need for a "One Health" approach to tackle it, is of fundamental importance.

iNAP aims to build upon the actions already being taken by each sector regarding AMR, with the overall goal being to reduce the quantities of antibiotics being used. This is to be achieved by using antimicrobials only when absolutely needed and by reducing the demand for antimicrobials in the first place by reducing the spread of infection and disease. This will help slow the rate at which resistance develops, maintain the effectiveness of existing antibiotics and potentially help some antibiotics to recover their effectiveness.

iNAP outlines five strategic objectives and over ninety actions to tackle the threat of AMR. Completion of these actions and achieving these objectives requires a co-ordinated multi-stakeholder involvement.

The five strategic objectives set out in iNAP include:

- Improve awareness and knowledge of antimicrobial resistance
- Enhance surveillance of antibiotic resistance and antibiotic use
- Reduce the spread of infection and disease
- Optimise the use of antibiotics in human and animal health
- Promote research and sustainable investment in new medicines, diagnostic tools, vaccines and other interventions.

An Animal Health Implementation Committee was set up in January 2018, chaired by Ireland's Chief Veterinary Officer, and tasked with overseeing the completion of the Animal Health actions outlined in iNAP. This committee brings together various animal health stakeholders to collaborate on achieving completion of the projects outlined in the Animal Health Implementation Plan which was developed jointly with the stakeholders. The stakeholders represented on the committee are Animal Health Ireland (AHI), Animal and Plant Health Association (APHA), Bord Bia, Department of Agriculture, Food and the Marine, Environmental Protection Agency (EPA), Food Safety Authority of Ireland (FSAI), Irish Co-operative Organisation Society (ICOS), Irish Creamery Milk Suppliers Association (ICMSA), Irish Farmers' Association (IFA), Irish Grain and Feed Association (IGFA), Meat Industry Ireland (MII), Safefood, Teagasc, University College Dublin (UCD), Veterinary Council of Ireland (VCI) and Veterinary Ireland (VI). This committee meets quarterly.

In Ireland, the main focus in on new guiding principles focussing on a prudent use of AM to monitor and combat AMR and to implement connected policies and actions. With targeted research programmes and surveillances of AMR and AMU contributes the knowledge base will increase.

In 2018, McDonald Ireland said, that they will measure AM residues in meat that the has committed to reducing the levels of antibiotics in its beef products, including those sourced in Ireland.

4.12 Austria

The public competence for the survey and action on AMR in Austria lies with the Federal Ministry of Social Affairs, Health, Care and Consumer Protection (BMSGPK). Since 2011, the antibiotics-platform of the BMSGPK coordinates AM initiatives in human and veterinary medicine. The goal of the antibiotics-platform is to create a common understanding and awareness, as well as coordinated action, regarding AM use and resistance in Austria. Therefore, the antibiotics-platform developed a national action plan on AMR in 2013, which summarises Austria's goals and measures thereof. The strategic goals are to strengthen surveillance-networks on AM sales and resistance, to fight the spread of resistant pathogens and to foster prudent use of AM. Other goals are to raise awareness of the implications of AMR among the general public.

As one of their tasks, the antibiotics-platform publishes the national report on AMR called "AURES", which summarizes the findings collected by the national surveillance programs of human and veterinary AM use and resistance. According to the report, 49.85 tons of AM pharmaceuticals have been distributed for treatment of farm animals in 2018. The sold amount therefore increased from 2017 by 11.7%. Furthermore, not only the overall distribution of AM increased but also the use of "Highest Priority Critically Important Antimicrobials" (HPCIA) by 8% compared to 2017.

In comparison to other EU countries, Austria performs relatively well regarding the amount of veterinary AM sold. According to the ESVAC report from 2017, Austria's population-adjusted sale of AM for food-producing animals is in the lower third of all 31 countries analysed. In terms of compounds, over half of the AM sales regard Tetracyclines. This is the highest proportion of Tetracyclines reported by any country. Furthermore, the report also indicates that almost 70% of all AM are sold in the form of oral powders. Less important pharmaceutical forms are oral solutions, premixes and injectable preparations. As oral powders and solutions are mainly suitable for group treatment, the sales of these pharmaceutical forms provide a good indicator of sales for group treatment. In conclusion, the data suggests that Austria's veterinary AMU use is highly dominated by group treatments.

4.12.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimensions
General	Surveillance of AMR in a nation-wide program using uniform sampling strategies. The aim is to recognize AMR early on in order to prevent serious issues during treatment. The results of the surveillance program are published annually in the AURES report.	Increase the knowledge base by data collection
General	Survey of AM mass flows by producers, distributers and veterinarians as part of the European programme "European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)". The thereby collected data is subject to various scientific analyses in order to identify patterns in AMU and develop strategies to reduce AMU.	Increase the knowledge base by data collection

General	Development of national guidelines regarding the "prudent use" of AM. These guidelines should inform veterinarians about appropriate prescription of AM, especially regarding highest priority critically important AM. In future, animal or disease specific guidelines will be developed.	Guiding principles focussing on the prudent use of AM communicated to vets
Poultry	The Austrian association of poultry farmers (QGV) developed a data collection platform called "Poultry Health Data" (PHD). The PHD contains information regarding all national poultry farms (number of stables and herds), their veterinary medicinal treatments, as well as analyses from slaughterhouses. Based on the PHD data, poultry farms can be ranked according to their AMU. Moreover, poultry farmers receive detailed information about the AMU in their herds and can compare themselves to other farmers. In the future, the PHD data should also be processed in order to inform veterinarians.	New technologies and infrastructure based on digital informational tools
Dairy cattle	The research project D4Dairy aims at improving the management of dairy farms through data driven digital tools. Among other areas, the project aims to reduce AMR. In collaboration with a dairy and milk processor, a decision tool is developed for veterinarians to advise farmers on the best drying off strategy for their farm. Moreover, the research uses a big data approach in order to identify health issues in animals or herds early on, ultimately improving overall animal health.	Increase the knowledge base
Piglets	An EIP-AGRI project coordinated by FiBL Austria analysed the impact of an extended suckling period on piglet health. In collaboration with farmers, researchers and extension providers, the project evaluated the implementation and economic impact of this changed piglet system. The project provides (anecdotal) evidence for the positive influence of an extended suckling period on piglet health indirectly resulting in reduced need for AMU.	Increase the knowledge base
Calves	In a joint research project called "ProYoungStock", different scientific institutions in Europe analyse the long-term effects of natural rearing and feeding strategies on calf health. The project also aims to identify best practice examples for youngstock rearing systems. The project lasts until 2021 and the Austrian BOKU is a partner in this project.	Increase the knowledge base

4.12.2 References

BMSGPK. (2018). *Nationaler Aktionsplan zur Antibiotikaresistenz NAP-AMR*. Wien: Bundesministerium für Arbeit, Soziales, Gesundheit und Konsumentenschutz.

BMSGPK. (2020a). Massnahmen im Bereich antimikrobieller Resistenzen (AMR). Retrieved from https://www.sozialministerium.at/Themen/Gesundheit/Antimikrobielle-Resistenzen-und-Gesundheitssystem-assoziierte-Infektionen/Antimikrobielle-Resistenzen/Ma%C3%9Fnahmen-im-Bereich-antimikrobieller-Resistenzen-(AMR).html

BMSGPK. (2020b). *Resistenzbericht Österreich AURES 2018*. Wien: Bundesministerium für Arbeit, Soziales, Gesundheit und Konsumentenschutz,.

COMET-Project D4Dairy - Digitalisation, Data integration, Detection and Decision support in Dairying. (2020). Retrieved from https://d4dairy.com/de/#projekt

Eichinger, A., Hagmüller, W., Raser, H., & Zollitsch, W. (2020). *Verlängerte Säugezeit in der Bioferkelproduktion Grundlagen, Tierwohlaspekte und Tipps aus der Praxis rund ums Absetzen*. Retrieved from https://www.fibl.org/de/infothek/meldung/verlaengerte-saeugezeit-in-der-bioferkelproduktion.html

European Medicines Agency. (2017). Sales of veterinary antimicrobial agents in 31 European countries in 2017. Trends from 2010 to 2017 (Vol. 9th ESVAC report).

FiBL. (2020). ProYoungStock. Retrieved from https://www.proyoungstock.net/about.html

4.13 Poland

As part of the European Union, Poland is required to monitor AMU and AMR and develop and implement a national action plan regarding AM. In Poland, the National Antibiotic Protection Program coordinated by the Department of Clinical Microbiology and Infection Prevention is responsible to implement the AM strategy. The strategy focuses mainly on measures in the health sector, which is also expressed in the overall goal: improve the safety of patients exposed to resistant bacteria. Reduction of AMU in livestock and agriculture receives little attention in the Polish AM strategy. Current activities in veterinary medicine are the development of guidelines for monitoring AMU and the preparation of guidelines for prudent-use by veterinarians. The unregulated nature of AM in Poland is further underlined by a report by the Alliance to Save our Antibiotics. There are no Polish laws specifically regulating veterinary AM, apart from EU regulations. Moreover, no regulations exist for the use of HPCIA.

In comparison to other EU countries, Poland's veterinary use of AM is above average. According to the ESVAC report from 2017, veterinarians sold 751 tonnes of AM in Poland. Among the 31 countries analysed, Poland has the sixth highest sales of AM adjusted to the countries' livestock population. Higher values are only reported in Cyprus, Italy, Spain and Hungary. Moreover, an increase in the sales of AM is reported in the time period from 2010 – 2017. As over 90% of the administered AM are in the form of oral solutions, oral powders or premixes, group treatments are the dominant form of AMU in veterinary medicine in Poland.

4.13.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimension
General	Development of guidelines for prudent-use of AM in veterinary medicine.	Guiding principles communicated to vets
General	Monitoring of AM sales for veterinary use.	Increase knowledge baseData collection
General	A project initiated by students from Czech Republic, Hungary, Poland and Slovakia aims at integrating a One Health approach in the curricula of undergraduate education of medical doctors, dentists, pharmacists and veterinarians. The project aims to establish interdisciplinary collaboration and knowledge exchange between the fields. The One Health approach is important to tackle different challenges related to public health (e.g. AMR). The collaboration during the education should ultimately also foster higher level of collaboration in practice.	Guiding principles communicated to vets during their education

4.13.2 References

Alliance to Save our Antibiotics. (n.d.). *Farm antibiotic use in Poland*. Retrieved from https://www.saveourantibiotics.org/

European Medicines Agency. (2017). Sales of veterinary antimicrobial agents in 31 European countries in 2017. Trends from 2010 to 2017 (Vol. 9th ESVAC report).

Narodowy Instytut Leków. (2020). Narodowy Program Ochrony Antybiotyków. Retrieved from http://antybiotyki.edu.pl/

Pharmaceutical Group of European Union. (2019). *Press Release – Implementing a One Health culture in undergraduate education to tackle current and future health challenges* Retrieved from Warsow: https://www.pgeu.eu/publications/press-release-implementing-a-one-health-culture-in-undergraduate-education-to-tackle-current-and-future-health-challenges/

5 Results Part II: Country Reports beyond Europe

5.1 Australia

Australia implemented its first National Antimicrobial Resistance Strategy in 2015. 5 R's:

- Responsibility: Veterinarians, feed lot management and staff are responsible to preserve the effectiveness of AM. The management team is responsible for developing and implementing an Antimicrobial Stewardship plan.
- Review: Compliance with the Antimicrobial Stewardship plan is reviewed regularly. Through a process of continuous improvement, practices are reflected and constantly adapted to the contemporary best practice.
- Reduce: Adopt preventative measures to reduce the use of AM
- Refine: Ensure the correct use of AM for the particular disease. Ensure that the AM is administered correctly (dose, route of administration, duration, and timing).
- Replace: Replacement of AM whenever possible.

Currently Australia implemented a new "National Antimicrobial Resistance Strategy 2020 and beyond". The action plans aim at health professionals, veterinarians and farmers so that they understand better how to reduce the emergence of resistant bacteria that are becoming increasingly more difficult to treat. The objectives and priority areas of action are

- Clear Governance for Antimicrobial Resistance Initiatives
    - Regulatory measures relevant to antimicrobial usage and resistance are monitored and reviewed
    - Monitor and review regulatory measures (legislated and other) relevant to antimicrobial usage and resistance
- Prevention and Control of Infections and the Spread of Resistance
- Greater Engagement in the Combat Against Resistance
    - e.g. Education and training across all relevant sectors and increase accessibility to evidence-based best-practice information
    - development and implementation of a One Health communication strategy, as well as monitoring and evaluation, to support whole-of-society awareness and behavioural change
- Appropriate Usage and Stewardship Practices
- Integrated Surveillance and Response to Resistance and Usage
    - AM resistances must be reported, a monitoring of actions and responses is important
- A Strong Collaborative Research Agenda Across All Sectors

- Therapeutic alternatives to antimicrobials (e.g. vaccines, improved diet) are enhanced. Also, food production practices, animal welfare strategies and environmental initiatives are considered.

- Strengthen Global Collaboration and Partnerships

5.1.1 Selected socio-technical strategies to reduce AMU

Targeted species	**Strategy**	**Socio-technical dimension**
All animals	Antibiotics can only be administered by trained individuals and every use must be recorded. https://www.beefcentral.com/lotfeeding/animal-health/why-australias-cattle-sector-has-a-good-story-to-tell-on-antibiotic-use/	Policy and regulations
All animals	Strategic plan 2017-2021 aims at: Veterinary Scientific and Technical Leadership, Education and Research, Supporting veterinarians, speaking for the profession, strengthening communities There are also policies on the use of antimicrobial drugs in veterinary practice (https://www.ava.com.au/policy/22-use-antimicrobial-drugs-veterinary-practice). And a policy on the responsible use of veterinary medicines on farms (https://www.ava.com.au/policy/24-responsible-use-veterinary-medicines-farms). https://www.ava.com.au/about-us/ava-strategic-plan/#top	Policy and regulations

5.2 New Zealand

The ministry of health implemented the national action plan on Antimicrobial resistance five year ago. For instance, the development of a step-by-step plan for increasing prudent use education for veterinarians or other animal health or agricultural sector groups that use antimicrobials is one of the activities foreseen in year one. Steady reflection on the outcomes of the first year and improvement are part of the education programme in the following years.

More detailed, the national action plan consists of various objectives:

- Objective 1: Awareness and understanding – Improve awareness and understanding of antimicrobial resistance through effective communication, education and training
- Objective 2: Surveillance and research – Strengthen the knowledge and evidence base about antimicrobial resistance through surveillance and research
- Objective 3: Infection prevention and control – Improve infection prevention and control measures across human health and animal care settings to prevent infection and transmission of micro-organisms
- Objective 4: Antimicrobial stewardship – Optimise the use of antimicrobial medicines in human health, animal health and agriculture, including by maintaining and enhancing the regulation of animal and agriculture antimicrobials
- Objective 5: Governance, collaboration and investment – Establish and support clear governance, collaboration and investment arrangements for a sustainable approach to countering antimicrobial resistance

5.2.1 Selected socio-technical strategies to reduce AMU

Targeted species	**Strategy**	**Socio-technical dimension**
General and plants	Prudent use of Antimicrobials on Animals and **Plants** Document that is designed to provide direction on the prudent use of antimicrobials in relation to animals and plants (in accordance with objective 4 of the New Zealand Action Plan on Antimicrobial Resistance). For instance, it is declared that the sale of antimicrobials must be limited to those who have the appropriate expertise and knowledge on storage of products, record keeping, security and legal requirements.	New guiding principles Policy and regulation
General	Species-specific information for veterinarians regarding antimicrobial treatment options for infectious diseases in animals. It consists of guidelines for Judicious Use of Antimicrobials, Empirical Use of Antimicrobials, Dosage strategy and Disease control programmes. The Disease Control Programmes require for instance protocols about the treatment which are regularly updated and reviewed more regularly (every four months) if critically important antibiotics are used.	Guiding principles

	Antibiotics for the prevention of diseases are only justified when it is shown that an outbreak of the disease can be prevented by that strategic antibiotic and that animal welfare concerns could be minimized.	
Cattle	There are courses and trainings offered from the NZVA. For instance, the course "Fundamental LAVT skills and procedures. Increase skills and knowledge on commonly encountered diseases and procedures" or "Animal health planning. Develop integrated animal health plans for sheep, beef and deer farming systems."	New practices / techniques

5.3 Iran

In Iran, the use of antibiotics has risen strongly in the last 17 years. The Iranian government implement a National Action Plan for 2016 – 2021. This action plan includes 5 main objectives and 17 strategies

- Knowledge and Information
- Monitoring and evaluation
- Preventing the spread of microorganisms resistant to antimicrobials,
- Promoting the rational use of antimicrobials,
- Promoting research and development in the field of AMR

Despite this national action plan, there has no nation-wide monitoring program on antibiotics utilization and bacterial resistance been established in Iran.

For cattle, there is a strategy under development based on an extract from *Scrophularia striata* as an alternative to antibiotic use. It is a traditional medicinal plant in Iran and Iranian folk medicine. Also, the use of other alternatives such as probiotics, prebiotics, biotech, ionophore, fatty acids and organic acids, and other medicinal plants are suggested.

5.3.1 Selected socio-technical strategies to reduce AMU

Targeted species	**Strategy**	**Socio-technical dimension**
Chicken	In Iran, there is the label "green chicken Iran" that chickens receive which are never given or treated with antibiotics. Those chickens are usually 20.25% higher in the price. The production is not organic. Some of these alternatives, such as probiotics, prebiotics, synbiotics, ionophores, acidic acids and organic acids, and recently referred to medicinal and phytogenic plants. https://financialtribune.com/articles/economy-business-and-markets/50389/no-organic-chicken-production-in-iran	Label for AM free meat initiated by the private sector.

5.4 India

An international **conference** on AMR - "Combating Antimicrobial Resistance: A Public Health Challenge and Priority" was jointly organized by the Government of India and the WHO in February 2016 and the "Medicines with the Red Line" media campaign was launched.

The Indian National Action Plan was adopted in 2017 and consists of various objectives:

- Improve awareness and understanding of AMR through effective communication, education, and training
- Strengthen knowledge and evidence through surveillance
- Reduce the incidence of infection through effective infection, prevention, and control
- Optimize the use of antimicrobial agents in all sectors
- Promote investments for AMR activities, research, and innovations
- Strengthen India's leadership on AMR by means of collaborations on AMR at international, national, and sub-national levels

The Indian Network for Fisheries and Animals Antimicrobial Resistance has been established with Food and Agriculture Organization's (FAO's) assistance

5.5 China

China is one of the major countries for the production and use of antibacterial agents. Antibacterial agents are widely used in healthcare and animal husbandry. However, antimicrobial resistance has become increasingly prominent due to insufficient research and development capacity of new antimicrobials, sales of antimicrobials without prescriptions in pharmacies, irrational use of antibacterial agents in medical and food animal sectors, non-compliant waste emissions of pharmaceutical enterprises, as well as lack of public awareness toward rational use of antimicrobials.

In order to deal with the challenge of antimicrobial resistance, the National Action Plan aims to establish comprehensive management strategies and measures on the national level for the overall implementation of strengthening the supervision of antimicrobial research and development, production, circulation, use and environmental protection, promoting advocacy and education, and international exchanges and cooperation was established in 2016 and aims at achieving improvements by 2020. Connected to animal husbandry, the following goals are relevant:

- To launch 1-2 new initiative antibacterial agents and 5-10 new diagnostic instruments and reagents.
- The proportion of sales with veterinary prescription of antibacterial agents in animal sector will be realized in 50% in provinces (autonomous regions and municipalities).
- To optimize the surveillance networks of antibacterial agents consumption and antimicrobial resistance in both healthcare and food animal sectors;
- To establish evaluation system for antimicrobials use and antimicrobial resistance control in healthcare system and animal husbandry.
- The antimicrobials shared by humans and animals or easily producing cross-resistance should be gradually withdrawn from the market of animal growth promoters.
- To develop and implement educational efforts to ensure that medical staff, veterinarians and animal producers receive information and training of rational use of antibacterial agents.
- To implement education and training about rational use of antibacterial agents in primary and secondary schools. To set up publicity week of the rational use of antimicrobials.

Some examples of how the strategies should be implemented are:

- Strengthen the training of med-pharm students. To encourage med-pharm schools and universities to set up the course of rational use of drugs. To encourage agriculture and forestry universities to set up the course of animal infectious disease therapy.
- Strengthen the education of the animal industrial practitioners and veterinarians. To train and strengthen the veterinary team. To enhance the education of rational use of antimicrobials among the veterinarians and breeding industrial practitioners. To promote the implementation of related regulations, and improve rational antimicrobials use in veterinary settings by conducting regular or irregular trainings.
- To improve awareness and understanding of antimicrobial resistance through widely promoting the knowledge of rational use of antibacterial agents via traditional media (e.g., radio, television) and new media (e.g., Internet, micro-blog, WeChat, etc.).

5.6 The USA

The US Food and Drug Administration (FDA) issues a report every year on sales of medically important antibiotics (i.e., antibiotics that are also used in humans) in food-producing animals. The reductions noted in this report are believed to be the result of new rules imposed by the FDA. Those rules banned the use of medically important antibiotics in food animals for production purposes (growth promotion) and required veterinary oversight for use of medically important antibiotics to treat sick animals or prevent disease. These rules only covered antibiotics that are used in both human and animal medicine. They did not cover antibiotics that are only used in animals.

Also, other measures are taken to prevent the use of AM. The United States Department of Agriculture (USDA), with support from the World Organisation for Animal Health (OIE) organized an international symposium for alternatives to the use of AM. The US focuses on six key areas: vaccines; microbial-derived products; non-nutritive phytochemicals; immune-related products; chemicals, enzymes, and innovative drugs; and regulatory pathways to enable the development and licensure of alternatives to antibiotics.

New rule of the Food and Drug administration - FDA are based on the sales data, which showed a 33% reduction in the sales and distribution of medically important antibiotics for use in livestock from 2016 (the year before the rules went into effect) through 2017. But this is only sales data. The FDA does not have data from farms on how exactly these antibiotics are being used. So, we won't really know how successful this program is for a few years.

The "organic" label, in the United States, does not necessarily mean antibiotic-free. Organic chicken, for example, can receive antibiotics within the first three days of life. So organic chicken is not necessarily the same as antibiotic-free chicken. But organic milk, on the other hand, must come from cows that have not been given antibiotics.

There are labels for AM-free labels. The packaging on meat (chicken, beef, pork) that has been raised without antibiotics carries a label saying that it's antibiotic-free. US consumers have become increasingly concerned about antibiotic use in animals, and many prefer meat that has been raised without antibiotics.

These labels appear on chicken, turkey, beef, and pork products that are packaged and sold in markets across the country. Here are a few examples.

Figure 4: Private label/claim indicating the non-use of AM in the US.

5.6.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical dimension
Chicken	Instead of antibiotics, Tyson Foods (meat company in the US) is turning to probiotics and to botanicals such as oregano and thyme for routine treatment, while still employing antibiotics if birds become sick. This strategy is in force for chicken already and planned to be implemented also for pork or beef farms. News Paper article: https://newsinfo.inquirer.net/880288/antibiotic-free-meat-gets-a-foothold-in-us Scientific article : https://veterinaryresearch.biomedcentral.com/articles/10.1186/s13567-018-0560-8 https://www.ams.usda.gov/about-ams/contact-us	New practices / techniques
Various (Chicken, turkey, cows, pig, sheep)	There are various companies, which label their packages of meat (chicken, beef, pork) as antibiotic-free. This is important as the US consumer have become increasingly aware of the use of antibiotics in animal production. For instance, Tyson ("no antibiotics ever"), Shady Brook Farm ("no-growth-promoting antibiotics") or Progresso have their own label for antibiotic free products. The "organic" label stands for antibiotic-free production. However, there is one exception. Chickens and turkeys can be given antibiotics in the hatchery while the chick is still in the egg and on its first day of life. But if you also see a "raised without antibiotics" claim on a chicken or turkey product in addition to the USDA organic label, it means antibiotics were not used at any point, even in the hatcheries. But organic milk, on the other hand, must come from cows that have not been given antibiotics. If an animal gets sick and must be treated with antibiotics, the farmer must report the case and cannot sell the animal as organic anymore.	Industrial structure Policy and regulations

	Guidelines for Organic Certification of Dairy Livestock https://www.ams.usda.gov/sites/default/files/media/Dairy%20-%20Guidelines.pdf newspaper article on AMU and organic: https://www.consumerreports.org/overuse-of-antibiotics/what-no-antibiotic-claims-really-mean/ regulations for handling of post-treatment animals that were raised organically: https://www.ams.usda.gov/sites/default/files/media/Organic%20Livestock%20Requirements.pdf	

5.7 Canada

In Canada, the establishment of a national surveillance system to monitor AMR and use in the agri-food and agriculture sectors and the impact of resistance on human health was formally recommended in 1997 at the national consensus conference "Controlling Antimicrobial Resistance: An Integrated Action Plan for Canadians" co-convened by Health Canada and the Canadian Infectious Diseases Society. Subsequently, this recommendation received further endorsement.

In Canada, provinces and territories are undertaking multiple initiatives to combat AMR, including surveillance, public and health professional awareness raising and hospital-based programs to reduce antibiotic use, and immunization programs to prevent and control infections and the spread of infectious diseases.

The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) monitors trends in antimicrobial use and antimicrobial resistance in selected bacterial organisms from human, animal and food sources across Canada. The program is based on several representative and methodologically unified surveillance components which can be linked to examine the relationship between antimicrobials used in food-animals and humans and the associated health impacts. This information supports: (i) the creation of evidence-based policies to control antimicrobial use in hospital, community, and agricultural settings and thus prolong the effectiveness of these drugs, and (ii) the identification of appropriate measures to contain the emergence and spread of resistant bacteria between animals, food, and people in Canada.

In Canada, the use of Antibiotics is approved for use in beef, dairy cattle, chickens, laying hens, turkeys, pork and fish. They may also be sprayed on fruit and given to honey bees. All antibiotics used with farm animals must meet Health Canada's standards for human and animal safety. Farmers need a prescription from a licensed veterinarian before they can access medically important antibiotics for use in livestock

The Veterinary Drugs Directorate of Health Canada - VDD is responsible for the approval and registration of all antimicrobials for use in agriculture and is developing a risk management strategy to reduce the human health impact of antimicrobial resistance due to the use of antimicrobials in animals. Antimicrobial resistance in humans and animal production systems and retail meat are monitored.

Since 2017, there is an effort to promote the prudent use of AM in food-producing animals. Further, they support research project to support new findings in the field of AM use. Alternative strategies to antibiotics in poultry and livestock are under investigation. These are for instance direct-fed probiotics which can have beneficial effect on the intestinal balance of the animals. Further options are prebiotics, vaccination and immune-stimulation through cationic peptides and cytokines. Also, a variety of plant products with bioactivities against a wide variety of pathogenic bacteria are reported. One example is cranberry extract to control pathogenic bacteria.

The CQA – Canadian Quality Assessment established by the Canadian Pork Council in 1998 promotes the use of good husbandry and management practices, and not antimicrobial use, as a first line of action against diseases. Setting up good production systems that include among others, vaccination, proper disinfection techniques and barn design focus on animal health and welfare, is helping to reduce the use of antibiotics. Through the CQA-Program producers also follow best practices in antimicrobial use, working closely with veterinarians and keeping records on medication used.

The CPC identified social and environmental factors that contribute to rising rates of AMR including poor hygiene, inadequate infection prevention and control practices, lack of awareness and education about AMR and appropriate antimicrobial use (AMU), insufficient access to health services, over-crowded housing conditions and a lack of clean water.

It is important for CPC to address public concerns and demonstrate a transiting into a more controlled use of antibiotics is more relevant that an antibiotic free production.

5.8 Ethiopia

Basically, in Ethiopia livestock production is at a stage of intensification and therefore AMU is rather increasing. The mentality is to save animals from diseases and therefore AM are also applied in preventative ways. There is no strategy to reduce AMU. The aim is to increase production.

There are research activities aiming to reduce AMU in livestock (focus on Ethiopia), as little is done at national level, e.g.

- Understanding drivers of use (p.e.: https://cgspace.cgiar.org/handle/10568/107007)
- Conduct trainings using participatory approaches with communities and monitoring the impact of these on AMU (https://cgspace.cgiar.org/handle/10568/106552)
- Improve herd health overall to reduce the need of AMs (p.e. strategic vaccination and deworming programs, improve husbandry and welfare, etc.)

The outlined activities above target small ruminants in Ethiopia and are mainly supported through the CGIAR research program on Livestock, coordinated through the CGIAR AMR hub (https://amr.cgiar.org/). We have similar initiatives in Uganda and Vietnam, and activities in Kenya

There is generally very scarce information available about AMU in animals. Factors and incentives influencing AMU are poorly understood. In Ethiopia, regulations on use of antibiotics in livestock are poorly enforced. Farmers do easily have access to veterinary drugs that can be illegal or counterfeit. Amona all agro-ecological zones, farmers use human antibiotics for veterinary purpose. 31% of the household seem to use AM wrongly.

Concluding, there is a lack of knowledge and wrong practices are common but different across production systems. There is a need to understand and monitor antimicrobial use in small holder livestock keepers in Ethiopia. Access to veterinary drugs is limited in some areas (highlands), whereas in others it is not. Further interventions to reduce antimicrobial use and resistance must be taken.

The use of drugs is not commonly supervised by a trained veterinarian.

In a case study, farmers reported to consume animal products like milk and meat immediately after antibiotic treatment of animals for any disease. This shows that there is a serious lack of knowledge about withdrawal periods and the effect of AM on animal products.

One attempt to reduce AMR was that farmers could consult trained animal health workers as measures to reduce emergence of AMR. Community members also mentioned infection prevention measures to reduce the use of antimicrobials such as vaccination, sanitation (cleaning stables) and nutrition (providing enough feed, water and salt).

In the case study, the following action points were suggested at the end of the community conversations:

- consult professionals about disease causes for proper drug choice, dosage and number of injection days;
- contact a professional person to prescribe drugs for diseased animals
- do not use expired drugs or treat animals with leftover drugs
- store drugs in a safe and clean place;

- do not use drugs which change from the original colour;
- consult a veterinarian before buying an animal drug;
- do not add to drugs without consulting an animal health worker
- Do not use human drugs for veterinary purposes

5.8.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy	Socio-technical strategies
Livestock	Conduct training using participatory approaches with communities and monitoring the impact of these on AMU https://cgspace.cgiar.org/bitstream/handle/10568/106552/CC_modue_AMR.pdf?sequence=1&isAllowed=y	User relations and Markets
Livestock (mainly small ruminants)	Improvement of heard health to reduce the overall need of AMs For instance through strategic vaccination and deworming programs, improvement of husbandry and welfare. These outlined activities target small ruminants in Ethiopia and are mainly supported by CGIAR research program on Livestock and coordinated through the CGIAR AMR hub https://amr.cgiar.org/	New practices / technologies

5.9 Mozambique

5.9.1 Selected socio-technical strategies to reduce AMU

Targeted species	Strategy / Research	Measures
Poultry	A government-led best practice guideline for a sustainable use of antibiotics will be developed.	Best practice guide

6 Discussion: compilation of socio-technical strategies to reduce AMU

In 2017, experts from the European Food Safety Authority (EFSA) and the European Medicines Agency concluded, that successful strategies to reduce AMU follow an integrated, multifaceted approach which considers the local livestock production system and involve all relevant stakeholders - from governments to farmers. Moreover, they stated, that there is not only a need to replace and reduce AMU but also to re-think the livestock system by implementing farming practices that prevent the introduction and spread of the disease into farms and by considering alternative farming systems which are viable with reduced use of antimicrobials (EFSA 2017).

Based on these conclusions, we aimed at collecting socio-technical approaches supporting a prudent use of AM, improving animal health and reducing the risk of the development of AMR.

In this study, we search information about AMU in 22 countries. The data collection turned out to be challenging due to language issue, identification or availability of experts. So, this compilation is not complete for any of the countries.

We identified several approaches developed or tested in research programmes which have been or will be carried out because of the new EU policy for a prudent use of AM. In most of the case, the implementation of measure developed in research programmes is not well documented or did not take place yet. However, these examples are of value for the Living labs and therefore kept in the compilation.

An exception is the EU Project DISARM (Disseminating Innovative Solutions for Antibiotic Resistance Management) and added them to the country reports. An example for such a strategy tested in DISARM is the NestBorn strategy. It offers on-farm hatching solutions of broiler chicks in Belgium. After 18 days of incubation, the eggs are hatched directly on the broiler farm. This decreases the animals stress during transportation. Field trials in Flanders analysed two farms transitioning from conventionally hatched broilers to the NestBorn on-farm hatching. The results show significant decrease in AMU by 62.76% mg per stocked chicken. (https://www.nestborn.eu/). A similar success could be achieved by improving rearing conditions for calves.

Our compilation shows that, in most countries included in the survey, policies are implemented to reduce antimicrobial resistance and the connected use of antimicrobials. These policies are resulting in national strategies which are mainly focussing on increasing the knowledge base (monitoring or research programmes) but also by implementing new guiding principles for a more prudent use of AM in order to avoid AMR. These guiding principles are communicated to vets, farmers and other actors in the livestock sector. Mainly training and education of different actors including the general public to reduce the use of AM but also targeted extension services. In the example of Poland, students initiated such a programme for vets.

There are examples, where these guiding principles haven been adopted by market actors and introduced in their value chains. The market actors use private standards or new practices / techniques to reduced or replace AMU by new products ore plant-based treatments. A change of the industrial structure, in user relations and markets, or a cultural change was rarely identified in this study.

In some countries addressed in this compilation, mainly in the global south, there is no policy nor strategy to reduce AMU livestock production. The aim is to increase production. At a stage of increasing intensification AMU is rather increasing. The priority is to save animals from diseases and therefore AM are also applied in preventative ways. Interestingly, some research done in these countries are

focusing more on the social part of AMU and develop strategies by involving the general public, but also women as caretakers, into the development of strategies

Different strategies to reduce AMU are implemented in the countries of the ROADMAP case studies, both in the socio-economic as well as in the technical area. For example, Italy focuses a lot on education of farmers, while France chooses also for a marketing strategy as well as organizing measures from the government. In Sweden, the use of antibiotics in animals is low. The situation in Sweden has been the result of decades of inter-sectorial collaboration of vets, animal keepers and animal health organizations on disease prevention and animal health. The nationally implemented one-health strategy covers monitoring of AM sales and AMR, no financial incentive to sell AM, support of farmers, specific control programs for some diseases, e.g. *Salmonella*, *Campylobacter,* as well as ongoing research to improve housing, management und animal welfare. In addition, there are strategies implemented by individual farmers or market actors developing supply chains without the use of AM.

Overall, we assume that policy serve as guiding principles, if implemented, have the potential to frame and change the behaviour of most actors in the food system, specifically, if the policy covers all sectors from animal health, animal production and food safety. The policy is a guiding principle for most of the activities identified and supports a transition towards a prudent us of AM by laws am regulations. But the Swedish example shows, that the potential for a successful limitation of AMU increases, when the agricultural sector and the value chains also benefit from the strategy. According to Smith (2007), the coverage of different dimension allows a transition towards a more prudent use of AM.

Despite the fact, that there are only a few socio-economic approaches, we can see that there is a diversity in the strategies chosen in the different sectors and countries; This compilation should also support learning from each other and try to foster a harmonisation of the strategies to promote prudent AMU involving socio-economic approaches.

During our study, it turned out, that socio-technical approaches (e.g. participatory development of strategies, learning in communities of practice or farmers stable schools) or economic approaches (Incentives, labelling) are rarely implemented. Since many technical approaches (improved documentation of AMU, improved hygiene, vaccination, feed additives) or improved trainings are used, some examples are also included in this compilation.

In Table 2, we compiled different strategies to reduce AMU identified in this study. Detailed information from the different countries are given in Chapter 4 of this document.

Rarely, strategies aim at changing the food system level, improving animal welfare beyond health, addressing specifically those, who take care of animals (e.g. technicians, women) or incentive systems that foster or reduce the use of antibiotics. In addition, precision livestock farming or support from big data analysis seem to play yet a limited role in the countries investigated here.

The socio-technical dimensions used by Smith (2007) were helpful the structure the compilation. However, it does not cover aspects of learning, education and trainings or behavioural change. In table 2, we added this aspect as 1.1 Targeted Communication on guiding principles. And we added 2 new practices / techniques, with interesting results from research programmes (knowledge base), which should not only increase the knowledge of the individual actors but also enable new actions.

Examples are the new practices developed in the DISARM- project, KOMETIAN for alternative treatments or the KGD, which provides extension services to calf rearing farmers.

The seven dimensions to characterize the *socio-technical* according to Smith (2007) also show, that rarely all dimensions are covered, specifically the *industrial structure*, *user relations and markets* are almost not addressed.

The compilation of activities in the various countries is not complete for any of them. The aim was to identify exemplary activities and to identify as wide a variety of strategies as possible. It could be of interest to explore in more details specific innovations addressing the above-mentioned aspects.

6.1 Follow up with of the collected strategies

The collection of the different strategies will inspire the co-creation of strategies in the Living Labs. This overview together with the critical points of change give partners insights in why strategies work, in which contexts, and why different countries have chosen certain strategies. In the different Living Labs and case studies the different strategies that will be co-created will be further examined, tested and monitored.

Table 2: Compilation socio-technical approaches to reduce AMU identified (from a questionnaire of partners and literature research). For the country code, please check Tab. 1.

Approach	Actors	Countries
1. Guiding principles incl. animal welfare		
Policy on AMU/AMR	Governments Private sector	all
Improved/Increased Animal Welfare	Individual farmers	SE, GE, CH, AT
Health of young animals	Private sector	NL
Biosecurity	Private sector	NL
Principles for the organic sector	Private sector	CH
1.1 Targeted communication of guiding principles		
Information, education, training and coaching of farmers and farm workers	Different in the food system Government	EU, CH, IR AU, CA, CN, IN
Information, education, training and coaching of advisors	Farmers organisation	NL, FR, BE
E-learning	Research	GE, UK, FR
Model farms	Research	GE, UK
Informing the general public with social media	Government	China
Information, education, training and coaching of vets	Government	SE, GE CN, NZ, PL
Specific trainings for young vets	Government (Initiated by students!)	PL
Communities of Practice	Farmers-Researchers	Implemented by the DISARM project in different EU countries.
Involving all actors along the supply chain for quality programs	Private sector	CA, US, UK, SE, DK
2. Technologies and infrastructure		
On-farm hatching of broiler chicks	Private sector	BE

Improved technologies and infrastructure based on digitalisation, data integration and detection and decision support.	Private sector	DE
Participatory training approaches and support activities	Research	Ethiopia
Surveillance of health and welfare indicators (KalfOK)	Private sector	NL FR
On Farm data collection and provision of extension	Private sector	UK, CH, BE, NL
Big data analysis e.g. for milk quality, poultry, pig	Research	DE, AT
Private sector programme to produce AM-free	Private sector	DE AT
3. Industrial structure		
Market actors establish a prohibition of imports, that do not meet their requirements	Privat sector	SE
Labelling Strategies for livestock products without the use of AM	Private sector	UK, FR, CH, GE IR, US
4. User relations and markets		
Prohibition of critical AM	Private sector	DE SE IR
Development of new AM	Government	IN, CN
5. Policy and regulations		
NOP - The US National organic Program does not allow the use of AM.		
Exclusion of financial incentives to sell AM	Government	SE, FR
Penalty of extensive use of AM	Government	DK
Target levels for AMU and connected penalties	Governments	DK
Restriction of use	Government	EU, CH, AU, NZ
Pathogen eradication plans		
Governmental driven education for farmers and vets	Government	IT
Governmental-driven promotion of prevention measures e.g. vaccination	Government	IT UK
Benchmarking of AMU	Government	NL
6. Knowledge base		
Research programmes		All
Monitoring and surveillance		All
KOMETIAN about alternative treatments	Private Sector	CH
6.1 Selected Practices		
Ear-Mark for AB treatments	Private sector	DK
Benchmarking	Private sector	BE
Use of plant-based alternatives	Government Private sector	US, Iran
Improved rearing conditions calves	Government	NL, CH
Monitoring of pathogens	Government	NL, FR, CN, IN,
Improved prescription systems	Governments	ET, IT, SE, CN
Vaccination	Governments Supply chains	UK, CH, SE, FR, ET
Improving hygiene	Supply chains	NL, FR
Mixed methods to improve health	Research Supply chains	CH, UK, NL
Modulation of the microbiome	Research	DE, HU
Extended suckling period for piglets	Farmers Research	AT
BioRiks App	Private sector	UK

Alternatives to AM - KOMETIAN	Private sector	CH
7. Cultural change		
Mother-Calf Systems		DK, CH
Improved, targeted and informed collaboration between farmers and vets	Government	SE
Collaboration between farmers and vets		SE UK IT NL BE CH
Joint learning	Government	DE
Extension for alternatives to AM	Private sector	CH

7 Literature

Darnhofer, I. "Socio-technical transitions in farming: key concepts." *Transition pathways towards sustainability in agriculture. Case studies from Europe* (2015): 17-31.

EFSA (2017) EMA Committee for Medicinal Products for Veterinary Use (CVMP) and EFSA Panel on Biological Hazards (BIOHAZ), et al. "EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety (RONAFA)." EFSA Journal 15.1 (2017): e04666

Loorbach, D., Frantzeskaki, N., & Meadowcroft, J. (2009). Discovering sustainability: A transition approach towards sustainable development.

Geels, Frank W., Boelie Elzen, and Kate Green. "General introduction: system innovation and transitions to sustainability." *System innovation and the transition to sustainability* (2004): 1-16.

Smith, Adrian. "Translating sustainabilities between green niches and socio-technical regimes." *Technology analysis & strategic management* 19.4 (2007): 427-450