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Efficient Carbon, Nitrogen and Phosphorus cycling in the European Agri-food System and related up- and down-stream processes to mitigate emissions

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D6.12. Compilation of EIP-Agri practice abstracts developed No 3

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Author(s)	Andreas Muskolus, Markus Herndl, Jan Willem van Groeningen, Joaquim Clemens, Marek Holba, Marta Terré, Paolo Mantovi, Wim Moerman, Aiman Anwar, Fabian Kraus, Elisa Rose, Carme Biel, Zein Kallas, Andreas Dünnebeil, Julien Guigue, Dolors Villegas, Gonçalo Nascimento, Victor Riau.
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Contact person EC	Violeta Kuzmickaite

Contributing partners	
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3.	CREDA
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5.	IASP
6.	IRTA
7.	KWB
8.	NRS
9.	PON
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1. INTRODUCTION. EIP-AGRI AND THE MULTI-ACTOR APPROACH

The European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) is a policy initiative launched by the European Commission in 2012. Its main goal is to promote innovation and sustainable farming practices in the European Union (EU) by bringing together farmers, researchers, advisors, and other stakeholders.

EIP-AGRI is built around three key elements: Operational Groups, Focus Groups, and Seminars. Operational Groups are composed of farmers, researchers, advisors, and other relevant actors who work together to develop and implement innovative solutions to specific problems. Focus Groups, on the other hand, bring together experts to exchange knowledge and share best practices on specific topics related to agriculture and rural development. Seminars are organized by the EIP-AGRI network to discuss and disseminate the results of successful innovation projects and to explore new ideas and approaches.

EIP-AGRI is based on the concept of "innovation through cooperation," which emphasizes the importance of involving all relevant actors in the innovation process. By working together, farmers, researchers, advisors, and other stakeholders can identify the most pressing challenges facing agriculture and rural development and develop innovative solutions that are both environmentally sustainable and economically viable.

Based on this key concept, several H2020 projects, mainly in the fields of agriculture, food and environment, have implemented the so-called “multi-actor approach”, which aims at an effective collaboration of the different actors relevant for the topic (researchers, practitioners, policy-makers, end-users, consumers…) in the throughout research process, that is, in the design, implementation, evaluation of research and innovation activities, and dissemination of results. This collaborative and inclusive environment is crucial to properly address complex challenges such as climate change, food security or sustainable agriculture, which require a holistic and integrated approach that considers different perspectives and needs. The multi-actor approach seeks to guarantee that EU projects are not only driven by scientific knowledge but also by the needs, perspectives, know-how and experiences of those who are directly affected by the research outcomes, leading to a more effective, efficient, and relevant research outcomes to a wider community that can increase the chances of a successful adoption of results.

By conducting research in such a way, European research and innovation projects:

- Increase their relevance: The involvement of different actors ensures that research and innovation activities are relevant to the needs and perspectives of different stakeholders, making them more likely to have a real impact.
- Have a better problem definition: By involving a range of actors, researchers can obtain a better understanding of the problems they are trying to solve and identify potential solutions that are more likely to be effective.
- Contribute to knowledge co-creation: The multi-actor approach fosters collaboration and co-creation of knowledge among different actors, leading to a better understanding of the challenges and opportunities.
- Are more innovative: The involvement of different actors with diverse backgrounds and perspectives can stimulate creativity and innovation, leading to new and more effective solutions.
- Enhance dissemination of results: By involving a range of actors, research results can be disseminated more widely and effectively, increasing their impact and reach.
- Improve the adoption of project results: The multi-actor approach can lead to research results that are more likely to be adopted by end-users, policymakers, and other stakeholders since are aligned to their needs and expectations.
- Are more resource-effective and efficient: The involvement of different actors can help to optimize the use of resources, ensuring that research and innovation initiatives are cost-effective and efficient.

- Have more sustainable results: The multi-actor approach can help to identify and address potential social, economic, and environmental impacts of research and innovation initiatives, ensuring their long-term sustainability.

- Are carried out in a trust environment: The involvement of different actors can help to build trust among stakeholders and create a more inclusive and participatory research and innovation process.

As mentioned above, the EIP-AGRI seeks to foster innovation and sustainable farming practices in the EU. To contribute to this goal, projects flagged with the multi-actor approach are expected to contribute to this dissemination to farmers and practitioners through the release of several "practice abstracts".

A practice abstract is a concise summary of a specific best practice or innovative approach used in the project. It aims to provide a brief description of the practice, its objectives, methods, and results achieved, and its potential for replication or transferability to other contexts. They are an essential component of the dissemination and exploitation strategy of the project, as it enables the sharing and dissemination of valuable experiences and knowledge among stakeholders, policymakers, and the wider community. It is written in a standardized format provided by the EIP-AGRI, in a plain language for better understanding of practitioners.

Overall, a practice abstract is a powerful tool for sharing best practices and innovative approaches developed in European projects, enabling stakeholders to learn from each other and promote sustainable change and impact in different fields and sectors.

Practice abstracts are available on the EIP-AGRI website and can be found searching by theme, sector, or region.

As a multi-actor project, Circular Agronomics aimed to produce at least 100 PAs during the project, which have been split into 3 deliverables to be submitted on M18, M36 and M54, and containing 35, 35 and 30 PAs, respectively.

The third set of 30 PAs prepared by those partners involved in work packages WP1, WP2, WP3, WP4, WP5 and WP6 are listed task by task in Table 2. A summary of the tasks to be performed within each WP that are liable to generate PAs, is shown in Table 1.

Table 1. Tasks to be performed within each work package:

WP	Task
1. Plant-Soil-Interactions	Task 1.1: Comprehensive analysis of C, N and P stocks, flows and emissions in crop farming
	Task 1.3: Fertilizer application strategies
2. Livestock emissions and residues treatment	Task 2.1: Feeding strategies, gaseous emissions and manure characteristics
	Task 2.2: Demonstration of innovative treatment technologies increasing efficiencies in valorisation and recycling of livestock/agricultural residues and minimizing emissions
3. Carbon and Nutrient valorisation from food-waste and food-processing-waste(water)	Task 3.2: Pilot Demonstration of innovative treatment technologies for recovery/recycling of C, N and P from food waste and wastewater
4. Social and Economic Evaluation	Task 4.2: Consumer Acceptance Evaluation
5. Environmental Evaluation	Task 5.2: Application of environmental assessments
6. Dissemination and Exploitation	Task 6.2: Know-how translation and exchange
	Task 6.3: Exploitation and Replication

The Excel EIP common format, including project information, partners contact information, keywords, related websites and full PAs will be sent to the EIP-Agri for its publication. A non-editable version of the Excel file can also be downloaded from: 773649_Circular Agronomics_Practice Abstracts_3.xls

2. LIST OF PRACTICE ABSTRACTS FROM MONTH 37 TO MONTH 54

Table 2. List of practice abstracts per task included in Deliverable 6.12

WP	Task	Practice abstract
WP1	**Task 1.1**	**71.** Circular fertilizers to improve the sustainability of intensively managed grasslands. **72.** Terrain attributes correlating with organic matter stocks at different depths in Alpine grasslands, investigations in Lungau, Austria.
	Task 1.3	**73.** Microfiltered digestate in fertigation via sprinkler plant (rainger). **74.** Struvite as an adequate replacement for conventional phosphorus fertiliser in the field. **75.** Struvite as a climate-friendly fertiliser. **76.** How does the nitrogen fertilizing effect of organic fertilizers change during processing by vacuum degasification? **77.** Pig slurry digestates used as fertilisers in field crops. **78.** Dried acidified pig slurry digestate is a good fertilizer for irrigated wheat. **79.** Benefits of biodiverse rotations in irrigated wheat production. **80.** Digestate-derived fertilizers used for horticultural production.
WP2	**Task 2.1**	**81.** Precision feeding on dairy cattle: performance, digestibility, and manure emissions. **82.** Identifying high ammonia producing bacteria and bacteriophages in the rumen of dairy cows.
	Task 2.2	**83.** How the carbon footprint of dairy farms can change with a biogas plant. **84.** Acidification during manure solar drying reduce emissions and improve the fertilizing quality of the dried product. **85.** Scrubbing of Ammonia and Carbon dioxide containing gases. **86.** Overcoming legal barriers for the application of biobased fertilizer products.
WP3	**Task 3.2**	**87.** Maximum admissible dose of acid whey for growth of plants. **88.** Extraction of lactoferrin from acid whey. **89.** Acid whey effect on maize production. **90.** Soil nitrogen transformations after acid whey addition. **91.** New scaling proof anaerobic reactor design. **92.** Increasing Biomethane Potential via Ammonia-Recovery. **93.** Heat management in degasification columns. **94.** Immediate harrowing during liquid ammonium fertilizers application reduces ammonia emissions. **95.** Using gypsum as reactant to produce ammonium sulphate and limestone from scrubbing liquid. **96.** Construction of a container plant for nitrogen recovery from organic agricultural residues using vacuum.
WP4	**Task 4.2**	**97.** EU consumers' purchase intention and willingness to pay for circular beef.
WP5	**Task 5.2**	**98.** Environmental assessment of Austrian dairy farms with closed production cycles.
WP6	**Task 6.2**	**99.** CIRCULAR AGRONOMICS Policy Note – Towards a circular EU agri-food system.
	Task 6.3	**100.** Concept studies to exploit technologies to real market conditions.

3. COMPILATION OF 30 EIP-AGRI PRACTICE ABSTRACTS (English version)

PA71. Circular fertilizers to improve the sustainability of intensively managed grasslands.

Grasslands store on average more soil organic carbon (SOC) than arable lands. Intensive managed grasslands tend to lose nutrients via e.g., leaching. We aim at optimizing the fertilization of these grasslands in order to reduce nutrient leaching and increase SOC stocks. We set up a field experiment in the case study 5 (WUR, the Netherlands) including four different fertilizer treatments (digestate, nitrogen-depleted rest-product from the vacuum degasification, calcium ammonium nitrate (CAN) and unfertilized control), applied on two different plant communities. Samples were taken using soil cores down to one meter depth and measured for SOC stocks and nutrient contents. The SOC stocks were barely affected by fertilizer's type and plant community composition. Nitrate was leached to the subsoil with using calcium ammonium nitrate, but not when using digestate or rest-product. In additional, the use of digestate and rest-product resulted in an increase of pH and cation contents (K, Na, Mg) in the topsoil. We prove that multi-species grasslands fertilized with circular fertilizers are equally sustainable for farmers as well as for the environment.

PA72. Terrain attributes correlating with soil organic matter stocks at different depths in Alpine grasslands, investigations in Lungau, Austria.

Alpine landscapes are known for their variety of topographical and geological features. These are introduced as major controlling factors for soil development and therefore ultimately control soil organic carbon (SOC) stocks and storage potentials. However but knowledge for their influence in subsoil is limited. We investigated the effects of topographic features and parent material on SOC and total TN stocks in permanent grasslands of the Lungau region, Austria. Grassland soils from fifteen organic farms were sampled down to a depth of one metre. These soils developed from two parent materials (moraine and alluvial-colluvial deposits) and under various slope aspects. The mean SOC stock in the region was 23.4 kg m-2, ranging from 11.4 to 38.8 kg m-2. The developed on alluvial-colluvial deposits had higher SOC and TN stocks than soil found on moraine. For both soils, SOC and TN stocks were higher in soils collected in areas under south and south-west aspects, than in soils developed in area receiving more sunlight under west and east aspects. Most of SOC stocks were found in topsoil (51% of total SOC stocks in 0-20 cm), compared to upper-subsoil (27% of total SOC stocks in 20-40 cm) and subsoil (22% of total SOC stocks in 40-100 cm). The topographic wetness index (TWI), which indicates soil moisture gradients, is the main topographic feature related to SOC and TN stocks (R2=0.5-0.7), particularly in the subsoil. Our results indicate that subsoil OC stocks in the alpine grasslands is influenced by topography, particularly by the slope aspect, and by parent materials.

PA73. Microfiltered digestate in fertigation via sprinkler plant (rainger).

Through fertigation applications of slurry and digestates, it is possible to significantly elevate the use efficiency of the plant nutrients that these by-products contain; in particular, nitrogen in ammoniacal form that is diluted with irrigation water has the potential to penetrate rapidly into the soil, and its emissions into the air are very low compared to more conventional distribution techniques.

In addition to the trials conducted in the European H2020 Circular Agronomics project, with drip lines in sub-irrigation, the CRPA in Ferrara (Italy) has also experimented with the use of microfiltered digestate in maize fertigation through sprinkler systems, such as rainger, demonstrating that the microfiltered fraction is suitable for this kind of use as it does not contain particles larger than 0.1 mm and therefore there is no risk of clogging of spray nozzles. The microfiltered digestate was distributed in two irrigation interventions, well diluted in the irrigation water, for a total of 118 kg N/ha, more than half of which was in ammoniacal form ready for uptake by the crop, and the rest in organic form with prolonged availability over time. The NUE (Nitrogen Use Efficiency) index of this fertilization on top of crop was 66% for urea (traditional BAU treatment) and 51% for microfiltered digestate, a value, however, that rises to nearly 100% when considering only the share of ammonia nitrogen in digestate.

PA74. Struvite as an adequate replacement for conventional phosphorus fertiliser in the field.

In a grassland field experiment lasting more than a year, we compared two kinds of struvite (an ammonium struvite produced in a pilot plan of the project and a potassium struvite produced in the laboratory) to triple super phosphate and a control treatment without fertiliser. Both struvite fertilisers performed just as well as the conventional fertiliser in terms of yield and plant phosphorus content. This contradicts the results of previous, greenhouse-based, studies where struvite performed poorly compared to conventional phosphorus fertiliser. In the field, the low dissolution of struvite is better suited to provide phosphorus at a sufficient rate to plants without the phosphorus bounding to the soil as it is the case for conventional fertilisers. In this respect, struvite can be seen as an “on demand” phosphorus fertiliser that is adapted to switch phosphorus fertilisation from the unrenewable resource that is phosphate rocks to a circular resource produced from wastewater.

PA75. Struvite as a climate-friendly fertiliser.

Struvite is often regarded as a phosphorus fertiliser but it also contains some nitrogen. Conventional nitrogen fertiliser use results in the production of nitrous oxide, a potent greenhouse gas that accounts for a large part of the agricultural impact on climate change. It is not clear to what extent struvite application will lead to nitrous oxide emissions. In a pot experiment comparing struvite with urea (a conventional nitrogen fertilizer), struvite led to very low nitrous oxide emissions, statistically not different from the unfertilised control treatment, while the plant performances of struvite were almost comparable to those fertilised with urea. This is due to the slow dissolution of struvite in comparison to regular fertilisers. Because nitrogen is released slowly, the plants take it up almost immediately and it doesn’t accumulate in the soil, and thus cannot be transformed into nitrous oxide. In addition to its circularity, the climate-friendliness of struvite makes it a fertiliser of choice for the future.

PA76. How does nitrogen fertilizing effect of organic fertilizers change during processing by vacuum degasification?

Organic fertilizers contain plant nutrients and carbon. Their total fertilizing effect on plants is complex because they consist of more than one nutrient. Their short-term fertilizing effect in a specific soil-plant situation is determined by the concentration of nutrients that limit plant growth. Mostly this is nitrogen. The ”plant availability” of nutrients in fertilizers determines their actual immediate effect. As a result of mineralization, organically bound nutrients enter the soil solution in mineral form after a certain time. In order to estimate the fertilizing effect during the year of application, the corresponding share of organically fixed to mineral nitrogen has to be taken into account. In the case of nitrogen, it can be expected that the mineral nitrogen forms ammonium and nitrate are readily plant available within days or weeks. However, not many organic fertilizers contain nitrate. The mineralization rate of the organic share depends on factors like temperature, moisture, and abundance of oxygen. As a rule of thumb, 15 % of the organically bound nitrogen will mineralize during one growing season in north-eastern Europe. If the share of organically bound nitrogen to mineral nitrogen changes as a result of fertilizer processing, its fertilizing effect changes, too. For example, the immediate nitrogen fertilizing effect of organic fertilizer is reduced as a result of ammonia removal due to vacuum degasification. At the same time the long-term nitrogen fertilizing effects is raised. The mineral fertilizer produced in the same process in parallel, has a high immediate fertilizing effect.

PA77. Pig slurry digestates used as fertilizers in field crops.

Several areas in Europe, including Catalonia, have an excess of slurry waste due to livestock concentration. The by-product of slurry anaerobic digestion is a valuable fertilizer product applied in agricultural fields. However, the untreated digestate (UD) still has a high percentage of water and its transport is expensive. With an acidification and solar drying process, we can concentrate the UD without significant energy costs, and avoiding nitrogen losses due to ammonia volatilization. Therefore, we have obtained a dried acidified digestate (DAD), that has been tested in field conditions comparing it to UD, mineral fertilization (business-as-usual) and a control without fertilizer. After 3 years cultivating several field crops in irrigated conditions, the fertilization treatments affected canola yields, reaching higher values with mineral fertilization and lower with UD, similar to the control. Intermediate yields were obtained when applying the DAD, indicating that it has a higher nutrient provision to canola compared to the UD. No significant differences have been detected for barley, triticale, and pea. In these cases, crops in the control treatment had also similar yields than the fertilized ones. The soil fertility in this area may explain these results, because of the high input of slurry during several preceding years. Additional years of experimentation would be necessary to precisely assess the digestate performance for these crops. These results suggest that, at least for canola, the DAD has a greater fertilising potential than the UD and may be considered as an alternative, cheaper, and more sustainable option for organic fertilization in field crop production.

PA78. Dried acidified pig slurry digestate is a good fertilizer for irrigated wheat.

Slurry management is an important issue in Catalonia and other regions in Europe, where there is a high concentration of livestock production. Anaerobic digestion presents itself as a solution to deal with this slurry while producing energy out of it. The digestate is the by-product of this process which still has the potential to be used as an organic fertilizer in agriculture. However, untreated digestates (UD) are diluted which pose an issue for transportation and field application. By acidifying and drying this product we can respectively reduce N losses via ammonia volatilization and increase dry matter concentration, possibly creating a better organic fertilizer product. Therefore, we tested the performance of the UD and the dried acidified digestate (DAD) as fertilizers for wheat in a cereal rotation over the course of 3 years, along with mineral fertilizer (business-as-usual) and control treatments. Higher yields were obtained when fertilizing wheat with the DAD compared to the control, while the UD and the mineral fertilizer performed intermediately. By drying the digestate we might have reduced N losses by leaching in the soil. Moreover, this process leads to a lower C:N ratio of the product, which may have accelerated N mineralization and increased N availability for the crop when compared to the UD. Still, we have seen that both digestates have the potential to substitute chemical fertilization in irrigated wheat production systems, while playing an important role in two major environmental issues that are waste management and energy production.

PA79. Benefits of biodiverse rotations in irrigated wheat production.
Wheat is one of the main crops produced worldwide, and it is fundamental to reduce chemical fertilizer dependency to produce it. Digestates are by-products of anaerobic digestion that can be used as fertilizers. Untreated digestates (UD) are very diluted, which makes transportation and application costly. Solar-drying this product is a solution to these issues, with little energy costs. Moreover, by previously acidifying the digestate we will prevent nitrogen (N) losses by ammonia volatilization, therefore obtaining a dried acidified digestate (DAD) product. Another way to reduce chemical fertilization is by introducing N rich crops in a rotation with wheat. Given this, yields of wheat were compared when applying UD, DAD and mineral fertilizer (business-as-usual) during three years in an irrigated field in Catalonia. There was also a control treatment where no fertilizer was applied. Moreover, we compared yield of wheat in two rotations: canola-pea-wheat and barley-triticale-wheat. The DAD was the only fertilizer that induced higher yields comparing to the control. However, the rotational effect was stronger than the effect of fertilization, with the wheat followed by non-cereals reaching higher yields. The yield difference between the two rotations increased further from the 2nd to the 3rd year (i.e., pea-wheat and triticale-wheat vs. canola-pea-wheat and barley-triticale-wheat), showing a cumulative effect of the preceding crops. We were able to show the potential of the DAD as an organic fertilizer. Still, we concluded that adequate crop rotations have a higher potential to reduce chemical fertilization in wheat cropping.

PA80. Digestate-derived fertilizers used for horticultural production.
An innovative manure processing developed in Circular Agronomics project increases the agronomic quality of the recovered products derived from digestates. The objective of this work was to test these products obtained in a nutrient recovery cascade from pig manure. The products were tested in lettuce plantlets grown in 1.3 L pots, with a substrate composed of peat:perlite (1:1, v:v), in a greenhouse. The products obtained in the pig farm were: dried digestate (DD), dried acidified digestate (DAD), dried concentrated fraction of digestate (DSF), dried acidified concentrated fraction of digestate (DASF), and three dried mixtures (DM1, DM3, DM6) of acidified concentrated fraction of digestate (ASF) and the residual liquid after stripping (SLF), with three ratios ASF:SLF (in wet mass): mixture 3:1 in DM1; 1:1 in DM3; 1:8 in DM6. All the products were applied to a dose of 150 kg N/ha trying to maintain a stoichiometric ratio of N:P:K=1:0.15:1.5 and thus compensating with K2O and TSP when necessary. All parameters, such as plant biomass (leaves fresh and dry weight), diameter, and relative chlorophyll content, were measured in 10 plants per treatment. The nutrient content of substrate and leaves were analysed, and the percentage of nutrient recovery was calculated. The best plant performance of the edible part was related to products DAS, DASF and DM3. Regarding the nutrient recovery, products DSF, DASF and DM3 presented the highest recovery, being similar to the control plants (with a mineral slow-release fertilizer). Therefore, it can be concluded that fertilizers derived from digested pig manure are suitable to be used for lettuce production, with DASF showing the best performance.

PA81. Precision feeding on dairy cattle: performance, digestibility and manure emissions.
Feeding different feed supplements in the milking parlour to achieve more precisely dairy cow nutrient requirements allowed to feed dairy cows a wide range of CP% in their diet. The range was between 13 and 16.9% CP, with an average of 14.3%, while control animals were fed a fixed concentration of 16.4% CP. Although animals were only followed for 21 days, cows within the first 150 DIM fed under a precision feeding system produced less milk with greater fat content, which similar energy-corrected milk was produced in control and precise fed cows. Furthermore, cows fed under this precision feeding system improved NDF diet digestibility and reduced N urine excretion. Consequently, there was a 30% reduction of manure ammonia emissions, but a 59% and 148% increase in CO2and CH4manure emissions. Differences in total C and fibre content could not explain this greater biogas production potential, and it was a finding that deserves further research.

PA82. Identifying high ammonia producing bacteria and bacteriophages in the rumen of dairy cows.
One of the tasks of the Circular Agronomics project aims to determine if bacteriophages against high ammonia producing bacteria (HAB) could be a feasible approach to reduce the amount of HAB in dairy cows rumen without affecting rumen microbiota. For that, HAB and bacteriophages against HAB have been isolated and identified from the rumen of cows. Clostridium argentinenses, Clostridium glycolicum, and Clostridum sporogenes were the main species of high-ammonia-producing bacteria (HAB) isolated from the rumen of lactating dairy cows, dry cows, and young heifers. Other HAB species

as Acidaminococcus fermentans and Actinobacillus succinogenes were also isolated from late lactating dairy and dry cows, respectively. We were also able to observe with electronic microscopy rumen bacteriophages compatible with Myoviridae, Siphoviridae, or Podoviridae bacteriophages families. However, when they were cultivated with isolated HAB, any bacteriophages were able to infect none of the HAB isolated. An in vitro assay incubating rumen liquid with or without (control) a concentrate of rumen bacteriophages was performed to assess bacteriophages efficiency in reducing ammonia production. In this case, neither a decrease of ammonia production was observed when bacteriophages were added.

PA83. How the carbon footprint of dairy farms can change with a biogas plant.

Biogas plants, which use only slurry and cattle manure, reduce greenhouse gas emissions (methane and nitrous oxide) thanks to the emissions avoided during the slurry storage. Anaerobic digestion reduces GHG by 58%, expressed as kgCO2-eq, compared to the cattle slurry. If solid-liquid separation is combined with anaerobic digestion, emissions from the fractions of the digestate are reduced by 71% compared to the raw cattle slurry.
The digestate, however, due to the ammonia nitrogen content, the higher pH than the slurry and the lower ability to form the surface crust, is subject to greater losses of ammonia into the atmosphere than the raw slurry (+ 94%). For this reason, ammonia emission mitigation techniques must be applied such as: storage coverage and the best innovative spreading techniques for digestate (i.e. band application or shallow injection).
The carbon footprint of 1 kg of milk for two farms involved in the Digestato&Emissioni OG under EIP-AGRI, dropped from 1.3 to 1.1 kgCO2-eq/kg of milk and from 1.1 to 0.9 kgCO2-eq/kg. Anaerobic digestion has reduced the carbon footprint of milk by about 20%.
It is a significant result if we take into account that most of the measures to mitigate greenhouse gas emissions are able to reduce the impact by a few percentage points. In addition, the electricity produced by biogas plants has a positive impact: it allows to account for credits rather than carbon debts.

PA84. Acidification during manure solar drying reduce emissions and improve the fertilizing quality of the dried product.

The acidification of manure and digestates is a common practice in the livestock sector to reduce ammonia and greenhouse gases emissions during manure storage, since at low pH most of the ammonia nitrogen is in the form of dissolved ammonium and not as free ammonia. In the Circular Agronomics project, acidification has been used to reduce emissions during the solar drying of the solid fraction of anaerobically digested manure, as well as of digestate without prior separation, since the drying process requires depositing these products on a large surface and stirring to break the crust and facilitate drying, which in turn facilitates the emission of gases. Acidification has allowed, on the one hand, to reduce ammonia and greenhouse gas emissions during the drying process and, on the other, to obtain a final dried product enriched in nitrogen, with a good fertilizing quality.
The acidified digestate and acidified solid fraction of digestate recovered more nitrogen and ammonia nitrogen than their respective non-acidified products (1.5 – 1.3 times for TN; 14 times for TAN). Ammonia and methane emissions were reduced up to 94% and 72% respectively, compared to the non-acidified ones.

PA85. Scrubbing of Ammonia and Carbon dioxide containing gases.

To recover stripped gases from digestate, such as ammonia and carbon dioxide, they can be absorbed in a scrubber column. Absorption is favoured at lower temperatures, high absolute pressure and low gas-liquid ratio. Additionally, to these physical factors, chemical absorption is favoured at low pH-values for ammonia and high pH-values for carbon dioxide. There are different scrubbing technologies available, such as spray absorption columns, packed columns or bubble columns. In pilot trails recovery rates for ammonia in a neutral solution of 40-60 % where achieved with spray absorption column. While different conditions as pH-value and loading rate where tested, the conclusion was that the retention time of the gas in the spraying phase was to short. Therefore, the column was adapted as packed column, to increase the specific surface and the exchange area between gas and absorption liquid. According to the process engineering design guidelines, a pH of 7 is necessary to achieve a recovery of both gases' ammonia and carbon dioxide towards a sufficient degree. A scrubber liquid temperature of 10 °C and a volumetric gas-liquid ratio of 25 are necessary. Therefore, an ammonia concentration up to 9 % and a low carbon dioxide concentration are achievable. By the use of gypsum and precipitation of carbonate as calcium carbonate, a marketable ammonium sulphate solution can be achieved.

PA86. Overcoming legal barriers for the application of biobased fertilizer products

Using manure as a source of macro and micronutrients in agriculture is a practice that, if sustainably performed, allows crop and livestock production without the depletion of non-renewable sources and without harming the environment. However, manure and by-products application to soil in the EU is strictly regulated (maximum 170 kg N ha−1 year−1 in Nitrate

Vulnerable Zones), considering the environmental risks associated with nitrate diffuse pollution.To overcome all these limitations, the European Parliament and the EU Council approved the new Fertilizing Product Regulation 1009/2019 (entered into effect on 16 July 2022), which opened the access to the EU Single Market for biobased fertilizers. The biobased fertilizers can receive the “CE mark”, making it easier to be commercialized and, consequently, promoting the production. In general, NPK solid organic fertilizers must have a concentration of TN > 1% TS, P_2O_5 > 1% TS, K_2O > 1% TS, NPK > 4% TS, and TOC > 15% TS. For a solid organic fertilizer declaring only a primary nutrient, the required concentrations are TN > 2.5% TS, or P_2O_5 > 2% TS, or K_2O > 2% TS.Besides, the possible application of the RENURE (REcovered Nitrogen from manURE) criteria (ratio Nmineral/Ntotal > 90%, or ratio total organic carbon/Ntotal ≤ 3; copper and zinc concentrations must be < 300 and < 800 mg/kg, respectively), defined by the Joint Research Centre, aims to diminish the legal limitations on the application of livestock manure in agriculture. Complying with this criteria, application of manure-based fertilizers in nitrate-vulnerable areas could be less restrictive and the production and use of bio-based fertilizers would be promoted.

PA87. Maximum admissible dose of acid whey for growth of plants.

Maximum admissible dosage of acid whey for plant growth is important for determination of proper nutrient management with acid whey application for field. Flower-pot tests with lettuce (Lactuca sativa) were performed during 2021 with 6 kg of soil per every flower-pot and one lettuce plant per every flower-pot. Thickened acid whey (TSS=18%) has been added into ten flower-pots up to 3 g N/pot with step 300 mg N/flower-pot at the start of the test once lettuce was ensconced. Flower-pots were protected against beetles and insects by construction from non-woven textile and plants have been regularly watered if no rain occurred. Lettuce was harvested after ten weeks and weighted. We could observe linear dependency on the biomass growth with addition of acid whey. Maximum possible dose of acid whey for lettuce (Lactuca sativa) has been tested in 2022 for possible replication to the field. We used the same condition as in 2021, only dosage of thickened acid whey (TSS=18%) has been increased up to 6 g N/pot (step of acid whey addition was 500 mg N/flower-pot). Lettuce was harvested after ten weeks and weighted. We performed tests about the maximum admissible addition of acid whey also in period 2021 with cabbage and lettuce. Those tests aimed to find approximate levels of whey addition. Results shown that it can be ranged somewhere between 2.5 – 3 g N/flowerpot. Results from 2022 showed that first estimation were very close since all lettuce with higher concentration than 2.5 g N/flowerpot was dead. Results should give information to farmers of maximum dosage of acid whey for plants at the agricultural fields.

PA88. Extraction of lactoferrin from acid whey.

Lactoferrin is part of acid whey. It is a multifunctional protein with a molecular mass of about 80 kDa and one of the components of the immune system of the body that is widely represented in various secretory fluids, such as milk, saliva, tears. Apart from its main biological function, namely binding and transport of iron ions, lactoferrin also has antibacterial, antiviral, antiparasitic, catalytic, anti-cancer, and anti-allergic functions and properties.

We used treatment train of membrane technologies for lactoferrin pre-treatment and thickening in the solution to produce a purified product applicable in the pharmaceutical and food-processing industries. Membrane technologies – microfiltration, ultrafiltration and reverse osmosis have been used in a technological train after sorption initial treatment process that has been performed at external facility. The overall technological process is recently under optimization, but first results show very promising outputs – lactoferrin has been concentrated up to 6% with high purity of the final product. It can be very promising valorisation of acid whey into pharmaceutical industry after technology is scaled up.

PA89. Acid whey effect on maize production.

Acid whey effect on maize production has been tested in two years period. We used 20 testing plots of area 10 x 3 m in 2021 in four replications. Dosage of thickened acid whey (TSS = 18%) was as follows (0, 30, 70, 110, 150 kg N/ha, respectively). Field was prepared and maize seeds (Type DEKALB: 31377) were manually seeded in four rows per one testing plot with distance 75 centimeters per row and 16 cm of distance in row between two seeds. Plants were treated by herbicide (Laudis) with dosage 2.25 L/ha. Acid whey was added manually (Day 46) by watering pots. Maize was harvested (Day 178) by combine harvester. We used 24 testing plots of area 10 x 3 m in 2022 in eight replications. Dosage of thickened acid whey (TSS = 18%) was as follows (0, 80, 160 kg N/ha, respectively). Field was prepared and maize seeds (Type DEKALB: 31377) were seeded by combine seeder in four rows per one testing plot with distance 75 centimeters per row and 16 cm of distance in row between two seeds. Plants were treated by herbicide (Laudis) with dosage 2.25 L/ha. Acid whey was added manually (Day 52) by watering pots. We added tap water to all testing plots to keep balance of liquid added per plot. Maize was harvested (Day 148) by combine harvester. We could see linear increase of maize yield in both normal 2021 and very sunny summer 2022 with acid whey addition, starting mainly from 70, 80 kg N/ha. Farmers should use thus higher dosage of acid whey to receive higher yield and harvest.

PA90. Soil nitrogen transformations after acid whey addition.

The application of organic and inorganic fertilizers with elevated nitrogen content to soil may create an environment where carbon is the limiting nutrient. In such an environment, microbial nitrogen use efficiency will be reduced, and microbial decomposers will begin to release increasing amounts of ammoniacal nitrogen. Released mineral nitrogen implies reduced input use efficiency and can pose a potential problem for soil and water quality. Therefore, one of the bases for assessing the sustainability of agricultural systems and farming techniques should be data describing the conversion, transformation, and distribution of nitrogen in the soil. The mineral nitrogen will be captured from the eluate using ion exchange grains placed in special discs made of PVC ring. The ion exchange resin discs has been applied to the experimental plots in the soil at a depth of 25 cm on Day 35 in a total of 24 units (4 replications, 6 variants). Discs has been removed from the soil and subjected to laboratory evaluation prior to harvest (Day 146). No significant differences were observed. Therefore, results of our method did not refute null hypothesis. Whey application did not significantly influence the amount of nitrogen leaking to a subsoil within any treatment. However, it is important to state that capacity of cultivated soil to bind mineral nitrogen is very dependent on local conditions.

PA91. New scaling proof anaerobic reactor design.

There is a possibility for struvite formation in soybean processing without addition of reagents. This is exceptionally possible in this sector, as there is an excess of magnesium versus phosphate. Under the right conditions of pH and in the presence of NH4-N, spontaneous struvite formation is then possible. In practice, however, there is also a high risk of the occurrence of severe scaling due to unwanted struvite formation resulting in pipe and pump blockages. This can result in complete process shut-down and high operating costs. To prevent this, a modified reactor was developed in which the pH can be kept sufficiently low at the critical reactor locations (pumps and pipework) by combining the acidic influent flow and the high risk anaerobically treated wastewater. It is also necessary to operate the anaerobic treatment at sub-optimal pH conditions (6.7-7.0) to further avoid the risk of clogging. It is also possible to construct certain critical segments of piping in high-quality plastic materials such as PVDF and to be carefully in designing the locations where turbulences occurs (linked to pH rise and uncontrolled struvite formation). Also installing for example long bends (instead of 90°) and easy-to-disassemble flanged pipe sections are needed. Even then it will therefore still be necessary to strictly monitor the pipe head losses via, for example, pressure measurements and/or power consumption of pumps. As a general conclusion, it can be said that struvite formation without reagents is a very interesting option but poses a number of challenges to control it properly and avoid negative consequences. Well thought-out engineering is crucial here and the Circular Agronomics project has been able to formulate clear engineering guidelines.

PA92. Increasing Biomethane Potential via Ammonia-Recovery.

The conditions for stripping/degasification of ammonia from digestates or manure are with high temperature (50-70°C) and high pH (9-10) similar to the conditions of thermal alkaline hydrolysis. Latter process is used to increase the biomethane potential from hardly degradable organic substances. Temperature and the alkaline conditions are able to destruct hardly degradable lipids and proteins towards lower molecule hydrocarbons which can be digested under anaerobic conditions. Also, low pressure conditions and the contact of steam with the substrate shows a sever effect on the digestibility. The influence was analysed in six test series based on variations of the degassing operating parameters temperature, stripping gas flow, pH value and absolute pressure. An increase in methane potential due to ammonia degassing was demonstrated. The highest methane excess yield of 15 Norm Litres per Kilogram organic dry matter was recorded at the operating parameter setting of 65 °C, 3 mL 50 % NaOH addition, 500 mbar operating absolute pressure, and a stripping gas flow rate of 5 cubic meters per hour with a volumetric gas to liquid ratio of approximately 33. This corresponded to a relative methane yield increase of 44 % compared to the methane yield of digestate. The parameter variation also provides a good composition for ammonium elimination and, accordingly, represents a good condition for combining the two processes. Thus, it is assumed that the increased electricity demand of the ammonia degassing plant can be compensated by the increased methane yield.

PA93. Heat management in degasification columns.

To recovery Ammonia from digestate or manure, a sufficient temperature of approximately 50-70 °C is needed to achieve a sufficient ammonia recovery with a reasonable column size under consideration of other operational parameters, such as pH value, absolute pressure and volumetric gas-liquid ratio. The temperature increase from e.g. mesophilic or ambient conditions up to 70 °C is can be quite energy intensive, especially when no excess heat is available. However also a temperature decrease (heat recovery) after the treatment towards ambient conditions or the conditions needed is advisable. As a matter of fact, low pressure conditions, the high temperature and the gas flow with dry air have the result, that the temperature decreases at the column bottom. A certain quantity of water is removed with the dry air as steam, according to the present equilibria. The energy, necessary for evaporation of water as steam is equal to the energy present in temperature reduction of the substrate. The steam is transported by air throughout the column until it enters the column head, where the cold substrate enters the column and thereby condensates due to the contact with the cold substrate. To reach a temperature increase and decrease of 55 K (from 15 °C to 70 °C and back) approximately 10 % of the water needs to be evaporated and re-condensed as steam. This effect is realised e.g. by for 70 °C for an absolute pressure of 900 mbar and a volumetric gas-liquid-ratio of 250.

PA94. Immediate harrowing during liquid ammonium fertilizers application reduces ammonia emissions.

From digestate treatment ammonia-containing fertilizers with N concentrations up to 10% or even more may be available. They are valuable but some of them have a high pH and relevant ammonia emissions may occur after field application, especially when the material is broadcastly applied and temperatures are high. Under such circumstances, nitrogen losses may be as high as 80%. As a result, the economic value of the fertilizer is reduced dramatically and the environment suffers from diffuse nitrogen emissions. An immediate incorporation of the fertilizer into the soil or an injection with injection hoses are useful to reduce ammonia emissions. Injection hoses and respective technology is rather expensive. In addition, it requires strong machines to fertilize an economical interesting width. For a cost-efficient use, it is recommended to install a harrow right behind the outlet of the liquid fertilizer. Harrows with a length of about 5 cm are sufficient to incorporate the fertilizer. The harrows should have the same working width as the system to apply the fertilizer on the soil. This incorporation technology reduces ammonia emissions and avoids anaerobic zones in the soil that may lead to unwanted nitrous oxide emissions.

PA95. Using gypsum as reactant to produce ammonium sulphate and limestone from scrubbing liquid.

Normally in ammonia scrubbers, sulfuric acid is used to absorb ammonia and produce di ammonium sulphate solution. When carbon dioxide is additionally stripped to ammonia, the carbon dioxide is not absorbed in the scrubber due to the acidic environment in the scrubber. Adsorbing ammonia and carbon dioxide in scrubber water without sulfuric acid, suffers from sub-optimal conditions for ammonia absorption. The scrubbing liquid ammonium hydrogen carbonate or ammonium carbonate is also not prominent in use as a fertiliser, nor legally allowed. However, the scrubbing liquid containing ammonium and carbonates with a pH value around pH 8-9, can transformed into di ammonium sulphate solution and limestone by the use of gypsum. Due to the slight alkaline conditions' limestone is preferred over gypsum and is precipitated and removes the carbonate from solution. Therefore, sulphate from gypsum is solubilised and forms di ammonium sulphate solution. The reaction had been described under lab environment with ammonium hydrogen carbonate or ammonium carbonate under saturated conditions. Gypsum was added and the pH drops immediately towards pH 7. After 1 minute of mixing, sulphate recovery rates of 80-90 % into the liquor solution had been achieved. Residual carbonate degases in form of carbon dioxide from the process. To continuously run the process, the reaction needs to be validated in an di ammonium sulphate solution with a low share of ammonium hydrogen carbonate or ammonium carbonate. Also, the technical implementation needs to be researched in the future. The process has the possibility, to use an easy to handle chemical (gypsum) in contrast to dangerous sulfuric acid and is able to capture biogenic carbon dioxide in form of limestone.

PA96. Construction of a container plant for nitrogen recovery from organic agricultural residues using vacuum

The idea of nitrogen recovery from organic agricultural residues is based on a process for vacuum degassing of digested sludge in a sewage treatment plant. This process is used there to remove methane and carbon dioxide from the digested sludge. Based on this process, a container system consisting essentially of:

- substrate acceptance,
- warming,
- dosing of chemicals
- stripping,
- scrubber and
- vacuum station

designed and built. The system was set up on the IASP site in Berge, near Berlin, so that the field tests could be carried out there. The system was modularly structured from the start so that different variants could be tested. After the construction of the plant, it was put into operation by the Berlin Water Competence Center (KWB) and various tests were carried out with various liquid manure residues. The associated results are published in the KWB report. The initial constellation with cascade stripping has proven in extensive tests to be not as efficient and technically feasible. The plant was therefore rebuilt and adapted several times in order to increase efficiency. Appropriate tests were run for the respective constellations.

The tests have reached an intermediate stage. Further investigations should be carried out to further optimize the tests and results from the KWB.

PA97. EU consumers' purchase intention and willingness to pay for circular beef.

Sustainable food production systems, such as circular farming, have been developed to recover nutrients and minimize negative environmental effects. Consumers´ circular products acceptance stimulates producers to introduce circular innovations in their farms away from organic certification schemes, helping to recover nutrients and mitigate greenhouse gas emissions (GHG). Using discrete choice experiment (DCE) and the random parameter logit model (RPL), consumer's purchase intention and willingness to pay (WTP) for circular beef in 5 EU countries (Germany, Netherlands, Italy, Czech Republic and Spain) were estimated within the Theory of Planned behavior (TPB). Data were obtained from 5246 consumers within 18 or more years old range stratified in terms of age and gender. Results showed that preferences for beef obtained by a circular farming system are higher than conventional but still lower than organic perceived benefits. Consumers are willing to pay a premium for circular beef but still give importance to the local origin of the meat. Preferences were heterogeneous according to subjective norms, attitudes, and perceived control constructs and the country analyzed. Social norms affect positively circular and organic beef preference in Italy and Netherlands. Environmental attitude reduced conventional beef preference except for Czech consumers, and increase organic beef interest in Germany, Netherlands, and Spain.

PA98. Environmental assessment of Austrian dairy farms with closed production cycles.

Case Study 3 investigated the environmental impacts of 20 organic dairy farms from the Lungau region of Salzburg, Austria. The farms were participants in the pilot project "Pure Lungau," which aimed to produce high-quality dairy products and close production and nutrient cycles within the project region. The environmental impacts of the Lungau farms were modeled using a life cycle assessment and related to two functional units (FU) (1 kg of milk and 1 ha of agricultural land). Subsequently, the environmental impacts were compared with those of a representative model farm, which was created from statistical data and average production values. The results show that the Lungau farms have a significantly lower eutrophication potential per kg milk and per ha compared to the model farm. Furthermore, the exergy demand per ha was lower by about a quarter, which can be attributed to a lower resource consumption due to the lower production intensity of the Lungau farms. In terms of global warming potential, the Lungau farms perform better when 1 ha is used as the FU, while the model farm appears advantageous when 1 kg of milk is used as the FU. However, due to the high variation of the purchased roughage and the lower production intensity, the Lungau farms cause a higher ecotoxicity potential (independent of the FU).

PA99. CIRCULAR AGRONOMICS Policy Note – Towards a circular EU agri-food system

The policy note has been developed to propose policy recommendations to achieve the Farm to Fork's objectives by 2030: 50% reduction in nutrient losses and 20% reduction in the use of fertiliser. Furthermore, it disseminates the projects results to relevant policy makers. The farmer willingness to adopt the innovations and the understanding of consumer preferences were key factors to develop these recommendations. The biggest challenges for farmers to implement technologies are economic. According to the consumer survey (> 5000 participants), the willingness to pay for specific products depends significantly on the variations of the country, the production system and the origin.

Three main recommendations are proposed based on the Circular Agronomics findings. First, EU support through the Common Agricultural Policy (CAP) to invest in emission mitigation practices and adoption of technologies. Second, strengthen the processes of dissemination of innovations and capacity building for farmers. Third, rising awareness for the value of food and establish sustainable consumer choices based on transparent product labelling. Circular economy, high nutrient efficiency and emission mitigation in agriculture aim to improve the agri-food chain at the start. Sustainable behaviour and responsible diets of consumers without wasting food target at the end of agri-food chain. Both ensures food security and environmental health on a long term.

PA100. Concept studies to exploit technologies to real market conditions.

Five technologies, namely solar drying, microfiltration, vacuum degasification, K struvite recovery and membrane treatment had been transferred to a potential replication site and been evaluated under these large-scale conditions. Thereby the specific site conditions, the integration of technology into the site, a cost estimation, a forecast on emissions, legal aspects to be considered and finally some conclusions on roll-out and/or further technology development had been included. To date the technologies reached TRL 6 or 7 and are applied to solid or liquid fraction of agricultural digestate or wastewater and waste streams from food industry. The scale of installations varies from concept studies for a capacity less than 1 m^3/h towards 15 m^3/h resulting in different cost profiles. In general, technologies recovering mineral products such as vacuum degasification and K struvite recovery are able to be neutral in terms of emissions, depending on their exact implementation and operation mode. The consumption of chemicals as caustics and acids is very relevant, especially if systems with a big buffer capacity are present. Secondly the use of energy (especially thermal energy) and their recovery is crucial for the environmental friendliness. The economy of scale is of major importance for a cost-efficient technology implementation. Depending on the technology and concept study (scale and boundary conditions), the capital costs are up to 80 % of the total costs, which may be a major barrier for an investor. Also, the regional boundary conditions are decisive for the cost effectiveness of such systems.