Animal Health and Welfare – ERA-NET (ANIHWA)

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Abstract:
A number of foresight activities were conducted with an aim to validate, update and expand the scope of the EMIDA Strategic Research Agenda (SRA) in a European and global context to cover infectious as well as production related infectious diseases and animal welfare, with particular emphasis placed on identifying future risk and the critical research capacity that needs to be developed or maintained. The resultant ANIHWA SRA provides a list of the scientific, technological, structural and related needs to prevent control or mitigate health and welfare challenges for the next 20 years.

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PP Restricted to other programme participants (including the Commission Services)	**[ ]**
RE Restricted to a group specified by the consortium (including the Commission Services) (precise to whom it should be addressed)	**[ ]**
CO Confidential, only for members of the consortium (including the Commission Services)	**[ ]**

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Table of Contents

Executive Summary

Changes in animal disease and welfare challenges are inevitable, but how these changes emerge and what the future outcomes could be are uncertain. The Strategic Research Agenda (SRA) developed under the EMIDA ERA-Net was updated and expanded to include production-associated diseases and welfare using a range of foresight techniques with the view that what is important is not trying to predict what will happen, but being more prepared to engage with whatever may happen.

While the foresight activities that were conducted focused on future challenges the potential opportunities arising from technological advances were also considered. The scientific, technological and related needs to prevent control or mitigate health and welfare challenges for the next 20 years and the opportunities arising from technological advances are presented in three separate lists, Specific Research Areas, Technology and Structural changes. Addressing the specific areas and/or maximising the benefits of technological advances will be enhanced if the capacity/structural changes recommended are also addressed.

The results clearly support the recommendations of the EMIDA SRA highlighting the importance of vector-borne diseases, antibiotic effectiveness and availability, vaccine development, diagnostic tests and biosecurity but also identifies the need of an improved understanding of the role of wildlife in disease occurrence, gut health and the importance of the research pipeline which is dependent on continued investment in underpinning science.

Introduction

A Strategic Research Agenda with a 10-15 year horizon was developed in the EU-funded FP7 EMIDA ERA-Net on "Coordination of European Research on Emerging and Major Infectious Diseases of Livestock". The aim of EMIDA was to build on and accelerate the work of the Collaborative Working Group on Animal Health and Welfare of the EU Standing Committee on Agricultural Research (SCAR CWG) in developing a durable focused network of national research funders in Member and Associated States of the EU for the purpose of sharing information, coordinating activities and working towards a common research agenda and mutual research funding activities in the field of animal health. The scope of EMIDA included emerging and major infectious diseases of production animals, including fish and bees and including those conditions that pose a threat to human health, but excluding foodborne zoonoses. The EMIDA ERA-Net was replaced by the Animal Health and Welfare ERA-Net (ANIHWA), with an expanded scope including animal welfare and production system-associated diseases as well as emerging and major infectious diseases. ERA-Nets are concerned with the coordination of research activities of Member and Associated states of the EU at the level of the research funding organisations through sharing of information, organising joint research calls and working towards a common research agenda.

In developing the common SRA under EMIDA, it was agreed that it should address research topics at a strategic level for the benefit of both the EU and the individual Member states. Common objectives were set out although a regional focus was included when considered appropriate. It was expected that the SRA would be useful as reference material for governmental research funders in EU Member states to manage and to coordinate research priorities and joint calls in the long term and to aid this the identified research needs were made available on a spreadsheet on the CWG website.

<u>List of pan-European research priorities identified in the EMIDA SRA</u>

1.**Surveillance systems and risk analysis**
- 1.1.Risk based improvement of surveillance
- 1.2.Improvement of risk analysis

2.**Control measures and biosecurity**
- 2.1.(risk analysis of) Biosecurity measures on all levels, including wildlife issues
- 2.2.Development of diagnostic tools and control methods for diseases of neglected species
- 2.3.Vaccination and vaccination strategies
- 2.4.Development of (novel) control methods for endemic diseases

3.**Ecosystem change, vectorborne diseases and preparedness** (in the field, laboratories and veterinary services)
- 3.1.Better understanding of vector borne diseases and health effects of ecosystem change
- 3.2.Improvement of preparedness for emerging and exotic diseases by improvement of diagnostic tools and by an epidemiological approach of risk pathways identification

4.**Host-pathogen interaction that serves the development of diagnostic tools and vaccination**
- 4.1.Vaccine development
- 4.2.Antiviral development
- 4.3.Improvement or development of detection tests

5.**Antimicrobial resistance**
- 5.1.Development of alternatives for antimicrobials
- 5.2.Molecular and cellular basis of antibiotic and anthelmintic resistance

6.**Zoonoses**
- 6.1.Unidentified/new, emerging, neglected and endemic zoonoses

Soon after this SRA was published in 2011 Schmallenberg virus infection was identified in north-western Europe, initially affecting animals in Belgium, the Netherlands and the western part of Germany. The initial site of infection appeared to be similar to that of BTV8 when it arrived approximately 5 years earlier. It would not have been possible to predict the arrival of Schmallenberg virus in Europe, however, the need for research on improved surveillance, diagnostics, vector borne diseases and biosecurity were all highly relevant to the Schmallenberg situation that emerged subsequent to the publication of the SRA.

The overall objectives of the Animal Health and Welfare ERA-Net (ANIHWA) foresight activities is to take a 20 year outlook on animal health and welfare issues, and develop a long-term Strategic Research Agenda in a European and global context covering infectious as well as production related infectious diseases and animal welfare, with particular emphasis placed on identifying future risk and the critical research capacity that needs to be developed or maintained. Specifically the EMIDA SRA would be validated, updated and the scope expanded, including production diseases and welfare, using a range of foresight techniques.

Rationale

To develop a SRA a vision is needed, preferably a shared vision, on future changing conditions that may influence the emergence of infectious diseases and expectations relating to animal welfare in the EU. When the work in the EMIDA ERA-NET commenced, one of the first issues was to describe the envisaged evolution of emerging and major infectious diseases of livestock. This enabled the setting of strategic goals and to prepare for this future. The SRA has now been expanded to include welfare and diseases associated with production systems. While the focus is predominantly on preparedness for future challenges identifying opportunities, as a result of technological developments or whatever, that could be exploited is also important.

In developing the EMIDA SRA the vision on the future was addressed through three foresight exercises, a review of relevant 'futures' publications and documents, a Delphi study, and a Strategic Research Agenda and Consensus workshops, conducted sequentially with each using the results of the previous. To update and expand the SRA: a) the drivers considered when developing the original SRA along with others identified in a number of more recent foresight studies were prioritised by a group of individuals from a range of backgrounds; b) scenarios were developed and their implications for animal health and welfare discussed after which c) a preferred future was outlined and the research needed to enable achievement of that future taking into account the challenges identified in developing the scenarios discussed. The overall results are on quite a high abstraction level, which is not surprising, given the longer the timespan of the future outlook the harder it is to be very precise. The impact of the various drivers on specific disease groups was also considered.

Animal diseases arising in one part of the world can rapidly spread to other regions and become global pandemics. The European Foresight exercises were conducted alongside and partly integrated with foresight exercises conducted under the STAR-IDAZ global network for the coordination of animal disease research. Initially separate foresight exercises were carried out for the Americas (using scenarios developed in Canada in the Fore-CAN exercise to consider their implications for animal health and the associated research needs) and Asia and Australasia (based on seven questions to encourage discussion on animal health challenges) followed by a combined online exercise involving driver prioritisation and their impact on various disease groups which was also extended to include Africa and the Middle East. Animal Health experts from all four regions then participated in a workshop in Moscow where they, in regional groups, considered a preferred future in a back-casting exercise before sharing their results with the other regions in a joint discussion session. A separate foresight exercise for the Mediterranean region was conducted by the Italian Ministry of Health.

Objectives

"To identify the scientific and technological needs to prevent, control or mitigate animal health and zoonotic challenges and address animal welfare requirements for 2030 and beyond“

Sub-objectives:

- To identify animal health, including zoonoses, and welfare challenges until 2030 and beyond
- To identify potential changes in legislative and regulatory requirements relating to animal health and welfare until 2030 and beyond (e.g. animal breeding, veterinary standards, vaccination, import/export custom regulations in regard with WTO enlargement and others relating to trade and economic integration)
- To identify challenges for prevention and control (mitigation) of animal infectious diseases
- To consider the whole variety of drivers to identify scientific and technological needs to address all the above mentioned issues until 2030 and beyond
- To allow better agenda setting

Overall Approach

The scope of the science base of the futures studies was defined and a Foresight Work Plan developed by the Foresight Working Group and approved by the Foresight and Programming Unit. Drivers identified in previous foresight exercises were prioritised in an online exercise involving 44 experts from 16 countries across Europe. The experts selected came from a range of disciplines including **S**ocial/Human; **T**echnological innovation; Conceptual change/New Paradigms/Scientific Knowledge and training; **E**conomic; **E**nvironmental; **P**olitical/Policy; Evolutionary; Agricultural systems; Animal health; Animal welfare and Infectious pathogens. A two-day foresight workshop was then held in Madrid, hosted by INIA, on the 2 and 3 April at which 39 of the experts:

a) Considered the implications of the high priority drivers for a range of disease groups and welfare;

b) Developed scenarios based on two critical uncertainties (**the state of human contentedness and the rate of environmental change**) and a range of drivers that were prioritised in the earlier on-line exercise and considered their implications in relation to animal welfare and disease challenges and the research needed to protect against these possible futures and

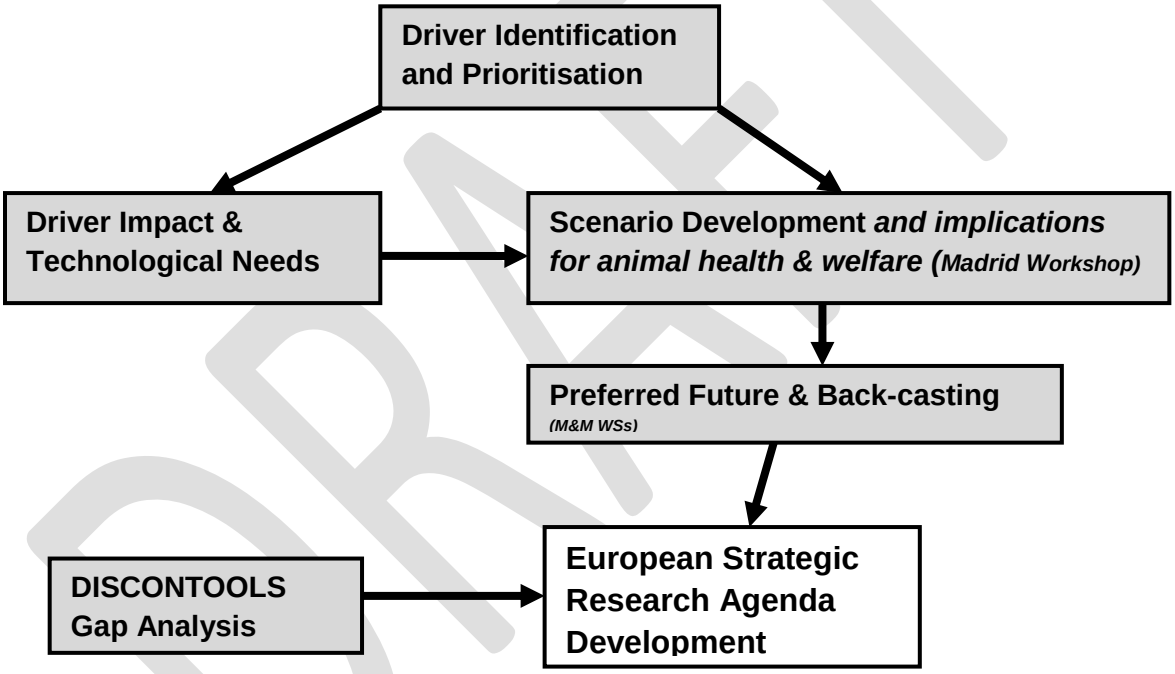
c) Considered a preferred future “Sustainable livestock production, with healthy animals reared under high welfare standards, disease minimised or rapidly contained, ensuring a safe and secure food supply and economic development” and how we get there taking into account the barriers and enablers identified in the various scenarios.

The challenges and research needs were refined at a further back-casting exercise during a STAR-IDAZ Foresight meeting held in Moscow where regional breakout groups for Europe, the Americas,

Asia and Australasia and Africa considered the preferred future and what is needed in terms of research capability to get from the present situation to the ideal future taking into account the possible challenges identified in the scenarios development exercise. The research needs identified in the scenario building and back-casting were then classified as relating to:

a) Structural/Political/Capacity – creating an enabling environment;
b) Technologies and
c) Specific topics/diseases.

Flow diagram of the Work Plan followed in updating and expanding the scope of the Strategic Research Agenda



Methods and Results

1. Driver Prioritisation and Likely Impact

Changes in the animal disease and welfare challenges are inevitable, but how these changes emerge and what the future outcomes could be are uncertain. Various external factors, including social, technological, economic, environmental, political and biological factors, referred to as driving forces, could contribute to the occurrence of these changes. Driving forces may act at the level of the source of infection, transmission pathways, and the outcome. The effects of some driving forces are predictable (trends) whereas in other cases they can be highly uncertain, with a wide range of possible future outcomes, and it is these ***critical uncertainties*** that are vital in developing the scenario framework.

Drivers identified in several other relevant foresight studies were classified under eight categories and the top 3 – 5 drivers in each category were initially ranked with the level of uncertainty noted (high/medium/low) by 44 experts from a range of backgrounds in the first round of a two stage online exercise (Stage 1). These were further prioritised across the various categories in a second round (Stage 2). The foresight studies researched included: the development of the Strategic Research Agenda by the ERA-Net on Emerging and Major Infectious Diseases of Animals (EMIDA; 2011), the FORECAN study (CFIA, 2011), the APEC project on Road-mapping Converging Technologies To Combat Emerging Infectious Diseases (APEC, 2009), the Foresight Infectious Diseases China Project (Nicoll et al, 2009).

Prioritised Key Drivers

Social/Human
Population size, density and demographic changes, including movement of people
Attitudes/expectations relating to production systems and animal welfare
Attitudes and expectations relating to food security, including cost, and food safety

Technological Innovation
Surveillance and monitoring, including related technological developments
Vaccine development
Biosecurity

Conceptual change/New Paradigms/Scientific Knowledge and Training
Balance between economy, ecology, environmental impact, animal welfare and sustainability
Social networking
Increasing knowledge and knowledge exchange

Economic
International trade
Movement of animals within and across borders
Economics of farming, including profitability and competitiveness

Alternative sources of protein

Environmental
Climate change, including extreme weather events
Disturbed ecosystems including invasive species
Human - domestic animal - wildlife interaction
Waste management

Political/Policy
Institutional short-thinking, including politics versus science
Stakeholder influence
Harmonisation, effectiveness and impact of regulations

Biological - Evolutionary
Pathogen evolution including anti-microbial/drug resistance
Greater host genetic uniformity- erosion of genetic diversity
Breeding for resistance

Agricultural Systems
Intensification/specialisation of livestock production
Alternative production systems

Overall top-ranked drivers

Population size, density and demographic changes, including movement of people
Economics of farming including profitability and competitiveness
Balance between economy, ecology, environmental impact, animal welfare and sustainability
Climate change, including extreme weather events
Pathogen evolution, including drug resistance

Driver – Disease/welfare interaction

A matrix was prepared involving a number of the highest ranked drivers in the various driver categories on one axis with welfare and different categories of disease on the other axis. Participants at the Madrid Workshop were divided into four groups and each group was asked to consider and classified (**low, medium or high**) the likely impact of the various drivers on different categories of disease and welfare. The type of technology needed to counteract the impact of the various diseases was also considered.

Welfare
Important drivers with a potential high impact on animal welfare include attitudes/ expectations relating to food security and cost, intensification of livestock production, population/demographic change, international trade and the economics of livestock farming. All of these drivers were considered to be of increasing importance. However attitude/expectations relating to animal production systems and harmonisation, effectiveness and impact of regulations were considered to be important drivers with a highly positive impact on welfare while alternative animal husbandry practices could have a positive or negative impact.

Disease

Climate change including extreme weather events is likely to increase in importance and was considered to have a high impact on the occurrence of vector-borne diseases and endemic parasitic diseases. Disruption of ecosystems, with invasion of exotic species/pests is likely to intensify, increasing the risk of new diseases, vector-borne diseases and endemic parasitic diseases. Increasing interaction between wildlife and domesticated animals and humans is also likely to contribute to an increased risk of Epizootic diseases and the emergence of "new" diseases. Pathogen evolution, including anti-microbial resistance was considered to be of increasing importance with a high impact in relation to the occurrence of vector-borne disease, epizootic disease, endemic bacteria/viral/fungal disease, the emergence of new diseases and endemic parasitic diseases. Demographic change combined with an increasing population will result in the emergence of new diseases while also making the situation relating to endemic bacterial, viral and fungal diseases and zoonoses worse. The economics of livestock farming, with increasing pressure on profit margins and intensification of production is also likely to impact highly on endemic diseases, especially endemic parasitic diseases while intensification of production could increase the challenge presented by epizootic diseases. However alternative production systems, which are likely to become more important, would pose challenges for the control of endemic parasitic conditions. Conversely increasing technological developments in relation to surveillance, monitoring and disease control will have a positive impact across all of the disease categories with harmonisation and improved implementation of regulations contributing further to improved disease control, especially in relation to epizootic diseases and zoonoses.

Full details of the Driver – Disease/Welfare interaction matrix are shown in Appendix 1.

2. Scenario Building

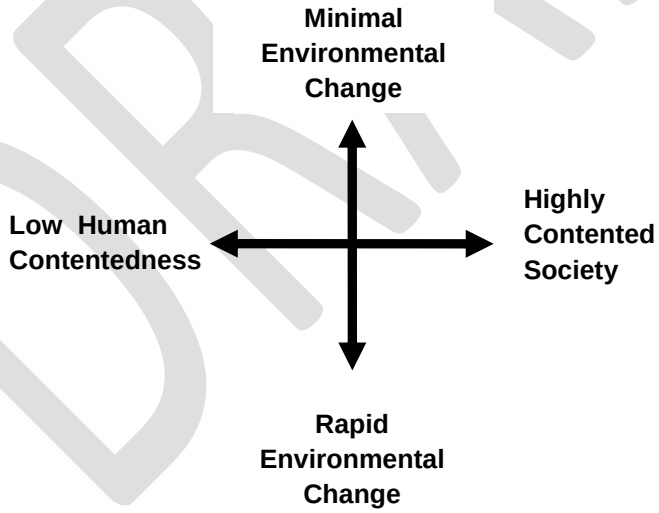
Scenarios are alternative descriptions of the future, charting the waters ahead so that the consequences of today's decisions can be played out, evaluated and tested against the uncertainty of the future and should be plausible and internally consistent.

The objective is to gain insight into the forces and factors shaping the future and the key uncertainties leading to a range of future outcomes. Ultimately the question is not what will happen but what research is needed (in terms of preventative measures, detection/surveillance and treatment) to prepare for the possibility it did happen.

Two critical uncertainties[*1], **the state of human contentedness** and the **rate of environmental change**, were identified from the prioritised drivers in Stage 1 and these were used to create the scenarios framework, identifying four different and challenging scenarios, the key characteristics and logic of which were then developed in four break-out groups. The scenario framework was a 2 X 2 matrix formed by the two orthogonal axes to create four quadrants.

The "state of human contentedness" focuses on societies' views and expectations, including economic well-being

The "environmental stresses" focuses on climatic and ecological change and resource depletion



Each of the quadrants represented a unique combination of the critical uncertainties with the resulting scenarios representing a basic picture of how things might evolve to 2034 under the influence of the aspect of the critical uncertainties defining the scenario to which were added the other main drivers from the various categories. With this framework the scenario question becomes: How does the outcome of a particular quadrant come about? All of the forces and how they play out in the future were utilised in developing each scenario. The implications of the various

scenarios for animal health and welfare and the technological and other developments needed to prepare for these challenges were explored.

Details of the various scenarios are shown in Appendix 2

*1 A driving force where there is a wide range of future outcomes, including chance of its occurrence and likely effects, is referred to as highly uncertain. Critical Uncertainties are forces that are both important and highly uncertain.

3. Preferred Future and Back-casting

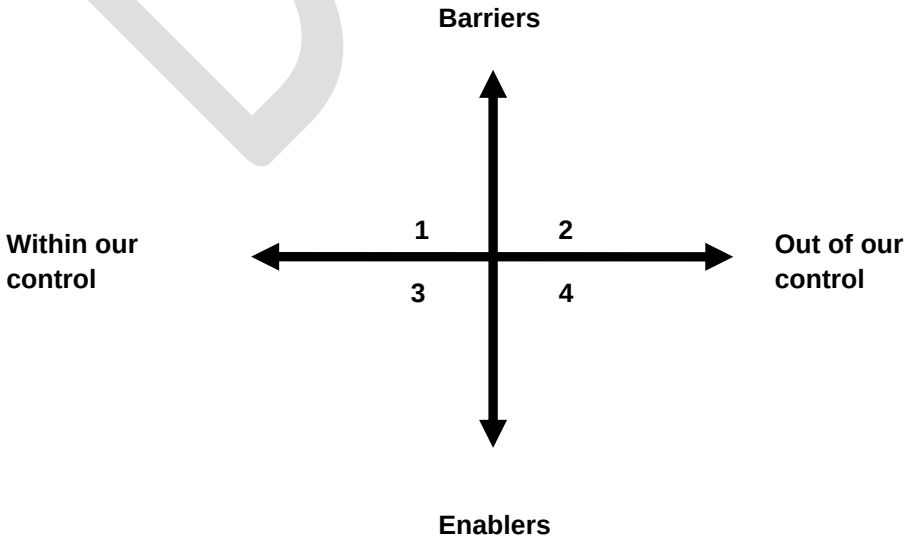
The objective of the back-casting exercise was the identification of pathways or strategies to reach an agreed vision of the desired future. In this case, core components of the future vision for livestock production in Europe were initially derived from the individual-level questionnaires on drivers. Across the questionnaires a variety of issues were raised regarding threats to the sustainability of the livestock sector.

Therefore, the preferred future scenario that was discussed and agreed at the workshop was:

> Sustainable livestock production, with healthy animals reared under high welfare standards, disease minimised or rapidly contained, ensuring a safe and secure food supply and economic development.

Where '**sustainability**' refers to livestock production, which is economically viable, socially acceptable with minimal impact on the environment.

The back-casting involved Identifying the main factors, which may impede or aid this vision by mapping the barriers and enablers across the following quadrants:



Therefore, the back-casting element of the workshop focused on the following five stages:

1. Discussion of the preferred vision.
2. Identification of steps or stages needed to meet this vision.
3. Mapping the 'barriers and enablers' of the vision.
4. Identifying the strategies or 'pathways of action' important to ameliorating Quadrant 1 issues and those which can help optimise Quadrant 3 factors.
5. Identifying the specific research topics or capacity needs associated with each of the Quadrants.

The expected outcome of the back-casting exercise was the identification of those elements of our preferred future that are presently within our control and the related research and capacity needs that can further foster/optimise these factors. Equally importantly, the exercise also helped to identify the manner and means by which those elements, which are currently out of our control can be better managed or contained going forward into the future.

Details of the discussion in the back casting exercise in Madrid and Moscow are available in Appendix 3.
The challenges and opportunities identified in Scenario building (Madrid workshop) and Back-casting (Madrid and Moscow workshops) are shown in a single table in Appendix 4.

Summary of Results

Scientific, technological and related needs to prevent, control or mitigate animal health and zoonotic challenges for the next 20 years identified during scenario building and back-casting exercises including during the Moscow Foresight Workshop.

The research needs were divided into three groups a) Structural/political, relating to the creation of an enabling environment to support research, b) Technology, where opportunities could be exploited and c) Specific disease/topic challenges and classified as urgent (Priority Box 1), less urgent (Priority Box 2) and important but not urgent (Priority Box 3)

Structural/political

Priority Box 1
Research pipeline – investment in basic research
Sound public polices relating to science and technology - Better impact assessment of new legislation
Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals; capacity in parasitology; neuropathology; Better capacity to address neglected diseases; government/professional bureaucrats
Partnerships/collaborations – global/regional research alliances – sharing information between countries
Knowledge management systems – Big data, GIS; Sharing Data - Integration and better use of existing data
Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry) - Strategy for protecting intellectual property – Public Private Partnerships
Integrated surveillance system/ Centralised diagnostic testing - Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming
Priority Box 2
Improved focus of research activities – gap analysis - Alignment of financial resources and research capacity with needs
Invest in new (more powerful) technologies
One health approach
Social acceptability of new technologies
Biosecurity - Management of waste - Improved inspection at borders
Operating systems in disease prevention and control - Operational research
WTO – lack of ethical issues relating to welfare and environment
Priority Box 3
Better monitoring of medications - Improve the control of drugs

Technology

Priority Box 1
Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR
Vaccine development/New genetically engineered vaccines – Immunology – bioinformatics - Predictive Biology - Reverse genetics – synthetic biology
Alternatives to antimicrobials – antimicrobial peptides – immunomodulators - New antibiotics
Alternative methods to control vectors - Integrated pest management - Biological control - Genetically modified insects

Biosecurity
Systems based approaches/research
Priority Box 2
Surveillance - Syndromic surveillance - Precision livestock farming/Automated disease surveillance; Big data; Risk-based approach to surveillance; More high-throughput technologies (metagenomics, sequencing and bioinformatics); Easy to use field diagnostic technology
Big data – bioinformatics
Nanotechnology – e.g. adjuvants
Animal breeding/genetics - disease resistance – local breeds - Cloned and GM engineered animals
New drug development - New therapeutics for parasitic diseases
Animal identification technologies

Specific topics/disease

Priority Box 1
Improved Understanding of the role of wild life - Epidemiological studies on wildlife - livestock interaction and disease spread
Vector-borne diseases - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification
Antibiotic effectiveness and availability - Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators
Disease introductions, including trans-boundary animals diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens
Improve food safety – traceability; risk analysis; antimicrobial/Residues
Gut health - Digestive physiology; gut microbiome - pre/probiotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut
Anthelmintic resistance - Mechanisms of resistance - Markers of resistance
New diseases
Lack of effective indicators of animal welfare
Stress due to intensification
Priority Box 2
Understanding disease ecology - Decrease evolutionary pressure on pathogens
Studies on the impact of diseases on ecology/environment/biodiversity
Socio-economic impact evaluation of main diseases
Sustainability of production systems - New production system; genetics - assure maintenance of biodiversity;
Welfare implications of keeping animals indoors
Controlled environment housing
Trade-off between welfare and cost to society
Public perception of welfare versus health
Priority Box 3
Alternative systems to compensate for downsizing of surveillance/detection systems - Integration and better use of existing data; Syndromic surveillance; Cost effective real-time collection of data; Risk-based approach to surveillance
Neglected diseases

Recommendations

Although developed with a 15 – 20 year outlook the high impact drivers could change quite rapidly, especially in the current climate of heightened political and economic uncertainty. It should therefore be validated and updated at least every 5 years through the conduct of further foresight studies.

ANIHWA is composed of a range of funding organisations with their own focus from basic science to applied research. Those wishing to use the outputs of this exercise will have different needs or interests such as animal welfare, zoonoses, opportunities for technological development or at different points along the research pipeline, so they will have to apply their own criteria for priority setting together with specific gap analysis. The research needs identified are at a relatively high level, but the driver disease/welfare matrix does provide a degree of focus as to broad areas of need, providing a framework for identifying topics for collaborative activities. It would be unwise to be more specific because what is important is not trying to predict what will happen, but being more prepared to engage with whatever may happen.

Glossary

Back-casting: A futures technique whereby a desirable future is defined and the path of action required to reach that future is identified.

Delphi study: A structured, iterative method of eliciting expert opinion usually involving two or more rounds of questionnaires.

Driver: (In this case) a general political, social, demographic, economic (including agriculture) or environmental condition acting on such a scale that it may directly or indirectly influence the (re-) emergence of animal and human infectious diseases (EMIDA FPU, 2011).

Foresight exercises: Activities aimed at thinking about, debating and shaping the future (Nicolini and Bagni, 2012).

One Health: An approach to improve health and well-being through the prevention of risks and the mitigation of effects of crises that originate at the interface between humans, animals and their various environments (One Health, 2015)

Research pipeline: A continuum from fundamental, basic research to applied research leading to product generation.

Scenario: A plausible description of how the future may develop, based on coherent and internally consistent set of assumptions about key relationships and driving forces (Nicolini and Bagni, 2012).

Syndromic Surveillance: The process of collecting, analysing and interpreting health-related data to provide an early warning of human or veterinary public health threats (PHE, 2014)

Acronyms

ANIHWA: Animal Health and Welfare (EU-funded ERA-Net Project)

APEC: Asia-Pacific Economic Cooperation

BTV8: Bluetongue Virus Serotype 8

CWG: Collaborative Working Group

DISCONTOOLS: Disease Control Tools (EU-funded project)

EMIDA: Coordination of Research on **E**merging and **M**ajor **I**nfectious **D**iseases of **A**nimals (EU-funded ERA-Net Project)

ERA-Net: European Research Area Network

EU: European Union

Fore-CAN: Foresight for Canadian Animal Health

INIA: Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

SCAR: European Commission's **S**tanding **C**ommittee on **A**gricultural **R**esearch

SRA: Strategic Research Agenda

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Appendix 1: Driver –Disease/Welfare Matrix

Europe		Disease Groups						
Drivers		**Vector-borne diseases**	**Epizootic diseases**	**Helminth diseases**	**Endemic bacterial/viral diseases, including disease syndromes**	**New diseases**	**Zoonoses**	**Fungal diseases, including mycotoxins**
Increasing population size/density	**Impact:**	**Low**	**Low**	**High**	**High**	**Very High**	**High**	**Very Low**
	Comments:	West Nile, Chikungunya, Bluetongue, Nipah, Lyme, TBEV	African Swine Fever, Influenza	Taenia	Herpes	Wildlife diseases, SARS, SIV, MERS	Brucellosis, Campylobacter, Samonella, Q fever; Hep E, MRSA	Manganese, toxins from pollution
Attitudes/ expectations relating to production systems and animal welfare	**Impact:**	**Medium**	**Very Low**	**Medium**	**Medium**	**Medium**	**Low**	**Very Low**
	Comments:			Related to outdoor production	Organic systems			
Attitudes and expectations relating to food security, including cost, and food safety	**Impact:**	**Very Low**	**Medium**	**Medium**	**Medium**	**Very High**	**Medium**	
	Comments:				Also consider endemic prion diseases.		Toxoplasmosis, Taenia	
Biosecurity including surveillance and monitoring (on farm level, national level)	**Impact:**	**Very High**	**Very High**	**Very High**	**Very High**		**Very High**	
	Comments:	Lyme disease, Cryptosporidium, Histomoniasis, Liver fluke	Brucellosis, FMD, Avian Influenza, CSF					
Desired balance between economy, ecology, environmental impact, animal welfare and sustainability	**Impact:**	**Medium**						**Very High**
	Comments:							Fish farming
International trade including movement of animals within and across borders	**Impact:**	**Medium**	**High**	**Low**	**Low**	**High**	**Very Low**	**Very Low**
	Comments:		Vesicular diseases	Drug resistance			Trichenalla, Taenia	
Economics of farming, including profitability and competitiveness	**Impact:**	**Very Low**	**Medium**	**Very High**	**High**	**Medium**	**Medium**	**Medium**
	Comments:		Cost of biosecurity	Gastro-intestinal parasites	Mastitis, BVD	Prion diseases	Cost of biosecurity	Economies and feeding, water quality, mycotoxins, metabolic
Alternative sources of protein for both humans and animals	**Impact:**	**Very Low**	**Medium**	**Very Low**	**Medium**	**Very High**	**Medium**	**High**
	Comments:							Plant related toxins or byproducts
Climate change, including extreme weather events	**Impact:**	**Very High**	**Medium**	**Very High**	**Medium**	**Medium**	**High**	**Very High**
	Comments:	Tick-borne diseases	African Swine Fever	Flukes, PGE			Leptospirosis	Undernutrition
Disturbed ecosystems including invasive species	**Impact:**	**High**	**Very High**	**Very High**	**Very Low**	**Very High**	**Medium**	**Very High**
	Comments:		Bee diseases, ASF	Bees			Tick-borne diseases, Echinococcosis	Fish metabolic
Human - domestic animal - wildlife interaction	**Impact:**	**High**	**High**	**High**	**Medium**	**High**	**Very High**	**Very Low**
	Comments:	ASF, West Nile; vector-borne diseases with a wildlife reservoir	Influenza	Fish	TB		TB, West Nile, Echinococcosis, Lyssaviruses	
Waste management, including recycling as animal feed	**Impact:**	**Very Low**	**High**	**Medium**	**Low**	**Medium**	**Medium**	**High**
	Comments:			Protozoa e.g. Giardia		Prion diseases	Salmonella, Taenia, waste from abattoirs/ human waste	Fish - hormone disruption Oher animals - heavy metals; poisoning, amplification of chemical contaminants by recycling
Harmonisation, effectiveness and impact of regulations and policies (including EU agriculture policies)	**Impact:**	**Medium**	**High**	**Medium**	**Medium**	**Very Low**	**High**	**Medium**
	Comments:	BTV vaccination	FMD, TB and other statutory diseases	Coccidiosis	Availability of medicines	Prions	Inter-departmental harmonisation - One Health - Public Health	High - phosphorous deficiency, mycotoxins
Pathogen evolution (including anti-microbial/drug resistance)	**Impact:**	**Very High**	**Very High**	**High**	**Very High**	**High**	**High**	**Medium**
	Comments:	Pathogen adapting to new vector and host; Schmallenberg, BTV				Pathogen evolution could lead to new diseases	Wildlife diseases	Mycotoxins might increase
Intensification/ bigger	**Impact:**	**Medium**	**High**	**Very High**	**High**	**Medium**	**Medium**	**Low**

production units and factory farming	**Comments:**	Intensification potentially decreases contact with vectors; ticks, mites, fleas	Affects larger numbers of animals due to intensification	Coccidia in pigs will increase and parasites needing pasture for their life cycle will decrease	BVD	Decrease		
Alternative animal husbandry practice	**Impact:**	**Medium**	**Medium**	**Very High**	**Medium**	**Medium**	**Medium**	**Medium**
	Comments:							Nutritional deficiencies - amino acids

Appendix 2: Scenarios

Scenario 1: Republica Discontenta

- Minimal environmental change
- Low human contentedness

KEY CHARACTERISTICS

Society

- Migration and demographic structure change are not very well addressed by policymakers
- Less young people are willing to stay in their home country
- Reality doesn't meet people's expectations which causes frustrations (people don't see the benefit from the resources spent on the environment; miscommunication)
- Not having all the basic things, such as energy and food, available at any moment anymore

Politics

- Lack of local decision making
- More centralized approach of decision making, will not always benefit the individual MSs
- Few stakeholders influence political situation
- Isolation / less engagement in EU-wide processes
- **Technologies**
- There are new technologies but the majority of population is unable to access, accept and leverage it
- Only a small group of people (investors from in or outside the EU) are benefiting from the technological break-through

Economy

- Overall economy depression
- Industry is moving elsewhere (other parts of the EU / outside EU)
- Intensification of production decreases quality
- Quality goods are not consumed by the EU (MS) population but are exported

Agriculture

- Family farms are replaced by agroholdings
- Less young people are willing to run a farm
- Agricultural education level decrease – farmhands becoming incompetent increasingly
- Food and feed prices are high

Bio-evolution

- Alternative scenario: ignorance regarding environmental and bio-evolutionary changes (ergo: decreased awareness and less preparedness for new challenges)
- Stable environment (doesn't mean perfect environment)

Scenario narrative:

Although people request to live in a stable environment with minimal change, the cost to achieve such a situation will lead in the end to discontent. Especially, when distribution of the many technological, agricultural and societal achievements appear to be uneven. Moreover, it should be mentioned that an environment with minimal change does not mean it is a perfect environment we are living in.

So, how come that we end up with a society of low human contentedness in 2035 while there is an environment with minimal change? Next to the fact that the population is aging, including the farmer population, there is increasingly less interest of young people to take over family-run businesses. They rather go to urban environments. Foreign investors recognise the opportunity and take over the farming society while maximising their profit, as they did with many family-run businesses. Family farms are replaced by agroholdings. Especially the economic recession of the beginning of this era made people even more cautious and reluctant to stay in family-farming and therefore migrated to the city.

Governments, however, were making costly decisions for the greater good, to improve the economic, social, agricultural and physical environment of their citizens. This required a dominant centralised approach in political decision-making. Unfortunately, migration and demographic structure change were not very well addressed by policymakers. Furthermore, governments couldn't prevent that industry moved their business to low-wage countries. This generated the first signs of discontent in Europe at the time.

Society was confronted with limits to endless growth at the end of the 20th century. In the first three decades of the current century it became clear that despite technological improvements and break-throughs most of the valuable Earth's resources are limited as well. To guarantee minimal change in the environment large investments were necessary for technology developments to exploit resources in a sustainable manner. Few stakeholders influenced the decision making to drive these new and future technologies, and by 2035 only a small group of people (investors from in and outside Europe) benefit from it. At the same time the majority of the population is unable to access and leverage these new technologies and its values other than the environmental stability.

Attention of the policy-makers and citizens is drawn to sustainability of environment in conditions of urbanisation and the ever-growing population. To meet the growing demand of an increasing global and urban population size intensification of production was made necessary, which led to a decreased quality of the products. The increased density of production animal population required large investments in biosecurity and biosafety technologies and procedures to guarantee safe and secure food supply. Nevertheless increasingly less attention is paid to animal health and welfare. Furthermore, the large urban societies in mega-cities required biosecurity measures in itself, because the large population of humans and disease transmitting

animals were prone for outbreaks of infectious diseases. Especially when climate change led to conditions similar to the subtropics and changes of zoonotic threats.

The change in supply and demand led to an increase of food, feed and energy prices and even turned into price volatility by 2035. While at the same time the high quality goods were not available for European consumers, because these products were exported. As animals are kept in huge herds, the conditions are poor and animals in majority are fed with cheap and not always properly controlled forage, thereby animal welfare decreases. Besides, managerial power to cope with outbreaks is lower than it should be. High antibiotic resistance in animals along with the risk of pathogens transmission is another challenge that has to be addressed. In such conditions any disease outbreak can lead to a pandemia.

Therefore people's expectations are not met increasingly which creates discontent. People don't see the benefit from the resources spent on the environment, because they don't have the basics, such as energy and food, available at all times. This leads to the desire to more local decision-making and less engagement in EU-wide processes.

IMPLICATIONS FOR ANIMAL HEALTH, WELFARE AND ZOONOSES

	Logic (Why)	**Science & Technology or other needs**
Animal Health Challenges	-Increased density of animal population (higher impact of diseases, high level of viral mutations) - Antibiotic resistance -Managerial power to cope with outbreaks is lower -Import of cheap products	- More investment in biosecurity / biosafety technologies
Animal Welfare Challenges	-Increased density of herds	More knowledge is needed about stress and animal welfare issues when the animals are kept in bigger herds
Zoonoses Challenges	- less contact between animals and humans - "urbanization" (concentration in mega-cities) of people will also increase the concentration of "pests" potential vector	- New sustainable (and cheap) systems to reduce the risk of pathogens transmission and antimicrobial resistance development along the food chain

	for diseases (mosquitoes, rodents, other animals that are showing a tendency to become urbanized)	(safer food at the table) - Innovative methods for the identification and characterization of vectors and their “competence” for known and emerging pathogens (immunology and vector-pathogen interaction)

Scenario 2: Too good to be true?

- Minimal environmental change
- Highly contented society

KEY CHARACTERISTICS

Description of Scenario based on quadrant defined by critical uncertainty axis:

Population: increase (immigration)

People tolerance increases: lowering of social tension

Well-balanced economy

Equitity of resources

High level of education (equity in access)

Economic wellness: more economic availability to most people

Good living conditions:

Political stability

Food security

EU self-sufficiency?

Food safety

Low unemployment

Nice climate

High social security

No extreme climate events

Sustainability

More holidays

Health status of people increase

Intensification on some area and extensification in other

<u>Narrative of how the story evolves with addition of the key drivers from the various driver categories:</u>

In the 2010s the EU is fragmented and divided, big differences exist across the countries. Politicians agreed on the need to act as unique economic and political element, going through common objectives. Economy goes toward centralisation in the European Federation (EF).

Big efforts are concentrated on the new investments, like the H2020 programme. Investments in education are carried out across the EU. Investment in technology improves the EU sector competitiveness globally. Export of goods increases. Economic crisis ends in the EU area.

The political unity helps to take action toward increased awareness on environmental issues. Measures are taken for waste recycling management and greenhouse gas emissions.

Also, the economic stability lowers social tension. Immigration fluxes toward the EU continue, leading to a global increase of the population in the area. The environment becomes more multi-cultural. Request of new food emerges (e.g. traditional ones from outside the EU). Food demand increases.

New technologies are implemented in European countries, which will improve farm management and farm competitiveness, leading to profitable food production. Differentiation and specialisation of farm sectors, some going toward intensification (high input) and other toward extensive (low input outdoor)/land use efficiency. Export of high quality agricultural products increases.

The investment in technology and the cohesion across countries help to get better surveillance. Eradication plans are carries out; animal health globally improves.

Awareness campaigns are carried out to modify people habits toward food buying, teaching the relevance of sustainable and animal welfare friendly production. It leads to sustain local (EU) agri-food productions.

It is not the perfect world, problems are still there, but people are satisfied overall and content.

IMPLICATIONS FOR ANIMAL HEALTH, WELFARE AND ZOONOSES

	Logic (why)	**Science and Technology or other needs**
Animal Health challenges:	Excess of contentedness leads to complacency including the attention to AH or AW Centralised authorities tend to lead to slower responsiveness Eradication programmes Biodiversity loss (AnGR) Growth in low input farm leads to more contact between farm/wild animals Intensification lead to production diseases (e.g. metabolic) Waste and pollution Antimicrobial resistance increase	- Harmonisation of IT tools for monitoring, surveillance and traceability data - Genetic modification (breeding for resistance/production); genetic selection on local breeds to sustain biodiversity - Technological development on both intensive and extensive system - Risk based modelling for surveillance - Development of sustainable waste recycling - Development of alternative or reversive mechanism for antimicrobial defence
Animal Welfare challenges:	Intensification and production disease Levelling out of AW standards Centralisation lead to longer transport	- development for technology for herd management and surveillance; automation - Development of adequate transport means/local slaughter plants - Scientific validation of practical AW indicators - Implementation of risk based surveillance for AW
Zoonoses challenges:	Interaction with wildlife People on holiday more often in contact with wildlife More travel of citizens outside EF for holidays bring home diseases/vectors	- Biosecurity development - Syndromic surveillance (intelligence surveillance) - Improve new tools for monitoring - Development or eradication programmes for wildlife (e.g. development of new vaccines, new carriers for vaccines)

Scenario 3: In Society we Trust: Semper Parati (Be prepared)

- **Highly contented society**
- **Rapid environmental change.**

Description of Scenario based on quadrant defined by critical uncertainty axis:

Three legged stool – Society, Economy and Environment. This scenario is the situation where the environment leg is missing (society and economy are stable).

Contented society: Immigration to federal Europe is intensive but stably regulated, economy is sound, no political upheavals, people are happy, culturally and religiously tolerant, how people perceive their own situation relative to others (within and outwith their society), opportunities for people, low level unemployment and corruption. Easy travel, good neighbourly relations with EU countries, free trade high level of regulation , choice, trust in government via technology and reliable communication. Transparency is effective.

Rapid environmental changes, instable annual cycles ,heat surges in summer: Mainly natural disasters, extreme weather, floods, pollution high although under control , unbalanced ecosystem with risk of destruction/loss under transparent control; satisfactory waste management, manmade disasters like nuclear meltdown technologically measured.,

Newly emerging diseases are spotted immediately – preparedness and prevention (good monitoring and surveillance, early detection = expensive costs to be paid now for future reward); risk communication from authority is trusted and public/private system is regulated with easily understandable rules.

Farming in Europe is mainly limited to high level, quality and price productions with technology, automated online controls and biosecurity system implemented. Lab food, transgenic and alternative protein sources are anyway accepted by consumers.

Mass food is cheap due to import; level of minimal standards is anyway granted by good clearance and on spot audit system.

Key characteristics:

- For a contented society in 2034 we need to focus on **preparedness and prevention** now and need the public to have trust/confidence in the government/risk managers in the future. This trust is gained by **transparency, effective communication**
- **Awareness, empathy and knowledge** now leads us to innovative mitigation strategies in preparation for the future including KT at all levels.
- More **public - private partnership** (collaboration) in the development of strategy and implementation.
- Most **food imported**. Meat imported into EU will need to meet **welfare requirements** and other products will need to have been ethically produced. Welfare standards are covered by SPS Agreement (not all agree).

- Genetically modified, cloned and genetic selected livestock becoming more of an issue in 20 years.
- **Technology** is central to this society as it provides solutions to our animal health and welfare issues and people accept it.
- Wealthy society that have developed wealth from innovation and intellectual property rights; become open to **GMO**
- Need **flexibility** in an uncertain environment – need to manage animal production and protect it from environmental effects.
- Increased detection and identification of disease by robots - **automated disease monitoring systems.**
- Production collapses in extreme environment conditions for many reasons – feed, housing etc

:

Societal

- Rapid communication because of extensive use of social media
- Differences in religions are respected and do not tensions between different cultures

Technological

- Technology is central to this society and develops at a high pace
- Automated transparent check systems

Economic

- Economy is stable in this society: a low rate of inflation and small national deficits
- Europe keeps know how on technological patents.

Environmental

- Sustainable production: food and commodities are produced environmentally-friendly
- Energy from fossile resources are reduced more and more; Green house gas emissions have been reduced to a very low level; Global warming is under control.
- Solar and wind gained energy increases
- Season cycles are unstable with great differences between years; extreme events are frequent; productive sectors are to grow flexible to adapt to variable conditions; technology and forecasting methods are crucial to profitability.

Political

- Political expediency. People is contented with policies.
- Mutual trust between Risk managers and R. Assessors
- Good institutional communication policy

Agriculture

- Cheap mass food is granted by import from third countries
- Different ways of development:
    - big farming holdings at the same time became bigger and bigger
    - more local agricultural production working with autochthon animal and plant varieties

IMPLICATIONS FOR ANIMAL HEALTH, WELFARE AND ZOONOSES

	Logic (why)	**Science and Technology or other needs**
Animal Health challenges:	1.Emerging new diseases: Environmental instability and potential effect of importing from outside Europe (international trade and movement of people/animals) 2.Potential for outbreaks of existing diseases: 3:New vectors: 4.Flood situation sees pathogens spread such as cryptosporidium and FMD 5. Higher sensitivity of society to animal diseases	1.Surveillance and monitoring, early detection biosecurity systems. Traceability of animals and products. Geographical Information Systems to track movements of animals and products 2.New/alternative drugs/intervention tools and devices for the treatment and prevention of diseases. Generic vaccine to treat several diseases. 3. Communication and education – keeps society happy every time. Knowledge transfer. 4. On farm rapid diagnostics 5.technology to improve response time. 6.Increased detection and identification of disease (abnormal conditions) by robots - automated disease monitoring systems. Even automated treatment
Animal Welfare challenges:	1.Clean food, clean water and shelter/housing in variable environment. 2.Dairy cows bred to maximise milk production have welfare issues – feet problems, short lives. 3.Increased production and increased time spent indoors will stress animals. 4.Hotter summers with high humidity causes poultry to die.	1.Practicable alternatives to antibiotics 2.Tools and agreed standards for measuring stress. 3.Understanding animal behaviour as benchmark for animal welfare standarts. 4.Need more storage of feed/feed security
Zoonoses challenges:	1.Disrupted environment means more vector borne zoonoses. 2. Society is even more sensibilized	1.Effective pest control in human and animal production environments. 2.Environmentally friendly

	for zoonoses problems 3. Global trade increase risk of zoonoses outbreaks 4. Bigger farm units and local small scale farms continue to keep high risk of zoonoses outbreaks 5. People live even more “aseptic” and became more susceptible to some zoonoses pathogens	pesticides/chemistry. 3.Genetic modification of vectors. 4.Biological control of vectors

Scenario 4: Riding the waves

- Low Human Contentedness
- Rapid Environmental Change

Key characteristics of the scenario based on quadrant defined by critical uncertainties:

- Conflict between have and have not (inequality), urban and rural,
- Concern about price of animal products.
- Political instability - Changes in governments – cycles of change
- Increasing nationalism
- EU volatility
- Lack of trust
- Lack of confidence in science, politicians, governments, food production etc
- Human disease spreading
- Access to health care declining
- Unemployment
- Ageing population
- Immigration
- Different values of young
- Frequent extreme weather events (drought, flooding, temperature extremes)
- Increasing levels of pollution - chemicals, Nano particles
- Loss of critical soil nutrients
- Loss of biodiversity
- Shortages of clean water
- Pathogen evolution (resistance to vaccines, antibiotics, anthelmintics),
- Increasing use of GMOs including crops
- Loss of host genetic diversity - Genetic concentrations (focus on production, health)
- Pollination decreasing
- Concern about CO2 and CH4 emissions

Narrative of how the picture evolves up to 2030, with addition of the key drivers from the various driver categories

Economic recovery following the recession of 2008 – 10 is short-lived with uneven effects across European states. Wealth and power are more concentrated in a small section of the population while the vast majority are struggling to make ends meet, with unemployment levels high. The native population is ageing and living standards and welfare supports are falling. There is increasing migration of displaced peoples into Europe with society becoming more fragmented. Although political power becomes more centralised in Brussels there is an increasing difficulty maintaining harmonised controls across sectors. There is significant distrust of politicians with increasing nationalism and support for more extremist groups. Multinational companies exert increasing influence.

Extreme weather events are more common, with flooding in northern Europe and drought in Mediterranean areas. Environmental controls are slipping in many countries. Soil erosion, loss of soil nutrients and decreased use of fertiliser due to escalating costs reduces biodiversity and the carrying capacity of the available agricultural land. Farming becomes more divergent with a small

number of large intensive livestock units, operating under conditions of low profit margins, and a large number of subsistence operations including backyard production in urban areas, with the feeding of kitchen waste to animals.
Capacity of the regulatory authorities to monitor imports and to conduct disease surveillance is eroded with responsibility to contain/control periodic disease outbreaks, which become more prevalent in the 2020s, resting with producers and processors. Drug resistance is a major problem.

Societal

- Tension between Cheap affordable food and production system (quantity – quality) leading to two tier production (high quality expensive & affordable quantity)
- Labour costs expensive
- Immigration/migration from worse off areas, including from outside Europe
- More risk averse older population

Technological

- GM soya grown more widely in Europe
- Importance of environment on epigenetics (nutritional aspects)
- More use of robotics, information and communication technologies for monitoring health - less human observation of animals
- Increasing use of biodigester, including using food waste

Economic

- Cost of fossil fuel escalates and as a result cost of concentrate feeds also escalates
- Compensation for disease outbreaks too expensive - Risk will be transferred to producer and producer organisations - increasing litigation among farmers due to alleged introduction of diseases.
- Veterinary charges not affordable - illegal imported medicines
- Farmers purchase medicines and vaccines from abroad or on the internet

Environmental

- Farmers put in place processes for capturing rainwater/recycling waste water
- Flooding exposes livestock to wider-range of pathogenic organisms? Not always necessarily wider range, but often heavier exposure to higher doses of pathogens
- Increased movement of livestock during flooding events
- High temperatures cause housing to be adapted (cooling/stocking density/ability to access water for cooling)
- Contingency planning for extreme winter snow events in mountainous regions –
-

Political

- Centralisation of power in a Brussels bureaucracy
- Institutional short thinking
- Lack of independent experts in Government regulatory areas
- Government will not have capacity to carry out monitoring – Need to be taken on more by producer.
- More turbulent regulatory environment

Agriculture

- Livestock industries fragment into smaller producers and large intensive commercial operations. Some small, part time, subsistence farmers operating in a lower knowledge base. Other small farmers operate within cooperatives.

- Risks increase and disease outbreaks increase
- Lack of traceability
- Rapid change and unpredictability of emergence of risks -

Bio-evolutionary

- Widespread drug resistance (including in wildlife)
- Increasing use of Bos indicus crosses/synthetics and in general highly selected populations (especially in poultry and pigs)

IMPLICATIONS FOR ANIMAL HEALTH, WELFARE AND ZOONOSES

	Logic (why)	**Science and Technology or other needs**
Animal Health challenges: Disease challenges increased, Unpredictable disease outbreaks Novel pathogens emerging Metabolic diseases increasing Drug resistance Disease resistance decreasing	Government can't fund surveillance / subsidised diagnostic systems. Importation of cheap livestock products Profitability for Pharma decreasing, focus on lifestyle drugs Producers can't afford vet bills so buying medicines on the internet	Monitoring/diagnostic tools need to be improved including more rapid results, Improved risk analysis, More translation of science, . Cheaper control methods, Better risk analysis, Better biosecurity, More effective legislation and its implementation, Need for a European wide database to improve traceability Facilitation of farmer self-help groups, farmer self-monitoring Creative/novel funding mechanisms to develop new vaccines/pharma products Ways of facilitating faster/cheaper regulatory approval while maintaining safety/efficacy
Animal Welfare challenges: Optimising the balance between welfare and intensification Welfare indicators need to be defined for backyard production	Demand for cheap food resulting in intensification Increasing amount of back-yard subsistence production	Monitoring systems, Knowledge transfer to farmers and citizens
Zoonoses challenges: Zoonotic diseases increasing		Monitoring systems

Challenges identified across the various scenarios

Challenges	Appears in scenarios	Disease/welfare implications	Research needs	Structural needs
Virus evolution	1			
Novel pathogens emerging	3, 4			
Antimicrobial resistance	1, 2, 3, 4		Systems to reduce AMR development Development of alternatives to antibiotics or reversion mechanisms.	
Disrupted environment	3	Increase in VBD	Effective pest control in human and animal environment. Environmentally friendly pesticides/chemicals. Genetic modification of vectors Biological control of vectors	
Vector(rodent/insect/tick)-borne diseases. New vectors	1, 3		Innovative methods for id and characterisation of vectors and their competence	
Environmental instability and international trade and movement of people	3	Emergence of new diseases	Surveillance and monitoring for early detection. Biosecurity. Traceability of animals and products – GIS to track movement.	
Increasing contact between farm animals and wild life and humans and wildlife	2		Biosecurity	
People on holiday coming into contact with animals People on holidays bringing back pathogens/vectors	2		Syndromic surveillance Improved tools for monitoring	
	2		New vaccines or carriers for vaccines for wildlife	Disease eradication programmes for wildlife
Global trade	3	Increased risk of zoonoses		
				Capacity to cope with disease outbreaks
	1, 4		Improved biosecurity and biosafety technologies	

Over centralisation leading to delayed responsiveness	2			
Complacency and lack of attention to health and welfare	2			Harmonisation of IT tools for monitoring, surveillance and tracing animals
Disease eradication	2			
Loss of biodiversity	2		Genetic selection on local breeds	
	2		GM – breeding for resistance/production	
	2		Risk-based modelling for surveillance	
Dairy cows bred to maximise production	3	Foot problems, longevity		
Decreasing disease resistance of the host	4			
Stress due to intensification Balance between intensification and welfare	1, 4	W	Knowledge on stress and animal welfare issues when animals kept in bigger groups	
Intensification leading to production diseases (e.g. metabolic)	2, 4	Metabolic diseases	Technological development for both intensive (automated technology for herd management and surveillance) and extensive systems	
Centralisation leading to longer transport journeys	2	W	Development of adequate transport means/local slaughter plants	
	2	W	Scientific validation of practical animal welfare indicators	
	2	W		Risk based surveillance for AW
Increasing potential for outbreaks of existing diseases	3		New/alternative drugs/intervention tools and devices for the treatment and prevention Generic vaccine to combat several diseases	
Waste/pollution	2		Sustainable waste recycling	
Flood spreading pathogens	3	Cryptosporidium; FMD;		
Higher sensitivity of society to animal diseases and	3			

zoonoses				
	3			Communication and education, KT
	4		Improved risk analysis	
	3		On farm rapid diagnostics	
	2, 4		Improved monitoring/diagnostic tools	
	3		Technology to improve response time	
	3		Robotic detection and identification of disease. Automated treatment	
	3		Improved understanding of animal behaviour as a benchmark for welfare standards	
	4		Welfare indicators for back-yard production need to be defined – monitoring systems	
	3			More storage of feed
Increased time animals spend indoors	3	stress	Tools and agreed standards to measure stress	
Hotter summers	3	Poultry deaths		
Bigger farm units and local small scale farms	3	Zoonoses risk		
People living “aseptic”	3	Increased susceptibility to zoonoses		
Increased disease challenges	4			
Unpredictable disease outbreaks	4			
	4			Knowledge transfer to farmers
	4			More effective legislation and its implementation
	4			European Wide database to improve traceability
	4			Facilitation of Farmer self-help group; farmer

				self-monitoring
	4			Creative/novel funding mechanisms for develop of new vaccines and pharma products
	4			Facilitation of faster/cheaper regulatory approval while maintaining safety and efficacy.
	4			Cheaper disease control methods

Appendix 3: Backcasting

Backcasting (Groups 1 & 2 – 'Within our control')

Identify elements of the future vision versus the present circumstances that differ

- Actually: relatively variable welfare and health standards among farms.
- Risk for emergence of diseases is present.
- Risk of contamination of food products during processing.
- Impact of "food businesses" across Europe on the environment should not be neglected.

Map the barriers and enablers that are 'Within our control':

Barriers and Disease or Welfare implications	Research capacity & knowledge networks to ameliorate the barriers or research needs
(AW): Insufficient compliance with the legislative system	
Cost of the AW	Cost/benefit balance (discussion)
Lack of effective indicators for AW	research on "omics" for AW indicators in animals
AW, AH: Lack of coordination, access to existing data	Collection, harmonization, utilization of existing data
Lack of resources	harmonized approaches for risk/benefit evaluation, research on effective tools/ways for data and knowledge sharing
Lack of proactivity	Surveillance, early detection and early warning, develop models
Lack of understanding of decision-making process, public perception	Better understanding of public perception, decision-making
Subsidy system / strategy	Needs to be revised
Shortage of feed protein within the EU, dependence on import	

Lack of knowledge of adaptation measures to environmental changes	Increase knowledge of the environmental drivers that we can control and manage

Enablers and Disease or Welfare implications	Research capacity & knowledge networks to optimise the enablers
Technology availability	focus on “life technologies” capable to provide detailed information on body response to “attacks” (pathogens-stress-ageing) for detection of useful “early” markers of change
Increase of awareness and communication	
IT	development of infrastructures/platforms to maximise the data harmonization and sharing
investments	
One-health approach (multidisciplinary approach)	Prioritize projects based on comparative and multidisciplinary approaches
Traceability of animal movements	To be improved

Backcasting (Groups 3 & 4 – 'Out of our control')

Identify elements of the future vision versus the present circumstances that differ

- Current practices not sustainable
- Welfare standards could be improved and standardized
- Animal health needs to improve
- Food safety could be improved

Map the barriers and enablers that are 'out of our control':

Barriers and Disease or Welfare implications	Research Capacity or knowledge networks to ameliorate the barriers or research needs
Water scarcity (including competition) – Welfare implications (esp fish), ducks Health – poor sanitation (endemic diseases and zoonoses) - water capture – water recycling	Engineering approaches to reduce water use and recycle water efficiently Low cost methods of cleaning potentially contaminated water for re-use (e.g. recycling or capture from roofs) Low cost diagnostics and diagnostic platforms, pen side test Water treatment options
Water quality (pollutants) (esp imp for fish)	Easy to use/rapid/cheap detection systems Risk analysis Indicators
Food – feed conflict (esp. imp for monogastricts)	Health implications of alternative feeds Do we know enough about the physiological interactions between feeds and high temperatures?
WTO Need to include ethical issues, welfare and environmental	Establishment of acceptable standards Development of measurable standards
Sustainable Resource management (for ruminants) Carrying capacity – we don't know this Land use/land use change – competition	Modelling different land use impacts on sustainable resource management and likely disease implications e.g. are there disease implications in more trees in upland areas for water management?

for resources Pasture use. Methane production - role of disease in GGH emissions. Disease implications of using different feeds to mitigate GGH emissions	Are there any disease implications from alterations in soil organic matter/carbon content? Does this impact on pathogen survival rates? Are there any health/welfare implications from increased use of legumes in leys/use of lupins or other Europe-grown protein crops?
Waste management Water distributed animal waste on pasture – pathogen spread Pollution from minerals (phosphorous deficiency)	Water vectored diseases Is enough known about the impact of different manure handling methods (actual on farm as opposed to best-practice)?
Public acceptance Conflict between perceived welfare vs health	Improved understanding of how people develop their concepts of 'welfare' and 'health' Further develop "benchmarking for animal welfare" people with distance to animals have other standards comparing with people living in rural areas
Sustainability of rural communities – bigger farms	Interactions of farms with the wider rural communities - where are the critical pathways, if there are any. e.g. need for ancillary industry (feed mills, slaughterhouses etc, veterinary practices etc)
Balance between livestock production and wildlife	Understanding implications of intensifying to free land for wildlife vs. sharing land
Adaptation of vectors to new environments	Vector control including natural predators or competitive inhibitors, Monitoring of vector population
Extreme weather events	Extremely hot summers and cold winters affect especially livestock animals and predispose to respiratory diseases.
Natural disasters	Flood predispose transmission of infectious diseases for (example) cows herds.
Population growth	Impact of increased contact between diverse city populations and farmed livestock. At the same time a lot

	of people living in urbanisation completely lose contact with livestock.
Population demographics	
EU Expansion	Possible expansion Ukraine/Turkey
Conflicts	Foresighting high potential areas for conflict with potential impacts on global animal health
Pandemics	Interactions of pandemics & food supplies - responses of consumers and food chain actors
Pathogen evolution, including to new vectors and resistance	Vector competence studies, Drivers of mechanisms of resistance development Genetics of resistance of host/ resistance of local breeds
Too narrow a focus on genetic selection	Research on genetic links of selection indices to host disease susceptibility
Migration	Changes in food demand patterns due to migration
Global Trade	Changes in food supply-demand patterns due to changes in global trade
Global economics	
Lack of trust communications between industries and between authorities and industries	A lot of research on trust has been done, is any of this relevant for this context or is new research needed? Clear transparent. actions from authorities. Primary sector still dont understand EU agricultural policy.More communication on primary level.
Vested interest and pressure groups Conventional systems of management resisting change,	Understanding change processes at system level
Price Competition(including power of	Research needs of health issues in small scale farming – monitoring animal deaths, mortality rates and

supermarkets) Welfare standards Health	behavioural on small farms. Basis for common certification schemes – science based standards
Energy costs and availability Environmental controls in houses Welfare implications of over heating	Coherent integrated farm energy supply/management, optimal balance between energy use and energy production Optimal environmental conditions for control of pathogens such as campylobacter Safety of by-products from bio-digesters
Invasive exotic species New diseases Disturb balance of ecosystem – Ecosystem health	Generic detection platforms Population control Control global warming
Trade-off between welfare and costs to society/willingness to pay	Knowledge transfer Economic research
Wildlife reservoirs of disease	High level of pathogen surveillance
Domestic pets as potential reservoirs of disease?	Exotic domestic pets

Enablers and Disease or Welfare implications	Research Capacity or knowledge networks to optimise the enablers
Education including introduction to agriculture earlier	Sharing pedagogical tools, best practice Understanding impacts of early years farm visits (evidence may already exist)
Systems approach/systemic thinking	Establish animal welfare as an indispensable aspect of sustainable animal production Exact tools to enable systems analysis Animal behaviour together with measurable parameters (stress

	hormones, acute phase proteins)
Current disease control infrastructure	Cost effectiveness calculations (I guess these exist already)
Social network	Building more health into existing farmer networks (including virtual ones) - e.g. via veterinary practitioners. Evidence on what works in different contexts? Good communication with new EU members.
Research networks	Need for greater investment Improved methods for easily sharing research outputs and data, and ensuring data collectors are appropriately rewarded?
Investment in science	Evidence on benefits from previous investment in science
Existing technologies in other disciplines	Building up interdisciplinary/transdisciplinary research capacity
CAP	Evidence of health/welfare impacts of different CAP measures?
Public private partnership	Knowledge transfer to companies developing and selling farm animal housing systems and equipment
International financial system	Evidence on impact of low/variable incomes on farmer actions relating to animal health/welfare
Environmental stability	Evidence of impact of controlled housing vs. outdoor production on animal health and welfare (only local environmental stability)
Competition	Evidence on competitive motivations for improving animal health welfare. Evidence of impact of rewards for welfare schemes on farmer practice/likelihood of engaging other farmers in improved practice
Harmonised international trade regulations	Scientific advice concerning good animal welfare standards

Moscow Workshop - Back-casting exercise - Europe

Elements of the future vision that differ from present

Current situation: we can provide safe food for all

Anticipated future changes - increase of antibiotic resistance
Increased of anthelmintic resistance
Russia Threat from wild fauna
Increased threat from travelling populations
Europe Surrounded by buffer-zone (buffer-zone has control, centre is looked at less as control concentrated on buffer zone.

Currently the focus in on large disease outbreaks and less attention to problems that are relatively small but very costly
Biosecurity prevents animal disease → on farm
Food fraud → consumers do not perceive as safe/secure. Fraud causes loss of production due to consumers' loss of confidence. Need for transparency

Future:

Increasing size and concentration of animal populations (Big farms with increased biosecurity)
Biosecurity is key at all levels
Policy level important
Loss of effectiveness of antibiotics in the future
Biosecurity provides conditions for reduction of antibiotics
Local breeds often provide genetic resistance
Change in breeding management
Cloned and GM engineered animals
Aquaculture more important
Governmental veterinary services are shrinking
Greater focus on Disease prevention/Early warning
Consumers want shorter supply chains

Neglected zoonoses?

Ensure animal health status in Europe area – add buffer zone
Closed system is not easy to sustain
Boundary system – develop security
Coming back on prioritisation

Barriers

1	Antibiotic effectiveness and availability		Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management; Epidemiology – integrated disease control; Alternatives – antimicrobial peptides, immunomodulators, New antibiotics
2	Anthelmintic effectiveness		Mechanisms of resistance; Markers of resistance; Others as in 1 above. Capacity in parasitology – shortage.
3	Gut health including problems related to feed (particular problem with fish, poultry and pig production)		Digestive physiology; gut microbiome; feed including sources; pre/pro-biotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut
4	Vector-borne diseases		Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification
5	Trade in food (and somewhat in animals) including from far countries		Standardised traceability systems – technology Detection systems, Data coming together in real time Technology for inactivation of pathogens
	Transport prices		
	Footprint (sustainability)		
6	Weakness of the system/ downsizing of veterinary services/ lack of control		Integration and better use of existing data Syndromic surveillance (get data of search engines of people looking at say FMD) Using production or food/water consumption data Cost effective real-time collection of data Risk-based approach to surveillance
7	Politics – transfer of ownership/responsibility for dealing with problems from government to industry. Transfer of responsibility of		

	research on certain animal diseases (PED (how to define))		
8	Immigrants - bringing disease; ethnic practices (Ritual slaughter)		
9	Migrant workers - education		
10	Economic – economic pressure not to maintain research capacity in areas where no immediate need e.g. BSE		
11	Regulatory barriers		
12	Intellectual Property rights		
13	Nguoi Agreement/ convention on biodiversity - limitation on importing biological materials		
14	New Diseases		
15	Management of by-products/waste		Waste → by-product safety – detection systems; Assessment of risk of reintroducing disease; research on food sources that are health for animals
16	Costs		
17	Gap between farmer needs and proposed research		
18	Loss of overall Research capacity – countries looking to others to cover gaps e.g. neuropathology; Loss of Parasitology expertise		collaboration
19			

Enablers

	Better use of antibiotics		
	Pressure to make livestock production more sustainable/pressure to innovate		
	Traceability		
	Good controls e.g. testing		

	Integrated surveillance system/ Centralised diagnostic testing		Research on tools for surveillance
	Automated systems		
	Big data – data sharing		
	Biosecurity - at all levels		
	One health approach		
	Management of by-products/waste		
	Precision livestock farming/Automated disease surveillance		
	Policy		
	Personalised technology		
	Translation of regulatory changes, KT to farmers Information to vets and farmers Education of farm helpers		
	New drug development		
	Improved inspection at borders (new concept, more global)		
	Improved vector/biological control		
	Early data interpretation		
	Early pathogen research related to parameter surveillance Biosecurity		
	Alternative protein sources		

Appendix 4: Challenges and Opportunities

Challenges and Opportunities identified in Scenario building (Madrid workshop) and Back-casting (Madrid and Moscow workshops)

Challenge/Barrier	*Disease*	*Research Needs*
Pathogen evolution, including new vectors and resistance	Drug resistance Pathogens adapting to new vectors	Drivers of mechanisms of drug resistance. Host resistance Surveillance and monitoring for early detection
New diseases	SARS, MERS, Wildlife diseases	Generic detection platforms
Antibiotic effectiveness and availability	MRSA	Host resistance; vaccine development / Vaccinology, including HPI; biosecurity/management; Epidemiology – integrated disease control; Alternatives – antimicrobial peptides, immunomodulators, New antibiotics; Development of systems to reduce emergence of AMR. Reversion of resistance of organisms
Anthelmintic effectiveness	Parasitic Gastroenteritis, liver fluke	Mechanisms of resistance; Markers of resistance in parasites; Host resistance; vaccine development including HPI; Epidemiology – integrated disease control/management; Alternatives – New anthelmintic compounds
Vector-borne diseases including adaptation of vectors to new environments.	Insect-borne diseases West Nile, Chikungunya, Blue tongue, nipah Tick-borne diseases Lyme disease, African swine fever, tbev Rodent-borne diseases Hanta, leptospirosis Other - liver fluke	Environmentally friendly pesticides Alternative methods to control vectors – a) Integrated pest management, b) biological control (natural predators and competitive inhibitors) and c) genetic modification. Monitoring vector populations Vector competence studies Innovative methods for identification and characterisation of vectors and their competence.
Disturbed Ecosystems/Ecosystem health Wildlife reservoirs of disease	Vector-borne disease (as above) “New” pathogens SARS, MERS, SIV	Surveillance and monitoring for early detection Biosecurity New vaccines or vaccine carriers for wildlife Syndromic surveillance Risk-based modelling for surveillance
Balance between livestock production and wildlife		Understanding implications of intensifying to free land for wildlife vs coexisting
Lack of knowledge of adaptation measures to environmental change		Increase knowledge of the environmental drivers that we can control and manage
Water-borne transmission	Infectious diseases Cryptotsporidium;	

	FMD; brucellosis; salmonella	
Disease introduction through international trade Invasive exotic species	Vesicular diseases, ASF	Standardised traceability systems – technology Detection systems, Data coming together in real time Technology for inactivation of pathogens Generic detection platforms Traceability of animals and their products
Unpredictable disease outbreaks	Influenza, African swine fever, FMD; brucellosis, Q fever	
Increasing potential for outbreaks of existing diseases		New/alternative drugs/intervention tools and devices for the treatment and prevention of disease Generic vaccine to combat several diseases
System weaknesses, including downsizing of veterinary services		Integration and better use of existing data Syndromic surveillance (get data of search engines of people looking at say FMD) Using production or food/water consumption data Cost effective real-time collection of data Risk-based approach to surveillance
Delayed responsiveness due to over centralisation		
Complacency		
Transfer of ownership/responsibility for dealing with disease to industry		
Lack of coordination and access to existing data		Collection , harmonisation and utilization of existing data
System weaknesses, including downsizing of research capacity	Neuropathology Parasitology	
Lack of resources		Harmonized approaches for risk/benefit evaluation, research on effective tools/ways for data and knowledge sharing Creative/novel funding mechanisms for development of new vaccines and pharma products Facilitation of farmer self- help groups; Farmer self-monitoring Risk-based surveillance for animal welfare
Reduced genetic pool of host/ Selection for production parameters	Foot problems in dairy cattle and longevity	Selection for production parameters and reduced disease susceptibility
Reduced resistance of host populations	(BVD following eradication at farm level	
“Aseptic” lifestyle of human populations	Zoonoses (EHEC)	
Domestic pets as a reservoir of disease Exotic domestic pets	Neospora; tape worms zoonoses	
Increasing sensitivity of society to		

animal disease and/or control options		
Lack or understanding of decision-making process, public perception		Improve understanding and public perception of decision-making
Lack of trust between industry, government, consumers and pressure groups		Communication Transparency of authorities Research Understanding change processes at a systems level
Management of by-products/waste	Spread of pathogens – brucellosis, salmonellosis, Hep E, Q fever,	Waste → by-product safety – detection systems; Assessment of risk of reintroducing disease; research on food sources that are healthy for animals. Research on manure handling practices Safety of by-products from bio-digesters
Food – feed conflict (esp. imp for monogastricts)		Health implications of alternative feeds
Gut health including problems related to feed (particular problem with fish, poultry and pig production)		Digestive physiology; gut microbiome; feed including sources; pre/pro-biotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut
Health implications of different feeds to reduce GHG		
Health implications of alternative protein sources (legumes, lupines etc..) to replace imports into Europe		
Environmental control in houses		Optimal environmental conditions for control of pathogens such as campylobacter
Production diseases associated with intensification	Metabolic diseases; patasitic ganstroenteritis	Automated systems for herd management and surveillance for both intensive and extensive production
Extreme weather events – hot summers and cold winters	Respiratory disease Welfare issues from overheating - poultry	
Centralisation of activities leading to longer journeys	Welfare	Design of improved transport facilities
Sustainable resource management	Disease welfare implications of changing water and pasture management and land use change. Pathogen survival	
Water quality and scarcity	Fish and duck welfare	Low cost methods of cleaning potentially contaminated water for recycling Engineering approaches to reduce water use and recycle water efficiently Water treatment options Indicators of water quality – easy to use/rapid/cheap detection systems
WTO – lack of ethical issues relating to welfare and environment		Establishment of acceptable standards. Development of measurable standards

Pressure to decrease price of food	Welfare Health	Basis for a common certification scheme – science-based standards
Profitability of livestock production	Health and welfare	Evidence relating to the impact of low/variable income on farmer actions
Perceived costs of improving animal welfare Trade-off between welfare and cost to society		Cost and benefits analysis Knowledge transfer
Lack of effective indicators of animal welfare		Research on "omics" technologies to develop AW indicators. Tools and agreed standards to measure stress Improved understanding of animal behaviour as a benchmark for welfare standards Scientific validation of practical animal welfare indicators
Stress due to intensification	Welfare issues related to keeping animals in bigger groups	Knowledge of stress relating to crowding and keeping animals in large groups
Keeping animals indoors for longer periods	stress	
Conflict between perceived welfare versus health		Improved understanding of how people develop their concepts of welfare and health
		Facilitation of faster/cheaper regulatory approval while maintaining safety and efficacy
CAP Subsidy system/strategy	Disease and welfare impacts	Impact assessment
Conflicts		Foresight to identify areas of potential conflict with potential impact on animal health

Opportunities/Enablers		***Research Needs***
Current disease control infrastructure		Establish cost effectiveness
Disease eradication		
Precision livestock farming/Automated disease surveillance		
Traceability		Needs to be improved European-wide database to improve traceability
Effective controls e.g. testing		
Improved monitoring and		

diagnostic tools Surveillance, early detection, early warning		Models for surveillance, early detection, early warning
Integrated surveillance system/ Centralised diagnostic testing		Research on surveillance tools
Early data interpretation		
Early pathogen research related to parameter surveillance;		
Big data – data sharing		
Risk analysis		
Biosecurity - at all levels		Development and implementation of improved biosecurity measures and approaches
Harmonised international trade	Animal welfare	Scientific standards
Improved inspection at borders (new concept, more global)		
Biosecurity and biosafety technologies		
Policy		More effective legislation and implementation
Better use of antibiotics		
New drug development		
Improved vector/biological control		
Personalised technology		
Translation of regulatory changes, KT to farmers Information to vets and farmers Education of farm helpers		
One health approach (multidisciplinary approach)		Prioritise projects based on comparative and multidisciplinary approach
Systems approach/systemic thinking		Improved tools to enable systems analysis

Research networks		Need for greater investment Improved methods for easily sharing research outputs and data and ensuring data collectors are appropriately rewarded
Investment in science		Evidence of benefits from previous investment in science
Existing technologies in other disciplines		Building up interdisciplinary/trans-disciplinary research capacity
Omics technology		Improved information on the body's response to attacks to identify early markers of change
		On-farm rapid diagnostics Robotic detection and identification of disease Automated treatments
IT		Development of infrastructures/platforms to maximise data harmonisation and sharing Harmonisation of tools for monitoring, surveillance and tracing animals
Public private partnerships		KT to companies developing farm animal housing systems and equipment
Pressure to make livestock production more sustainable/pressure to innovate		
Alternative protein sources		
Breeding for resistance/production Genetic selection of local breeds		
Controlled environment housing		Evidence of impact of controlled housing versus outdoor production on health and welfare

Management of by-products/waste		Improved techniques for sustainable recycling of waste
Competition/benchmarking		Evidence of competitive motivation for improving health and welfare and the impact of reward schemes