WORKSHOP REPORT

2ND JOINT WORKSHOP

SMART MITIGATION OF GHG EMISSIONS FROM LIVESTOCK PRODUCTION

20-21 FEBRUARY 2018 | TEAGASC ASHTOWN
DUBLIN | IRELAND




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Contents

1. Publishable Summary

The 2nd Joint Workshop of the ERA-NETs FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2, was held in Dublin, Ireland on the 20-21 February 2018. The workshop was hosted by Teagasc, the Agriculture and Food Development Authority in Ireland and coordinator of FACCE ERA-GAS, at the Teagasc Ashtown Food Research Centre in Dublin. The focus of the workshop was "*Smart Mitigation of Greenhouse Gas Emissions from Livestock Production*". Over sixty participants attended, including representatives of the ERA-NET partners, nominated scientific experts in the workshop topic areas and invited speakers. Following "scientific scene setting" presentations from scientific experts, key greenhouse gas (GHG) source categories were discussed in break-out groups and priority research topics identified and voted upon. The outcomes of this workshop and the 1st Joint Workshop in Potsdam will provide the basis for developing the scope of the joint call planned by the three ERA-NETs in the area of livestock GHG emissions.

2. Background

The three ERA-NETs FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2 have worked in close cooperation since 2015 to coordinate and align efforts in areas of mutual interest. The ERA-NETs cover the following topics:

- ERA-NET SusAn (Sustainable Animal Production Systems) promotes research that contributes towards the development of a more Sustainable European Animal Production sector which requires interdisciplinary systems research with multiple objectives within the sustainability triangle of economic competitiveness, social acceptability and environmental protection to maximise benefits and minimise trade-offs

- FACCE ERA-GAS (Monitoring and Mitigation of Greenhouse Gases from Agriculture and Silviculture) aims to strengthen the transnational coordination of research programmes and provide added value to research and innovation on greenhouse gas (GHG) mitigation in the European Research Area

- ICT-AGRI 2 (Information and Communication Technologies and Robotics for Sustainable Agriculture) aims to strengthen European research within the area of precision farming and to develop a common European research agenda concerning ICT and robotics in agriculture.

Four fundamental cross-cutting areas have been identified by the ERA-NETs (see Figure 1 below, grey shaded area), the first of which was discussed in depth at the 1st Joint Workshop held in Potsdam, Germany in November 2016 (***Comparison of animal production systems with respect to GHGs***). Building on the cooperation, discussions and outcomes of the 1st Joint Workshop, the aim of the 2nd Joint Workshop was to discuss promising strategies and innovations to reduce livestock GHG emissions relating to the three remaining cross-cutting

areas: ***Evaluation of Feed Chain, Manure Management*** and ***Reducing Nitrogen Excretion.*** As the three ERA-NETs plan to launch a joint call for proposals in 2018, the workshop attendees were asked to help identify priority topics for this call within these cross-cutting areas. The workshop also provided a forum for discussion among the funders of the three ERA-NETs on potential funding instruments for the joint call and available national resources.

The first day was open to all participants (scientific experts, ERA-NET partners and invited stakeholder speakers), while the second day was only open to ERA-NET partners. All of the attendees were surveyed during registration on their expertise in relation to the three workshop topic areas and knowledge of ruminant or monogastric livestock systems to aid in the pre-allocation of participants to Break-Out Groups.

The 2nd Joint Workshop is reported in detail in the following pages.

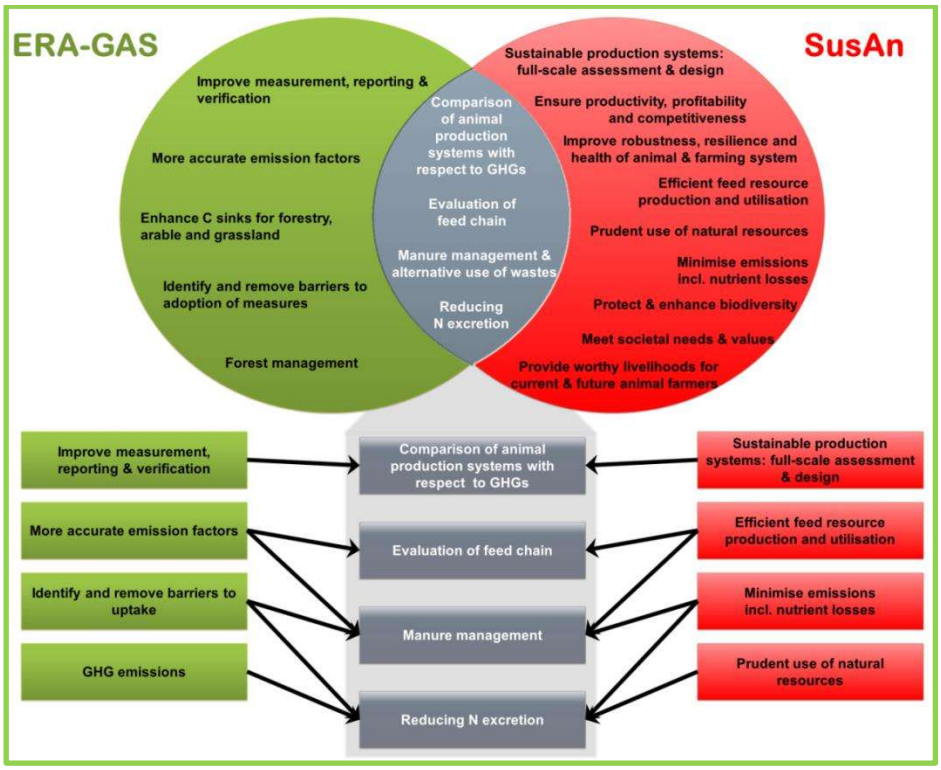

Figure 1: Cross-cutting areas between FACCE ERA-GAS and ERA-NET SusAn and links to thematic areas of common interest.

3. Implementation of the 2nd Joint Workshop

The 2nd Joint Workshop took place on Tuesday 20th February 2018 from 9:00 to 17:15 and Wednesday 21st February 2018 from 9:00 to 12:00 at Teagasc Ashtown, Dublin. Teagasc, as coordinator of FACCE ERA-GAS, hosted and organised the workshop at its Food Research

Centre in Ashtown, with the support of the other ERA-NET coordinators (ERA-NET SusAn and ICT-AGRI 2). A cultural tour and workshop dinner for all attendees was held in Dublin city centre on Tuesday evening.

Over the two days of the workshop, a total of 63 people participated in the activities, representing 22 different countries (the full participant list is provided in Appendix A).

Figure 2: Participants at the 2nd Joint Workshop in Dublin

2.1 Objectives of the Workshop programme

The workshop programme was developed to serve two key objectives:

1. To identify research topics and questions that are (i) most challenging, (ii) most urgent or (iii) involve solutions that show most promise, and to rank these in order of priority
2. To provide a forum for discussion among the partner funding agencies on potential funding instruments for the joint call planned by the ERA-NETs and the extent of financial resources availability for this call.

Furthermore, many networking opportunities were provided during the workshop at coffee breaks, the social dinner and cultural event and during the break-out groups, to ensure that new working connections were established, information was shared and collaborative opportunities could be developed. The workshop programme is included overleaf.

2ND JOINT WORKSHOP

SMART MITIGATION OF GHG EMISSIONS FROM LIVESTOCK PRODUCTION

20-21 FEBRUARY 2018 | TEAGASC ASHTOWN
DUBLIN | IRELAND

WORKSHOP PROGRAMME: ERA-NET PARTNERS

FACCE ERA-GAS:
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ICT-AGRI 2:
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DAY 1: TUES 20 FEB

- **Scientific Experts & ERA-NET Partners**

Chair: Prof. Frank O'Mara

MORNING

08:45 - 09:00 **REGISTRATION**

09:00 - 09:15 **WELCOME & INTRODUCTION TO FACCE ERA-GAS**
Frank O'Mara, Teagasc

09:15 - 09:25 **ICT-AGRI 2 INTRODUCTION**
Niels Gøtke, InnoFund

09:25 - 09:35 **ERA-NET SUSAN INTRODUCTION**
Elke Saggau/Babette Breuer, BLE

09:35 - 09:45 **OUTCOMES FROM 1ST JOINT WORKSHOP**
Elke Saggau, BLE/Raymond Kelly, Teagasc

09:45 - 10:15 **KEYNOTE PRESENTATIONS**
Perspectives from leaders in industry and farming:
Stan Lalor, Grassland Agro
Andrew McHugh, Smart Farming Dairy Farmer

COFFEE BREAK

10:45 - 10:55 **INSTRUCTIONS FOR BREAKOUT GROUPS**
Órlaith Ní Choncubhair, Teagasc

10:55 - 12:40 **BREAKOUT GROUPS 1: *EVALUATION OF FEED CHAIN***

Scientific scene setting:
Dirk von Soosten, Friedrich-Loeffler-Institut
Albert Sundrum, University of Kassel
(10 mins)

Table discussions (50 mins)
Plenary discussion & voting (45 mins)

LUNCH

DAY 1: TUES 20 FEB

- **Scientific Experts & ERA-NET Partners**

Chair: Prof. Frank O'Mara

AFTERNOON

13:25 - 15:10

BREAKOUT GROUPS 2:
MANURE MANAGEMENT

Scientific scene setting:
Barbara Amon, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)
Dominika Krol, Teagasc
(10 mins)

Table discussions (50 mins)
Plenary discussion & voting (45 mins)

COFFEE BREAK

15:20 - 17:05

BREAKOUT GROUPS 3:
REDUCING NITROGEN EXCRETION

Scientific scene setting:
Tim McAllister, Agriculture and Agri-Food Canada
(10 mins)

Table discussions (50 mins)
Plenary discussion & voting (45 mins)

17:05 - 17:15

CLOSE OF DAY 1
Frank O'Mara, Teagasc

DINNER & CULTURAL VISIT DUBLIN CITY CENTRE

DAY 2: WED 21 FEB

- **ERA-NET Partners only**

Chair: Dr. Elke Saggau

MORNING

09:00 - 09:15 **FUNDING INSTRUMENTS FOR ADDITIONAL JOINT ACTIVITY**

Christine Bunthof, Wageningen University & Research

09:15 - 09:30 **EXAMPLES OF JOINT RESEARCH CALLS**

Niels Gøtke, InnoFund

09:30 - 09:45 **KNOWLEDGE HUBS: THE MACSUR EXPERIENCE**

Nicolas Tinois, Jülich

COFFEE BREAK

10:15 - 10:40 **INDICATIVE FUNDING COMMITMENTS & PROPOSED TIMELINE FOR JOINT CALL**

Raymond Kelly, Teagasc

10:40 - 11:40 **OPEN DISCUSSION OF OPTIONS**

11:40 - 12:00 **CLOSE OF WORKSHOP**

Elke Saggau, BLE

LUNCH

Day 1: Tuesday 20th February – Scientific Experts & ERA-NET Partners

Chair: Prof. Frank O'Mara

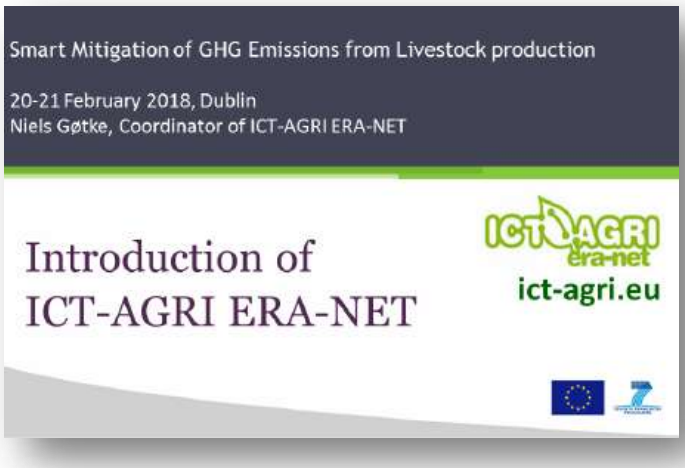
3.2 Welcome & introduction to FACCE ERA-GAS

Prof. Frank O'Mara, Director of Research, Teagasc and Coordinator of FACCE ERA-GAS

In his capacity as Coordinator of FACCE ERA-GAS and Director of Research in Teagasc, Prof. O'Mara warmly welcomed all of the participants to the Training and Conference Centre at Ashtown, Teagasc's Food Research Centre. He introduced attendees to FACCE ERA-GAS, the ERA-NET Cofund for monitoring and mitigation of GHGs from agri- and silvi-culture. Stressing the three core goals of FACCE ERA-GAS to achieve *cooperation, alignment and impact*, Prof. O'Mara said that the Joint Workshops in Potsdam and Dublin and enhanced cooperation between ERA-GAS, SusAn and ICT-AGRI 2 were crucial for harmonising activities across Europe, ensuring optimal use of national and EU funds and establishing durable cooperation between the partners.

3.3 ICT-AGRI 2 introduction

Mr. Niels Gøtke, InnoFund



Mr. Gøtke provided a short introduction to ICT-AGRI 2, the ERA-NET for Information and Communication Technology and Robotics for Sustainable Agriculture, which he coordinates. In recent years, ICT-AGRI has implemented four calls for transnational projects on topics such as precision farming and integrated ICT and automation. Mr. Gøtke outlined

ICT-AGRI's plan of activites for 2018 and looked forward to cooperating with ERA-NET SusAn and FACCE ERA-GAS on a joint call.

3.4 ERA-NET SusAn introduction

Dr. Elke Saggau / Babette Breuer, BLE

Babette Breuer, Project Manager for ERA-NET SusAn, gave attendees an overview of ERA-NET SusAn, the ERA-NET Cofund on Sustainable Animal Production. She outlined the scope of the action to develop socially acceptable, economically viable animal production systems that have a minimal impact on the environment. Ms. Breuer described SusAn's progress to date in meeting its key objectives, including the joint actions so far between the three ERA-NETs.

3.5 Outcomes from 1st Joint Workshop

Dr. Elke Saggau, BLE / Dr. Raymond Kelly, Teagasc

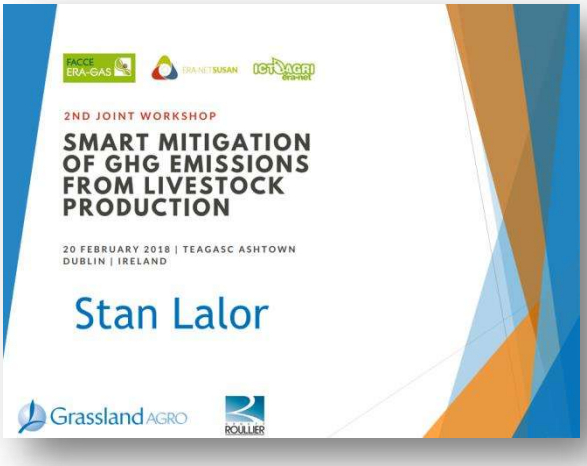
An overview of the 1st Joint Workshop in Potsdam was provided by Dr. Elke Saggau and Dr. Raymond Kelly, highlighting the aim of the workshop, the participants and topics discussed during the break-out sessions. The key questions addressed and main outcomes (ranked list of topics/questions) were described to attendees.

3.6 Keynote Presentations: Perspectives from leaders in industry and farming

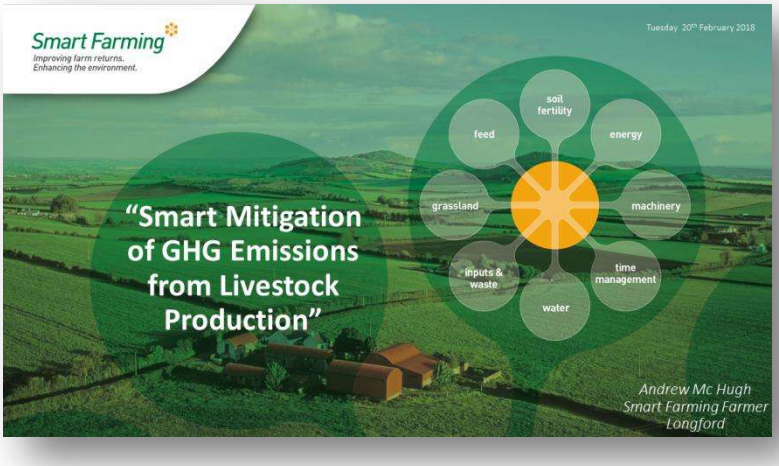
Dr. Stan Lalor, Grassland Agro

Andrew McHugh, Smart Farming Dairy Farmer

Presentations from two leaders in key stakeholder communities provided fresh and insightful perspectives on the topic of agricultural GHG emissions.



As a former researcher now working in industry (Group Head of Speciality Business in Grassland AGRO), Dr. Stan Lalor presented his thoughts on how research can drive industry change on GHG mitigation. Stressing that **industry will react to opportunities**, Dr. Lalor said that low GHG food must pay its way and will be **driven by end-user demands**. For researchers and research funders, Dr. Lalor highlighted the importance of analysing the motivation for technology adoption and practice change, of maintaining capacity in the fundamental sciences while also utilising research capacity within industry and of ensuring clarity of message on complex issues. Dr. Lalor also remarked that **policy is an instrument, not an outcome** and that we must all look beyond policy if we are to achieve desired effects.



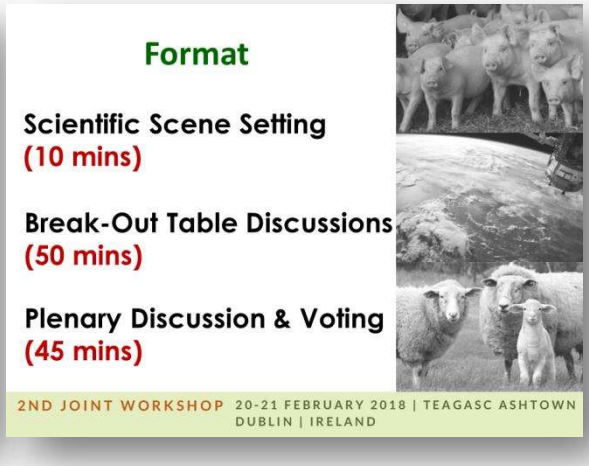
Andrew McHugh is a dairy farmer in the midland region of Ireland and is an active member of the *Smart Farming* initiative which seeks to improve farm returns and enhance the environment. Mr. McHugh gave attendees an overview of his family farm and how ***Smart Farming*** **was implemented on his farm** by identifying **monetary savings** and ways to **reduce climate impact**. By examining soil fertility, energy and water use, grassland management, feed, inputs, waste, time and machinery management, Mr. McHugh was able to achieve costs savings of over €9,000. Also, his actions resulted in a 20% reduction in on-farm GHG emissions. Mr. McHugh highlighted the importance of farmer discussion groups for mutual

learning and development and highlighted how **government can enable farmers to be climate leaders**.

3.7 Instructions for Break-Out Groups

Dr. Órlaith Ní Choncubhair, Teagasc, Consortium Manager of FACCE ERA-GAS

The format and instructions for the Break-Out Groups were provided by Dr. Órlaith Ní Choncubhair from Teagasc, who is Consortium Manager for FACCE ERA-GAS. Dr. Ní Choncubhair described the key objectives of the Break-Out Group sessions, the topic areas that would be discussed in the three Break-Out Group sessions and the common format for each session:



Each session began with a ***Scientific Scene Setting*** presentation (10 minutes duration) from a scientific expert in the area to provide a short introduction to that particular aspect of livestock production, outline key GHG source categories, their relative uncertainties and the focus of research to date in that area.

Attendees then broke out into pre-allocated Break-Out Groups, grouped according to expertise in ruminant versus monogastric livestock systems where possible. In the **Break-Out Table Discussions**, participants were encouraged to put forward and discuss priority topics in the research area, focussing on:

- why they feel that topic is important
- what research/networking/capacity building needs to take place to advance that research
- what impact the proposed research would have

Each group was asked to write all their topics on large post-its and then to agree on five high priority topics.

In the **Plenary Discussion**, Prof. O'Mara worked around the room, **collecting priority topics** from each table. All of the topics were posted on the wall and similar topics were grouped under each other to consolidate the ideas. Once completed, it was time for **voting** on the priority topics identified. Each participant had five votes (stickers) to allocate as they wished – if they felt a particular topic was a very high priority they could allocate five votes to it, or they could distribute their votes between topics as they saw fit. The voting was conducted to assess the attendees' views on the most urgent and challenging topics, or most promising solutions and ideas in the area of livestock GHG emissions and provided information on the relative importance of different topics generated during the workshop (see Figures 4-6).

Figure 3: Plenary topic gathering and voting

3.8 Break-Out Groups 1: Evaluation of Feed Chain

Scientific Scene Setting:

Dr. Dirk von Soosten, Friedrich-Loeffler-Institut
Prof. Dr. Albert Sundrum, University of Kassel

The scientific scene setting for the 1st Break-Out Group session was provided jointly by Dr. Dirk von Soosten, who specialises in ruminant livestock systems, and Prof. Dr. Albert Sundrum, who focussed primarily on feed chain emissions relating to monogastric animals.

Dr. von Soosten gave an overview of the **elements of the feed chain** that are required to **produce food of animal origin**, and the corresponding GHGs that are emitted. As enteric fermentation is a major source of GHG emissions from ruminant systems, Dr. von Soosten outlined some of the methods for quantifying methane emissions and some interesting research relating to methanogenesis and methane inhibitors and the impact of concentrate

proportion in the diet of dairy cows.

Prof. Dr. Sundrum outlined some of the **challenges concerning reactive nitrogen in the feed chain**. He firstly compared the nitrogen cycle in the EU-27 in 1900 and 2000 and outlined the implications of the huge increases in nitrogen fertiliser inputs, including a decrease in the utilisation efficiency of reactive nitrogen. Prof. Dr. Sundrum described how increased efficiency in the use of reactive nitrogen requires (i) full quantification of nitrogen flows between and within farm sub-systems, (ii) efficient resource allocation and recycling of manure within farm systems, (iii) benchmarking of reactive nitrogen efficiency rates at different scales to prevent unfair competition.

The results of Break-Out Group discussions on the **Evaluation of Feed Chain** topic area and subsequent votes were analysed and similar topics were grouped together into themes. In the table below (Figure 4), the priority topic themes receiving at least ten votes are listed. Appendix B provides the full list of priority topics and themes identified.

Evaluation of Feed Chain

- Benchmarking, traceability of GHGs and incentives
- Digital and precision farming
- New feedstuffs
- Animal breeding
- More efficient production systems
- Animal feed vs food production
- Animal fertility/lifetime

Figure 4: The top priority topic themes identified in the area of feed chain evaluation

3.9 Break-Out Groups 2: Manure Management

Scientific Scene Setting:

Dr. Barbara Amon, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)
Dr. Dominika Krol, Teagasc

The scientific scene setting for the 2nd Break-Out Group session on **Manure Management** was prepared by Dr. Barbara Amon (ATB), Dr. Dominika Krol and Dr. Karl Richards (Teagasc) and presented by Dr. Krol. She began by describing the manure management chain (MMC), potential losses (gaseous and non-gaseous) in the chain and the various nitrogen fluxes observed. To best address environmental needs, Dr. Krol said that best practices must be based on three key concepts: (i) a detailed understanding at the process level, (ii) consideration of pollutants and interactions and (iii) development of flexible concepts for environmental improvement. Taking each of the elements of the MMC (livestock feeding, housing, manure storage, manure treatment, manure utilisation), Dr. Krol outlined the **key messages for optimised management**. Dr. Krol also described the opportunities provided by ICT and big data and some of the main research gaps in the area.

The results of Break-Out Group discussions on the **Manure Management** topic area and subsequent votes were analysed and similar topics were grouped together into themes. The topic themes receiving at least ten votes are provided in Figure 5 below. Please see Appendix B for the full list of priority topics and themes.

Manure Management

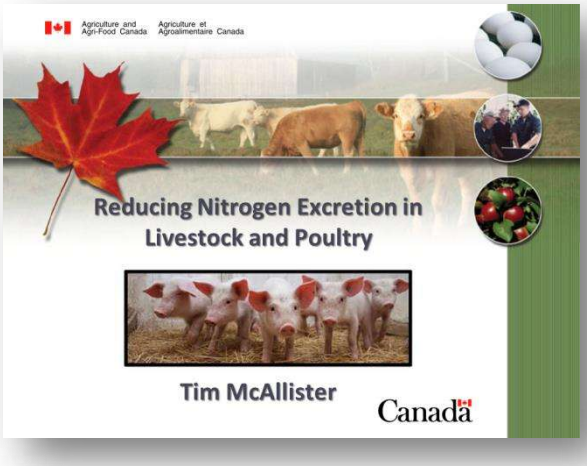
- Circular bioeconomy
- Technologies for manure characterisation
- Manure processing
- Technologies for traceability, emissions reductions
- Feed digestibility
- Regional solutions
- Socio-economics/Multi-actor approach
- Biohazard management
- Smart housing systems
- Policy measures & incentives
- Better quantification of emissions

Figure 5: The top priority topic themes identified in the area of manure management

3.10 Break-Out Groups 3: Reducing Nitrogen Excretion

Scientific Scene Setting:

Dr. Tim McAllister, Agriculture and Agri-Food Canada



Dr. Tim McAllister, Agriculture and Agri-Food Canada and FACCE-JPI Scientific Advisory Board Member, provided the scientific scene setting for the 3rd Break-Out Group session on **Reducing Nitrogen Excretion** in livestock systems. Dr. McAllister began by summarising best estimates of nitrogen utilisation efficiency for different livestock (beef, dairy, swine and poultry) and the proportion of N intake ending up in animal products, animal waste or as volatilised N. Focussing on the ruminant as the more complex system, Dr. McAllister described the process of protein metabolism and the feed factors affecting this process (amount fed, form fed, amino acid profile). As the requirements of individual animals differ

greatly, Dr. McAllister advocated for **balanced and precision feeding to optimise efficiency** and also highlighted the potential role the rumen and intestinal microbiome could play in driving feed digestion. Finally, Dr. McAllister described how manure handling systems could help us to better manage animal waste products and minimise the environmental consequences on water quality, GHG emissions etc.

The results of Break-Out Group discussions on the **Reducing Nitrogen Excretion** topic area and subsequent votes were analysed and similar topics were grouped together into themes. The topic themes receiving at least ten votes in this session are provided below in Figure 6. The full list of priority topics is provided in Appendix B.

Figure 6: The top priority topic themes identified in the area of reducing nitrogen excretion

After the 3rd Break-Out Session concluded, a summary of the outcomes of the discussions and voting for each of the topic areas was presented to attendees. The Chair, Prof. O'Mara, thanked all of the participants for attending Day 1 of the workshop and especially for their active engagement in the group discussions and voting which created a lively and interactive atmosphere.

Day 1 of the workshop concluded with a cultural visit and social dinner in Dublin city centre.

Day 2: Wednesday 21st February – ERA-NET Partners only

Chair: Dr. Elke Saggau

The programme of activities on Day 2 of the workshop was developed to provide a forum for discussion among the partner funding agencies on the joint call planned by FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2. Firstly, Dr. Christine Bunthof, a member of the FACCE-JPI Secretariat, gave an overview of the possible funding instruments and mechanisms that could be employed by the ERA-NET partners. The attendees then heard from two speakers who had been involved in the planning and implementation of joint transnational funding activities and who shared their experience and lessons learnt from the activities. The discussion then moved to plans for the current joint call, the funders' preferences in terms of funding instrument and the extent of financial resources available for this call.

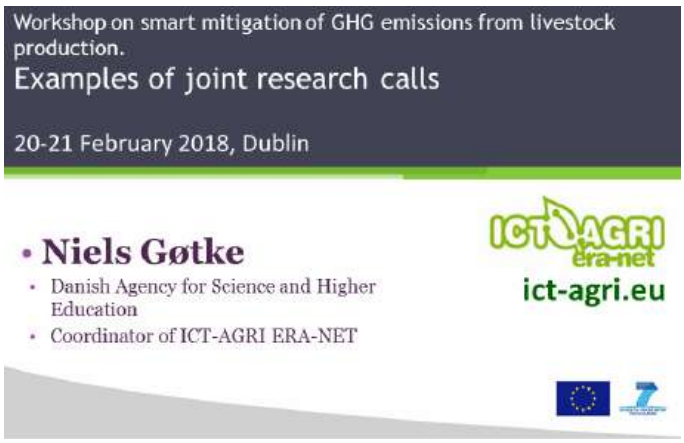
3.11 Funding Instruments for Additional Joint Activity

Dr. Christine Bunthof, Wageningen University & Research

Dr. Christine Bunthof gave an overview of the possible funding instruments available to the three ERA-NETs for the additional joint activity. Dr. Bunthof explained that there are many different instruments and mechanisms for programming and performing research and so we would need to be clear on what the objectives of the proposed action is. She described the four broad categories of joint activities (joint research, workshops, activities focussed on early career researchers and the knowledge hub) and explained the relative merits of each, focussing on financial requirements, versatility and complementarity with national funding schemes.

3.12 Examples of Joint Research Calls

Mr. Niels Gøtke, InnoFund



Mr. Niels Gøtke made a presentation on the experience of implementing two joint research calls. The first example was the 2014 joint call for applications on smart agriculture, organised by ICT-AGRI and SmartAgriFood2, a Future Internet Public-Private Partnership Programme (FI-PPP) supporting SMEs in the development of smart services and applications for the agri-food sector. This call had a budget of €4.75M and had a successful outcome, with the main finding being that the funding mechanism was not more complicated than a normal ERA-NET call. The second case highlighted by Mr. Gøtke was the COFASP (Cooperation in Fisheries, Aquaculture and Seafood ERA-NET) and MBT (Marine Biotechnology ERA-NET) 2016 common call. This call built on the common interests and excellent contacts established between the partners of both ERA-NETs. It has since led to the merging of the two ERA-NETs into BlueBio. The greatest difficulty encountered during this joint call was securing sufficient financial commitments from funders in Member States and Associated Countries.

3.13 Knowledge Hubs: The MACSUR Experience

Mr. Nicolas Tinois, Jülich

Mr. Nicolas Tinois from Project Management Jülich spoke to attendees about the experience of implementing MACSUR, the FACCE-JPI knowledge hub aimed at modelling European agriculture with climate change for food security. This funding instrument comprised three complementary dimensions – networking, research and capacity building – with the aim of increasing and facilitating transnational cooperation and coordination between excellent researchers and research organisations, building a progressive and long-lasting network. Mr. Tinois outlined the genesis and chronology of MACSUR, and described how this knowledge hub has resulted in many new collaborations and research projects and is recognised as a brand for excellent

research. He also outlined some of the challenges faced by the consortium, especially in relation to coordinating a very large network, ensuring sufficient resources for all partners and contending with variable national funding rules.

3.14 Indicative Funding Commitments & Discussion of Proposed Timeline for Joint Call

Dr. Raymond Kelly, Teagasc

Prior to the 2nd Joint Workshop, partners of all three ERA-NETs were surveyed to gauge interest and preferences in relation to the joint call planned by the ERA-NETs. In particular, partners were asked about:

A. available resources for the joint call (indicative funding contributions)
B. funding instrument: which type of funding instrument their contribution could be used to fund and what was their preferred funding instrument.

Dr. Raymond Kelly from Teagasc presented a summary of the results of this survey to attendees and thanked the funders for their positive response and strong interest and support for the proposed joint call. Based on the survey, it became clear that a number of funders could not use their financial resources to fund a knowledge hub, whereas all funders with indicative funding contributions could fund a competitive call for joint research projects. Therefore, it was agreed by consensus that the preferred funding instrument was a joint call for research projects. Dr. Kelly then opened up the discussion to the room to debate the proposed timing, structure (1-stage versus 2-stage evaluation) and resourcing of the joint call.

3.15 Closing remarks

The workshop concluded with closing remarks from Dr. Elke Saggau (Chair of Day 2) and Prof. Frank O'Mara (Chair of Day 1). Dr. Saggau summarised the key messages from the workshop, in particular, that FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2 had agreed to implement a common call for research projects, that the proposed timeline was to launch this call in 2018 and that the scope of the call would be fair to all funders and partners and take into account the outputs of the two Joint Workshops. Prof. O'Mara acknowledged that the challenges presented to the livestock sector by GHG emission targets and global food security were significant. However, he emphasised that the European research community would help to meet these challenges and that, in that context, the upcoming joint call was very welcome. Prof. O'Mara said that the scoping activities conducted in Potsdam and Dublin had been hugely beneficial in helping to identify priority topics and emerging issues relating to livestock emissions. He pointed out that the planned cooperation involving three ERA-NETs was unique and noteworthy and would bring many advantages, such as an greater geographic spread. He thanked all of the participants for attending the workshop, for their

enthusiastic engagement in the workshop's activities and their commitment to the future joint activities planned by the three ERA-NETs.

3.16 Workshop Evaluation

All participants were encouraged to complete the workshop evaluation form. The results of the evaluation are presented in Chapter 4.

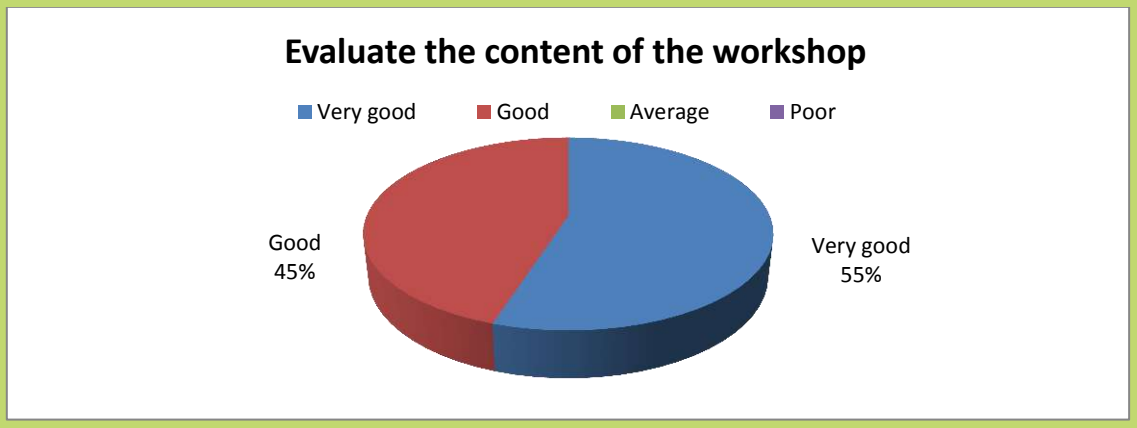
4. Feedback Evaluation from 2nd Joint Workshop

4.1 Workshop participation

Attendance at 2nd Joint Workshop	
Total attendees over both days	63
No. involved in organising/facilitating the workshop	4
No. of attendees who left early	4
No. of Evaluation Forms completed	31 (59%)

4.2 Workshop Content

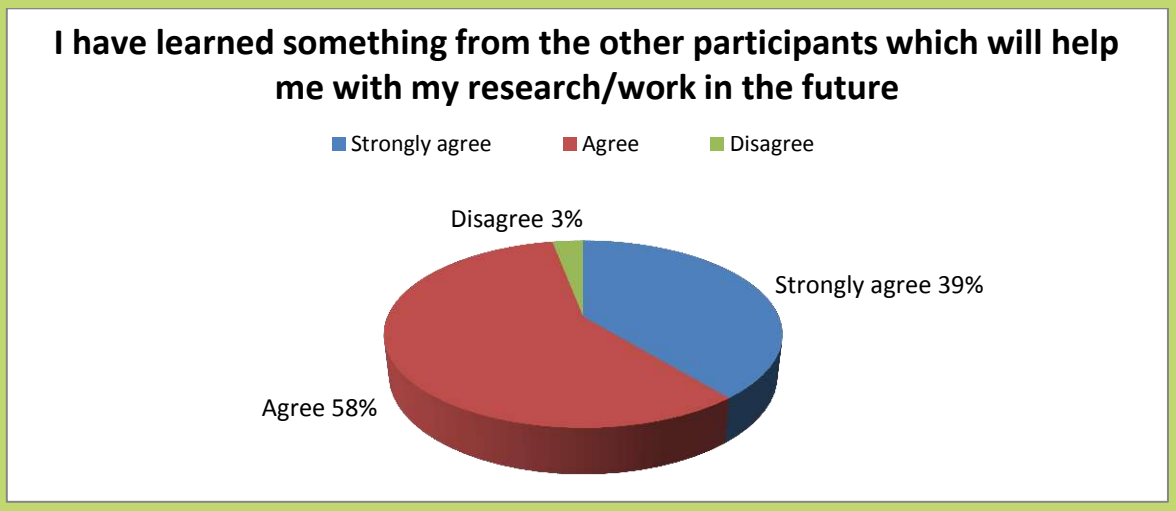
100% of participants rated the workshop content as either very good or good.



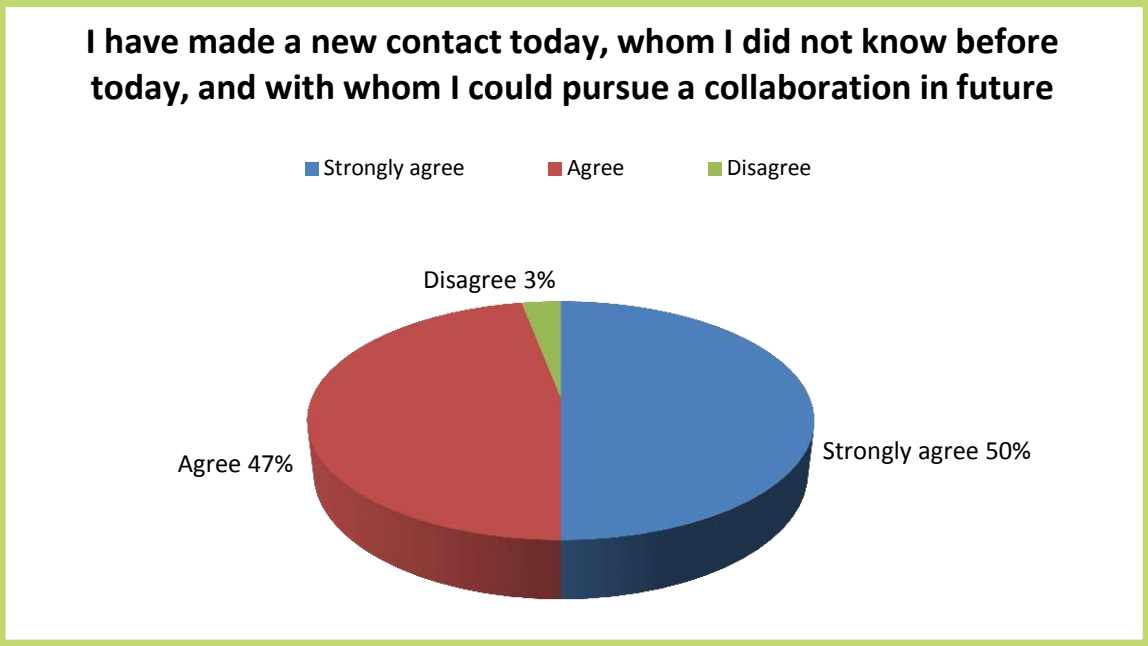
4.3 Impact

The objectives of the workshop were to identify priority research topics within key GHG source categories in livestock production, to provide opportunities for learning between participants, to allow for networking which may lead to future collaborations and to provide a forum for discussion on the planned joint call. The workshop's impact was evaluated through four questions:

97% of participants indicated that they had learned something from attendees that will help with their future work.

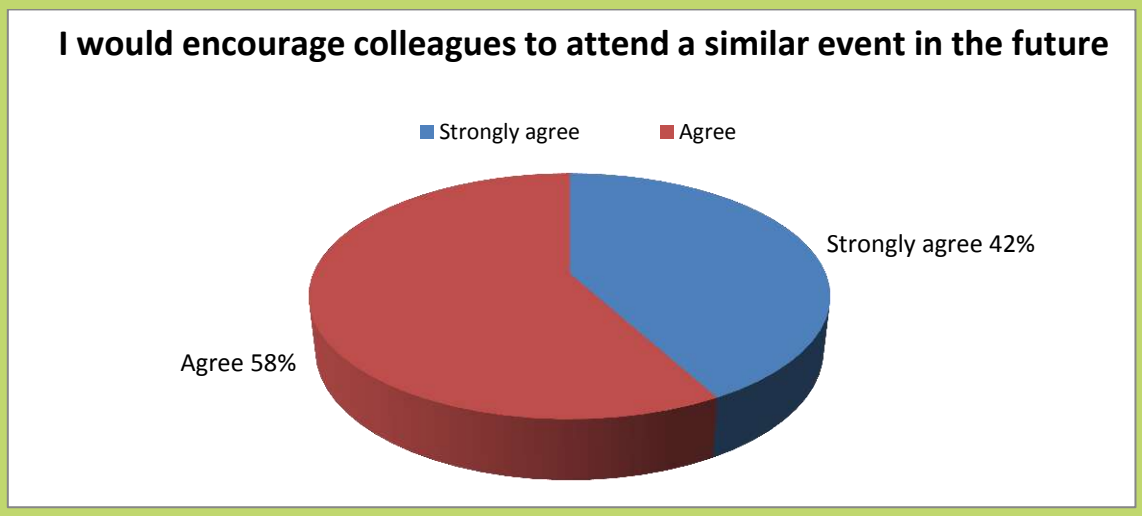


97% of participants said that they had made a new contact during the workshop with whom they could pursue a collaboration in the future.



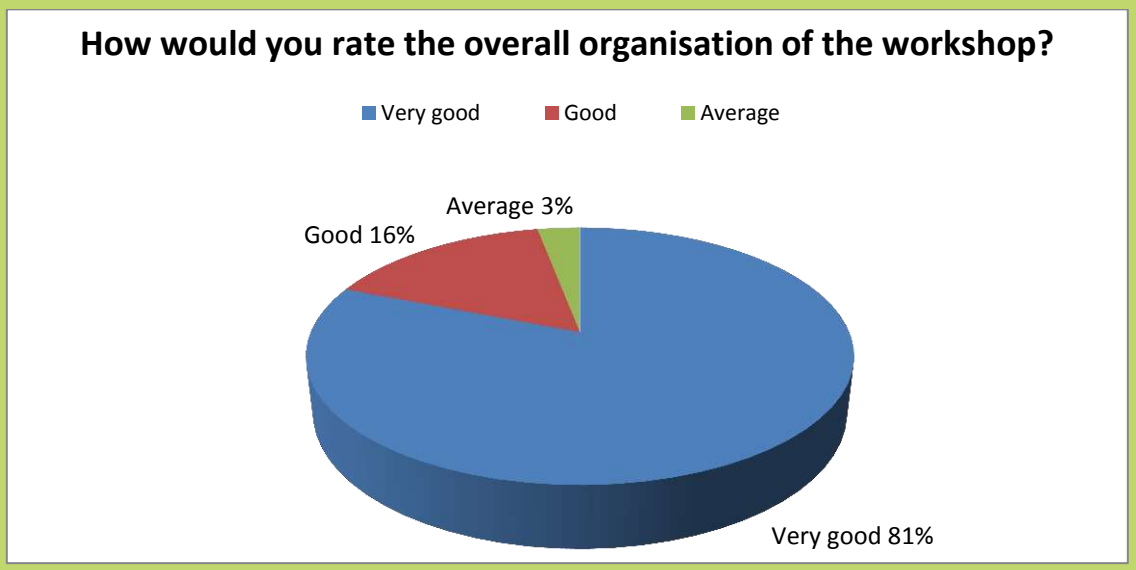
100% of participants agreed that the workshop was a good use of their time.

100% of participants said they would encourage their colleagues to attend a similar event if organised in the future.



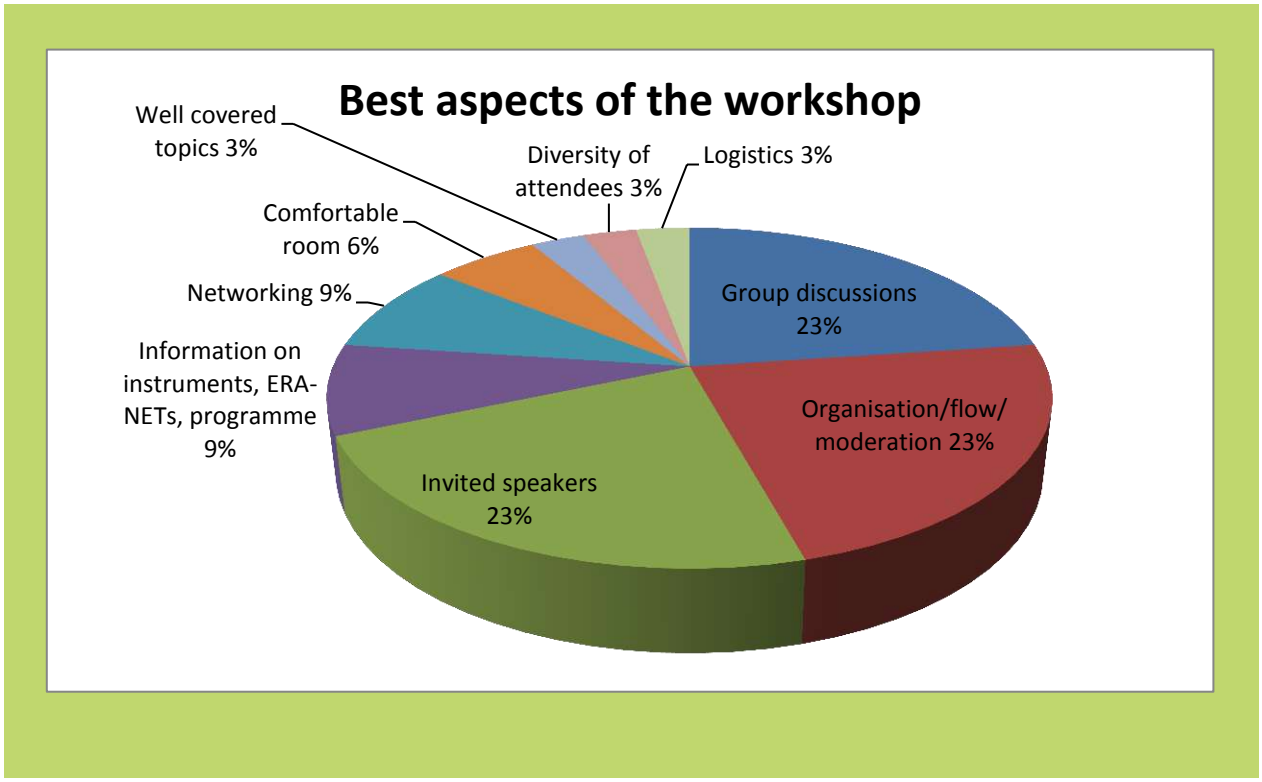
4.4 Organisation

97% of respondents who rated the overall organisation of the workshop said it was very good or good.



4.5 Best aspects of the workshop

The most positive aspects of the workshop listed by participants were the **Break-Out Group discussions**, the **organisation/moderation/flow** of the activities and the **invited speakers**, both scientific and stakeholder. The information provided on the ERA-NETs themselves and potential funding instruments, and the opportunity the workshop provided for **networking** and meeting new contacts were also highlighted. Participants also listed the workshop venue and coverage of topics as positive aspects, as well as the diversity of attendees and workshop logistics.



4.6 Room for improvement

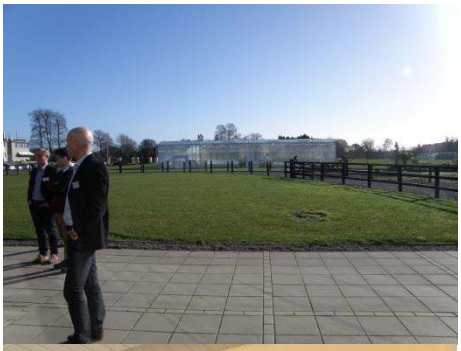
Suggestions for aspects of the workshop that could be improved included having a greater number of scientific experts for the group/plenary discussions and it was also suggested to improve the clustering and allow more time for clustering of the priority topics. Other suggestions were to perhaps have the workshop in a location closer to the city centre and to appoint facilitators to the Break-Out Groups to steer the discussions. Other suggestions for improvement are detailed in the table overleaf.

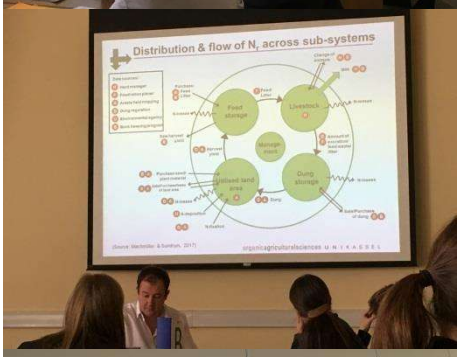
Aspects of the workshop that could be improved and number of participants making the suggestion	
More experts per table / for discussion	3
Clustering of the topics needs to be improved / further discussed	2
Location more central maybe	2
Appointing facilitators for the table discussion as these were 'self-organising'	2
Short overview of the venue	1
More discussion on procedure to select topics	1
Discussion on those topics having the highest impact	1
More insight into historical perspective (development of three topic areas)	1
Breakout sessions were too broad	1
More scientific presentations	1
More representatives from other stakeholder groups	1
More out of the box/strategic thinking	1
To add a technical trip to show work in institution	1
Funders have not enough insight into research topics	1
Take-up content outcomes in funder's session	1
Unequal representation of countries with respect to number of stickers	1

4.7 Other comments

Other comments from participants	
+	Good meeting, thanks!
	Very fruitful workshop with many interesting and friendly people
	Thank you for the invitation
	Organisation has been excellent!
	Very nice workshop
	Thank you for your hospitality
	Great workshop format
	Fantastic social programme, really enjoyable
-	Late invitation letter caused problems for visa application
	Location too far to attend
Suggestions:	Pre-event with experts to find new 'research topics'
	More frequent meetings and workshops to improve the network and work

5. Images from the 2nd Joint Workshop





6. Conclusion

The 2nd Joint Workshop between FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2 was well attended by ERA-NET partners and nominated national scientific experts. The feedback received from attendees was very positive in terms of the workshop content, impact and overall organisation and flow. In particular, the format of the Break-Out Group discussions, plenary topic gathering and voting was seen as a highlight, as were the "scientific scene setting" presentations from invited experts and keynote presentations from two

representatives from the farming and industry stakeholder communities. All respondents to the evaluation form said that the workshop was a good use of their time and that they would encourage their colleagues to attend a similar event in the future.

Across the three topic areas explored during the workshop, some strong cross-cutting themes emerged. In particular, research on digital/precision farming and big data was identified as critical for enabling both improved monitoring and mitigation of livestock GHG emissions. Animal diets and feed were highlighted as having the potential to optimise feed chain dynamics (incorporation of new feedstuffs), to reduce nitrogen excretion (optimise protein content) and impact GHG emissions (improve feed digestibility). Research relating to benchmarking and traceability of GHGs was also regarded as crucial for applying "true pricing" to food, for conveying the benefits to farmers of implementing mitigation actions and for accounting for the impact of imported feed on GHG emissions. Attendees also highlighted the need to prioritise research that helps the sector move towards a circular bioeconomy. This would allow farmers to increase nitrogen efficiency in the manure management chain and couple environmental gains with economic returns. Finally, attendees felt that animal breeding was a priority research area, both in terms of enhancing feed efficiency and reducing nitrogen excretion as well as improving animal health.

The partner funding agencies in the three ERA-NETs have shown a strong commitment to fund a joint call on the topic of livestock-related GHG emissions. The Joint Workshops at Potsdam and Dublin have identified key emerging issues and priority topics for research in the area. This has provided an excellent basis for developing the scope of the joint call which will aim to develop smart solutions to reduce GHG emissions in the livestock sector.

Appendix A: Participant List

PARTICIPANT LIST

Name	Organisation	Country
Adrian Asanica	Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI)	Romania
Adrianna Pawlik	National Centre for Research and Development (NCBR)	Poland
Aidan Holohan	Department of Agriculture, Food and the Marine	Ireland
Albert Sundrum	University of Kassel	Germany
Andrew McHugh	Farmer	Ireland
Anne-Marie Clarke	Department of Agriculture, Food and the Marine	Ireland
Babette Breuer	Federal Office for Agriculture and Food (BLE)	Germany
Barbara Amon	Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)	Germany
Bente Aspeholen Åby	Norwegian University of Life Sciences	Norway
Bettina Heimann	InnovationsFonden/Aalborg University	Denmark
Boris Vashev	Agency for Renewable Resources (FNR)	Germany
Christine Bunthof	Wageningen University and Research	Netherlands
Dace Tirzite	State Education Development Agency (VIAA)	Latvia
Diane Drescher-Petersen	Projektträger Juelich	Germany
Dirk von Soosten	Friedrich-Loeffler-Institut	Germany
Dominika Krol	Teagasc – Agriculture and Food Development Authority	Ireland
Eeva Saarisalo	Ministry of Agriculture and Forestry (MMM)	Finland
Elena Rodríguez-Valín	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)	Spain
Elke Saggau	Federal Office for Agriculture and Food (BLE)	Germany
Enyew Negussie	Natural Resources Institute Finland (LUKE)	Finland
Evgeniya Titarenko	Istituto Zooprofilattico Sperimentale delle Regioni Lazio e Toscana (IZSLT)	Italy
Floor ten Hoopen	Ministry of Environment and Food, The Danish AgriFish Agency	Denmark
Françoise Divanach	Ministry of Agriculture, Nature and Food Quality	Netherlands
Frank O'Mara	Teagasc – Agriculture and Food Development Authority	Ireland
Frans Lips	Ministry of Agriculture, Nature and Food Quality	Netherlands
Giacomo Contò	Ministry of Agricultural, Food and Forestry Policies (MIPAAF)	Italy
Grazyna Sender	Institute of Genetics and Animal Breeding PAS	Poland
Henk van der Mheen	Wageningen University and Research	Netherlands
Jana Hreňová	Ministry of Agriculture and Rural Development of the Slovak Republic	Slovakia
Johannes Pfeifer	Federal Office for Agriculture and Food (BLE)	Germany
Joze Verbic	Agricultural Institute of Slovenia	Slovenia
Jürgen Vangeyte	Institute for Agriculture and Fisheries Research, Technology and Food Science (ILVO)	Belgium

Name	Organisation	Country
Karen Goossens	Institute for Agriculture and Fisheries Research, Technology and Food Science (ILVO)	Belgium
Karl Richards	Teagasc – Agriculture and Food Development Authority	Ireland
Katrien Broekaert	Institute for Agriculture and Fisheries Research, Technology and Food Science (ILVO)	Belgium
Liisa Pesonen	Ministry of Agriculture and Forestry/LUKE	Finland
Lucia Rumanová	Slovak Academy of Sciences	Slovakia
Lucy Dorey-Robinson	Department for Environment, Food & Rural Affairs (DEFRA)	U.K.
Luke Spadavecchia	Department for Environment, Food & Rural Affairs (DEFRA)	U.K.
Maarja Malm	Ministry of Rural Affairs	Estonia
Mahur Altay	The Scientific and Technological Research Council of Turkey (TUBITAK)	Turkey
Mattias Norrby	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)	Sweden
Maurice Heral	Agence Nationale de la Recherche (ANR)	France
Mónica de Prado	Basque Food Safety Foundation (ELIKA)	Spain
Nicholas Hutchings	Aarhus University	Denmark
Nicolas Tinois	Projektträger Juelich	Germany
Niels Gøtke	Danish Agency for Science and Higher Education (DASHE)	Denmark
Órlaith Ní Choncubhair	Teagasc – Agriculture and Food Development Authority	Ireland
Pilar Merino	NEIKER Basque Institute for Agricultural Research and Development	Spain
Raymond Kelly	Teagasc – Agriculture and Food Development Authority	Ireland
Rebecca Danielsson	Swedish University of Agricultural Sciences	Sweden
Sari Luostarinen	Natural Resources Institute Finland (LUKE)	Finland
Sean Fair	University of Limerick	Ireland
Sezer Öz	Ministry of Food, Agriculture and Livestock (GDAR)	Turkey
Silvia Baralla	Ministry of Agricultural, Food and Forestry Policies (MIPAAF)	Italy
Stan Lalor	Grassland AGRO	Ireland
Stefan Vetter	Federal Ministry of Sustainability and Tourism (BMNT)	Austria
Tavs Nyord	Aarhus University	Denmark
Thorbjørn Gilberg	The Research Council of Norway (RCN)	Norway
Tim McAllister	Agriculture and Agri-Food Canada	Canada
Violeta Juskiene	Lithuanian University of Health Sciences	Lithuania
Vivi Hunnicke Nielsen	Aarhus University	Denmark
Yasar Inci Tekeli	Ministry of Food, Agriculture and Livestock (GDAR)	Turkey

Appendix B: Full list of priority topics identified

1. Evaluation of Feed Chain

Priority Themes Priority Topics under that Theme
Benchmarking, traceability of GHGs & incentives
- Benefits for farmers for implementation - Opportunities, Incentives, Climate Mitigation, Quantify & Benchmark, Labelling
- How to incorporate the environmental and health costs into the price of food paid by consumers - true pricing
- Impact of imported feed on GHGs
- Emission traceability for consumers
Digital and precision farming
- Precision feeding - meet the demand of animals individually by sensor technique
- Managing feed intake efficiency
- Measuring/monitoring feed quality at farm when mixing the portions
- Piloting and demonstrating tools (also ICT tools) to monitor, reduce GHG and nitrogen efficiency at farm level
- Sharing data between farmers for cost benefit calculation, training, F2F learning
- Precision Livestock Farming - health, managing feed intake/efficiency
- Life cycle assessment - big data - how farmers access/use information
New feedstuffs
- New feed: new genotypes? CO_2-emission? Grass based products, perennial, former food stuff, insects, algae, other species from sea
- New protein sources (insects)
- How to use animal by-products safely as animal feed
- Identify, select, breed easily digestible and high biomass forage species
- Protein crop (pulses) breeding - EU alternatives to imported soya
- Identify, test and validate the GHG potential of locally adopted new feedstuffs
Animal breeding
- Breeding for efficiency
- Feed efficiency benchmarking - lot of data at farm level - utilise data to optimise efficiency - big data - externalities
- Animal health -efficient control of mastitis - antibiotic resistance - breeding for health -support decision for antibiotics -diagnostic tools-vaccine development
- Breeding livestock for better feed utilization efficiency
- Breeding index to include: GHG reduction, animal health, feed efficiency, farmers profit

More efficient production systems

- Efficient feed production (nutrients, smart tools, crop protection, breeding, plant selection, water use)
- Optimization - develop sustainable production systems for dairy cows 8000L 10000L 12000L
- Possibilities for more efficient use of manure in feeding crops (application…) including larger scale to reduce losses
- Microbiome

Animal feed vs food production

- Quantification of amount of animal feed without competing with food production at EU level

Animal fertility/lifetime

- Life time of animals - impact on carbon footprints (breeding, feeding, management of animal health)
- Animal fertility - improve animal fertility - reduce negative energy balance - fertility diagnosis sensors

Additives

- Additives with least negative effect
- Diet balance to promote health - dietary additives to support/improve health

Stress levels on farms

- How to reduce stress level on a farm?

Economic validation of animal feed/feeding interventions

- Economic validation of feeds, additives or any intervention related to animal feed and feeding

Systems approach to feed chain analysis

- Real/potential losses along the whole feed chain
- Feed transport logistics - prioritise locally produced feeds, maximising feed use efficiency

Impact of local conditions on mitigation options

- Importance of local conditions on recognized efficient mitigation options

2. Manure Management

Priority Themes Priority Topics under that Theme
Circular bioeconomy
- What are the opportunities for manure in the circular/bioeconomy? - Use of biorefinery concepts to derive quality fertilizer products from manures that are suitable to replace mineral N --> reduce bulk + H2O content to help transport - Who will sell/buy manure - create a market - Producing single cell protein from manure/wastewater - Anaerobic co-digestion CH4 production energy - New applications of manure use: example: as feed for insects - Increase N efficiency in the whole manure chain - Quantification of multiple benefits of manure use - How to turn manure in the long promised brown gold? - Integrated plant - animal production systems
Technologies for manure characterisation
- Methods to measure organic and mineral N content of manure at different stages of MMC - (ICT) tools for rapid manure characterization - Manure characterization & Precision farming in spreading - Technologies for rapid analysis of manure nutrient composition - Low cost sensors to characterize nutrient content of manure + slurries - Cutting edge and low-cost methods for quantification of emission from manure - Demonstration and pilots for adoption of precision farm technologies at high TRLs e.g. manure characterisation, manure rate, application time
Manure processing
- System-level analysis of manure processing - farm level - larger plants - Manure process to aid transport + application - Improvement of systems separating liquid/solids in pig-housing /poultry. Combination with feed improvement - Manure fractionation - liquid to solid separation - compost bedding - Logistics for Manure Management - Manure storage (open/close) and processing (microbes)inoculation

- Use of biochar or zeolyte to adsorb N+P: use as fertilizer product? (perhaps useful as slow release fertiliser, separate organic carbon from nutrients to aid application planning)

Technologies for traceability, emissions reductions

- Nutrient and emission traceability in the MMC (Manure management chain): data collection & identifying the problem source
- Ecologic footprint label for food products
- Inter-operable ICT modules for manure management decisions throughout the MMC
- Blockchain technologies and manure management (transparency)
- ICT - decision support tool for manure management to optimise utilization and reduce emissions along the MMC -odour - carbon -nutrients
- Whole systems approach - retaining N over the whole manure management chain - how might technologies fit together and complement each other?

Feed digestibility

- Feed for improved digestibility to reduce GHG outputs & manure quantity
- The effect of feeding into quantity and characteristics of manure

Regional solutions

- Regional solutions for animal farms considering climatic conditions, production conditions
- Identify regionally adapted mitigation solutions

Socio-economics/Multi-actor approach

- Multi-actor approach to MMC-farmer /consumer. Barriers to manure utilisation, technology adoption, socioeconomics.
- Economic modelling of manure transport, storage, processing. Inform policy/farmer willingness to adopt
- Opportunities for farmer collaboration to improve outcomes

Biohazard management

- Manure decontamination & pathogens, including antibiotic resistant strains
- Food safety associated with manure use in animal feed and human feeds - pathogens - veterinary residues
- Waste management in terms of biohazards & unknown ingredients

Smart housing systems

- Housing systems reducing storage time of manure in pig housing - effect on GHG
- Smart dairy barns for measuring emissions, steering ventilation & indoor climate with smart sensing
- Monitoring and improving the performance of air cleaners

Policy measures & incentives

- State support (incentives) for farmers in smart manure management
- Allocation of money and resources to the best benefit of public value
- Why does policy not want to implement appropriate legislation?
- Lower administrative burden by technology accepted by legislation

Better quantification of emissions

- Quantification of losses when processing manure
- Refinement of MMC emission factors - techniques for quantification -mitigation
- Factors that influence N2O emissions both direct and indirect throughout MMC

Decision support tools

- Data analysis and decision support to utilise information from sensors
- ICT tools from predicting crop demand + soil fertility

3. Reducing Nitrogen Excretion

Priority Themes Priority Topics under that Theme
Precision farming and big data
- Big data: how low can we go? Reduce protein intakes without negative impacts on yield or welfare
- Monitoring / ICT tools for improvement of precision feeding
- Dietary optimisation / precision nutrition
- Precision farming - feed intake on an individual animal basis. Should we generate more "big data" via more sensors to understand individual animal variability?
- Use of biomarkers - reflect protein utilization e.g. milk urea N, real-time, robots
- Monitoring systems to track health and nutritional status of animals individually
- In-line sensor in milk to identify rate limiting amino acids in cows
- ICT-tools for grass/forage intake - precision tools to monitor feed intake at farm level
- Tools for integration of farm data - develop precision feeding tools
- Improvements in targeted feeding systems - reducing costs
- Precision feeding
Optimising protein content & diet
- Evaluation of crude protein content in diet
- Reducing protein level in diet to appropriate level: role of education and knowledge transfer, social science, farmer attitudes & behaviour
- Protein requirement: genetics aspects, animal individual aspects for milk and beef production
- Dietary manipulation for increasing organic excretion fraction and/or urine dilution
- Balanced and precise diet formulation
- Individual feeding of livestock, targeted diets
- How much variability exists in N excretion? Does it matter for diet formulation?
Animal breeding
- Animal breeding to reduce N excretion (protein utilization efficiency) - what is the best trait? - milk urea - trade-offs -heritability?
- Breeding for feed quality - amino acid profile - protein quality - anti nutritional factors
- Breeding for less excretion
Microbiome
- Fundamental research on understanding of rumen microbiology in production of GHGs and nitrogen utilization
- Ruminal/intestinal microbiome - supplements to inhibit proteolysis --> increase N-efficiency

- Impact of microbiome on N-utilization
- What is the role of the microbiome? Can we manipulate or manage it to improve N excretion?
- Microbiome understanding
- Microbiome research where information is lacking - feed efficiency - ammonia optimization

More productive animals

- Reducing the number of animals: shorter non-productive period, no lazy cows

Incentives/barriers to adoption

- Incentivise farmers to reduce N Excretion
- Socio-economic study on barriers of adoption of precision feeding

Market analysis

- Scientific progress does not equate to market consensus to pay
- Today's animals are almost fully optimized --> change the market instead

Molecular improvements in physiological processes

- Molecular improvements in physiological processes, intestinal absorption

Emission factor refinement for reduced protein intake

- Emission factor refinement for reduced protein intake

Animal behaviour

- Can animal behaviour help management decisions? If we know where they excrete - can we manage better?

Additives

- Additives to prevent volatilization
- What is the role of additives in reducing N Excretion - cost benefit - trade-offs
- Possibility of utilizing alternative feeds/supplements

Education

- Educate the next generation

Transdisciplinary research consortia

- Do we need input from other disciplines? Fund and invite inter- and transdisciplinary consortia, formed not only of agronomists and life scientists, but also of sociologists, economists, ecologists

Crop/forage breeding

- Improve amino acid profile of the plants for feeding monogastric animals
- High sugar - low protein grasses

Manure handling

- More complete separation of faecal matter and urea in farm buildings

Appendix C: Minority Report

Personal comments from Prof. Dr. Albert Sundrum

Comments regarding the proceeding regarding the selection of topics for scientific investigations towards mitigation of GHG emissions from livestock production

Albert Sundrum, Department of Animal Nutrition and Animal Health, University of Kassel

Agricultural processes of land use and livestock production contribute considerably to the emission of GHG. Emissions of GHG occur during chemical processes of composition and decomposition of organic material and thus cannot be prevented completely. However, the degree of emissions in relation to the amount of food produced are highly variable between farm systems. This leaves ample room for improvements regarding the relationship between the outputs of a farm system, i.e. output of food on the one and output of GHG emissions on the other hand. While the GHG emissions deriving from cars and from traffic are the subject of EU Regulation, in particular limiting the permitted carbon-dioxide emissions of cars per driven km to 95 g CO_2, agricultural lobby was up to now very successful in preventing, apart from the nitrate directive, any additional regulation that might force farmers to reduce emissions and take responsibility for their contribution to climatic change.

Economists and many agricultural scientists pretend to have confidence in the ability of the markets and of agricultural science to drive technological changes that will enable the capacity of the economy-environment system to satisfy the increasing global needs and simultaneously solve the problems in relation to GHG emissions and environmental pollution. In contrast, ecological scientists tend to believe that solving problems in relation to environmental pollutions and restrictions in the availability of resources cannot be left to technological developments and economic growth alone, but requires different kinds of regulation. Contradicting scientific approaches would be a sufficient and obvious reason for a fundamental scientific debate. Unfortunately, this debate does seldom take place within agricultural science. Among other things, there is no institution that feels responsible to organize such a scientific debate.

Also the 2nd Joint Workshop at TEAGASC, Ashtown did not offer a frame for such a debate. It just offered the possibility to exchange opinions without providing convincing arguments. Knowledge is by definition ‚a reasoned opinion'. From my perspective, the proceeding regarding the selection of topics to specify the scope for a call has fallen short of what it could have become. To prevent being captured, I herewith dissociate myself from the given approach. Agricultural and animal science as applied scientific disciplines are asked to contribute to the solutions of societal challenges. In case that the salary of scientists is paid by public and not by private money, scientists are obliged to contribute to the enhancement of public goods in the first place while the personal interests of scientists or of other involved stakeholders should be subordinate to it. When investigating public money for the improvement of public values (mitigation of GHG emissions), the challenge is to identify the best cost-benefit relationship. This challenge has not been addressed at the workshop.

People's and also scientist's perceptions are limited. We do not have the perfect information, and we have limited capacity to process the information we do have. So the question becomes whether we want preferences to be manipulated unconsciously, or whether we want to formulate preferences consciously, based on a scientific debate and consensus, with a higher goal in mind. Scientists can make better choices about the priorities of scientific issues if the valuation issue is made as explicit as possible.

Valuation is the process of assessing the contribution of a particular object (scientific issue) in meeting a particular goal. Given the goal to mitigate GHG emissions, scientific issues are valuable to the extent that they contribute to this goal. Voting by people who have only a limited understanding of the complex processes that lead to GHG emissions while being offered a limited number of alternatives which have not been discussed appropriately, cannot claim to be an adequate method to assess the relative contribution of scientific issues in meeting important societal goals.

Decisions regarding priorities in processing scientific issues involve either explicit or implicit considerations of relative costs and benefits. To use cost-benefit analysis[1] for decision making, one needs to think very broadly about which categories of costs and benefits need to be addressed and deal with the inherent uncertainty and imprecision attached. One needs to consider the full range of possible values and valuation methods, to shift the burden of proof to the parties that stand to gain from the decision, to deal with the distributional consequences of decisions, and to be clear about the social goals being served by the decisions. Failure to think broadly enough about costs and benefits leads to decisions that serve only narrow special interests, not the sustainable well-being of society as a whole.

Both outputs (food and GHG) of a farm system emerge from very complex processes which take place in sub-systems, embedded in hierarchical organized scales. Focusing on single aspects without taking the context and the conflicting areas between the goals of productivity and the mitigation costs of GHG emissions into account does not allow any extrapolation or generalization of results and can be blamed for an excessive narrowness and incompleteness of the subject at hand. For example, the microbiome in the rumen has an impact on the emission of methane as a by-product during the decomposition of carbohydrates to volatile fatty acids. On the other hand, the microbiome is influenced by the quantity and composition of the feed as well as by the individual conditioning processes of the microbiome after birth. Thus, a better understanding of the very complex interconnectedness of factors that have an impact on the composition of the rumen microbiome of single animals and that might have an impact on their individual GHG emission might be an interesting subject for pure science but cannot be justified when searching for the best options regarding the relative costs and benefits of research work to mitigate GHG emissions.

The focus on single aspects and possible gaps in the knowledge of processes with a rather minor connection to GHG emissions can be blamed for creating or sustaining the believe and the expectations in solutions provided by innovative technological developments while simultaneously disregarding other more promising approaches. The problem might be that other approaches, although providing a better cost-benefit relation, would require clarification processes and possibly also a re-orientation, i.e. you might no longer be able to follow familiar paths.

[1] Costanza, R. (2005). Thinking broadly about costs and benefits in ecological management. Integrated Environmental Assessment and Management 2, 166-173.