Nutri2Cycle

D.3.2 Priority shortlist of 12-16 innovations selected for upscaling, demo and further investigation

Deliverable:	Priority shortlist of 12-16 innovations selected for upscaling, demo and further investigation
Author(s):	SM. Ashekuzzaman, P. Forrestal (TEAGASC), E. Michels, E. Meers (UGENT)
	Editors: Ç. Akyol., E. Meers (UGENT)
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Co-ordinator:	Prof. Erik Meers, Ghent University
Contact details:	Erik.meers@ugent.be

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Abbreviations

CBA: Cost Benefit Analysis

CNP: Carbon Nitrogen Phosphorus

LCA: Life Cycle Analysis

LL: Longlist solution, as inventarised in D.2.1.

OC: Organic Carbon

OG: Operational Group

RL: Research Line – in total there are 5 Research Lines

SRL: Subresearch Line, as inventarised in D.2.2. – in total there are 24 SRLs under the 5 main research lines

TRL: Technology Readiness Level

WP: Work Package

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Glossary

Agro-typology: Agricultural system as a wider term which emphasizes on the functional attributes which be a single farm or a group of inter-related farms having similarities of agricultural attributes.

Cost benefit analysis: A cost-benefit analysis is the process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project decision to determine whether it makes sense from a business perspective

Innovation funnel: Data sourcing and scrutinizing strategy to evaluate and priotize solutions for their ability and potential to close N, P and C loops and their technological, environmental and economical validity.

Life cycle assessment: Life cycle assessment or LCA is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service.

Operational group: Operational groups are intended to bring together multiple actors such as farmers, researchers, advisers, businesses, environmental groups, consumer interest groups or other NGOs to advance innovation in the agricultural and forestry sectors.

Scalability: The measure of a system's ability to increase or decrease in performance and cost in response to changes in application and system processing demands.

Techology readiness level: Technology readiness levels are a method for estimating the maturity of technologies during the acquisition phase of a program

Venn diagram: A Venn diagram is an illustration that uses circles to show the relationships among things or finite groups of things.

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Executive Summary

The Nutri2Cycle project provides a channeling and funneling strategy in which in at first in D.2.1 we first attracted a broad list of suitable solutions that can optimize N, P and (organic) C cycles in European agriculture. This 'longlist' contained ongoing research from the participating partners as well as information gathered from other parties engaged in relevant research and development. In order to rationalize the workload and provide focus in the work plan of the project, the longlist was reduced to a shortlist (D.2.2) at a dedicated 'boot camp' linked to the European Sustainable Initiative conference. In further internal alignment of research efforts as well as to integrate even greater focus, the short list was further reduced to a priority list (the current Deliverable; D.3.2.).

In this the retained priority solutions are covering the extent of the 5 research lines of the Nutri2cycle project :

- Innovative management systems, tools & practices for optimized nutrient and GHG management in animal husbandry
- Innovative soil, fertilisation & crop management systems & practices for enhanced N,P efficiency and increased soil OC content
- Tools, techniques & systems for higher-precision fertilization
- Biobased fertilisers (N,P), soil enhancers (OC) from agro-residues
    - a. Engineering nutrient recovery processes
    - b. Substituting primary resources by biobased products
- Novel animal feeds produced from agro-residues

This Deliverable provides the priority listing carrying on from the Shortlist of solutions (D.2.2) adding further focus in the broad scope of investigations within the Nutri2Cycle project. The final priority listed solutions resulted from the surveys carried out in WP2 (agro-technical research), WP3 (environmental assessment), and WP6 (upscaling and demonstration activities). The resultant of these three surveys were subsequently processed in a subsequent Venn-diagram exercise discussed with consortium for joint approval at the general assembly of the consortium meeting *de dato* 15/02/2021. The identification of those solutions that will be the subject of further demonstration activities to be carried out in frame of the Lighthouse Demonstration Network in frame of WP6 is also further explained in the current Deliverable.

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Introduction

Nutri2Cycle aims to deliver a logical flow to identify and enable most promising scenarios on nutrient recycling for EU agriculture. In the previous project period, a longlist of innovation solutions was developed in D2.1 from three sources of information as follows: (i) Innovative solutions provided via Operational Groups (OGs), (ii) Innovations proposed by pioneering farmers & agri-businesses and (iii) New (Pilot) solutions (TRL 3-5) acquired from progressive research. In the following deliverable (D2.2), the Nutri2Cycle experts further prioritized these solutions to a manageable and structured set of technical and management solutions for efficient farming systems. An innovation funnel approach aimed at closing nutrient loops and efficient mitigation measures for reducing environmental impacts. Subsequently, the further prioritisation process reported in the current report (D3.2) took place.

In the Nutri2Cycle project a range of solutions for closing CNP cycles in agriculture are investigated as well as demonstrated. The project started with the collection of a longlist of proposed technical and management solutions aimed at closing nutrient loops and the efficient mitigation of losses in EU farming systems. This list of solutions was based on a bottom-up approach where solutions were acquired through partner and stakeholder collaboration, including via EIP-AGRI Operational Groups. In the so called innovation funnel of WP2, a further selection of the solutions has been made to come to a manageable number of solutions that will further be investigated, included in the impact assessment (WP3 and 4) and demonstrated (WP6). This selection process is schematically presented in Figure 1.

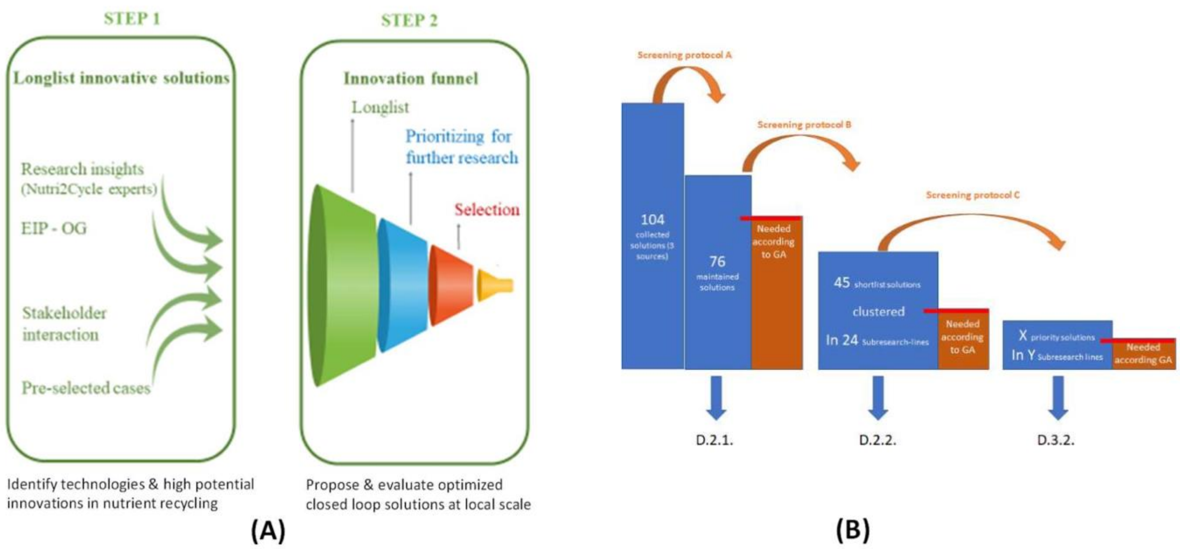

Figure 1. Schematic procedure for selection of the priority solutions in the Nutri2Cycle project: (A) Collection & & Selection process as illustrated the Grant Agreement, (B) Practical link to project Deliverables.

In the current particular deliverable D.3.2, the above-mentioned D.2.2 Shortlist is further scrutinized into a priority list.

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1. Priority selection

1.1. Prioritization protocol

In the Grant Agreement it is stated that from the Shortlist, at least 12 solutions will be prioritized for demonstration purposes (WP6) and detailed impact assessment (WP3), including Life Cycle Assessment (LCA), Social LCA and Cost Benefit Analysis (CBA).

This selection is based on Screening protocol C using a Venn diagram approach, in which solutions were scored across three dimensions:

C1. Potential availability of background information & documentation related to environmental analysis (in order to be able to conduct reliable LCAs),

C2. Sufficient agrotechnical expertise, competence, and research capacity on the solutions within the Nutr2Cycle consortium,

C3. Potential for scalability and demonstration of proposed solution within the project duration.

The approach positioned all investigations from the Shortlist and placed them on a Venn-diagram and solutions which scored positively in all three dimensions are placed in the centre of the Venn diagram, those that score positive according to two dimensions are placed in between both of them and those that only score for one dimension are only placed in the appropriate part of the Venn-diagram.

The three sets of criteria C1-C3 are that data needs to be available (or be made available) on which to assess environmental impact, it makes little sense to prioritize on solutions for which there is no or limited expertise and capacity within the consortium and the solutions need to be scalable with access to potential infrastructure (either at farms or at institutes involved).

For each of the three dimensions, a dedicated survey & analysis were therefore performed:

For **dimension C1**, a "traffic light" study was carried out by UCPH in which the feasibility of each shortlisted solution for subsequent environmental modelling and/or LCA analysis was scored using a green-orange-red light system indicating positive (green), negative (red), or expected problems/limitations (orange). Each shortlisted solution was reviewed by Daisy, SWAP-ANIMO, and MITERRA-Farm modellers to assess its feasibility to be simulated by each model. The assessment took into account model capability, assumptions that must be made, Technology Readiness Level (TRL), and potential data availability by M16 (tier 1) and M20 (tier 2). Following that, the solutions were also screened by LCA partners to select their preferred cases for LCA, considering both the scientific merit, and data availability from modelling and technology owners. The selection process also aimed to distribute the selected LCA cases among the 5 research lines as well as partner countries. Finally, the overall feasibility for each shortlisted solution was scored by combining the two assessments.

For **dimension C2**, a survey was carried out by Ghent University in which the consortium was probed for active expertise and capacity – both in human resources (PhD, postdocs, PIs) and research infrastructure to address the solutions.

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For **dimension C3**, a mapping exercise was carried out by Teagasc in which the pilot & demonstration capacity on each of the solutions was evaluated, which combined both 'scalability' of solutions within the project lifetime as well as the infrastructure at hand allowing a TRL-lift within and by the project.

The outcome of the Venn-diagram investigation, converging the three above-mentioned dimensions into one Venn-diagram comparison was presented at the midterm consortium meeting in February 2021. The ensuing discussion that emerged from that analysis resulted in the prioritization, bearing in mind the following criteria:

• Solutions scoring positive in two or three of the Dimensions (C1-2-3) deserve priority based on the alignment between agro-technical capacity, environmental data & infrastructure availability/suitability.

• In the discussion further scrutiny was needed and applied in order to further streamline the number of retained solutions to add focus in the project. The consortium was guided by the following key questions:

1) are all 5 research lines sufficiently represented in the final list of priority solutions?

2) do we expect good accessibility and willingness-to-share economic data so that abovementioned studies can be expanded with the full (required) economic assessment on the final solutions?

3) from which of the solutions do we expect most/least direct impact on advancing the state of knowledge and our ability to validate on closing NPC cycles within the project lifetime?

In addition to the priority listing, at the consortium meeting (15/02/2021) it was confirmed that ongoing investigations and communications which are NOT on the final priority list, themselves do not need to end or be discarded. The priority list implies further scrutiny, prioritization, alignment and focus but Nutri2Cycle will continue to also support the other originally (short-)listed solutions. Nonetheless emphasis for further environmental, agro-technical, economic and social investigation will be placed on the selected priority solutions.

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1.2. Venn diagram exercise

As mentioned above, on the general assembly of the consortium meeting *de dato* 15/02/2021, all solutions from the D.2.2. shortlist were scrutinized further according to the above-mentioned 3 dimension - which were respectively prepared leading up to the partner meeting, based on (i) WP2 surveying (active agro-research & competence, expected agrotechnical potential), (ii) WP3 traffic light approach on data availability & quality, (iii) WP6 surveying towards scalability up to demo scale. A Venn-diagram approach was adopted, mapping all solutions of the Shortlist to subsequently identify the common denominator solutions that scored most positively along these sets of criteria.

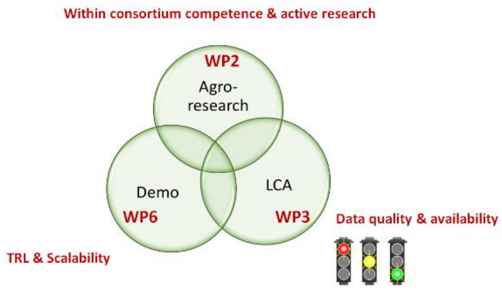

Figure 2. Venndiagram approach

Following the three mapping exercises in frame of the three contributing WPs, the following guidelines were indicated at the start of the prioritization brainstorm:

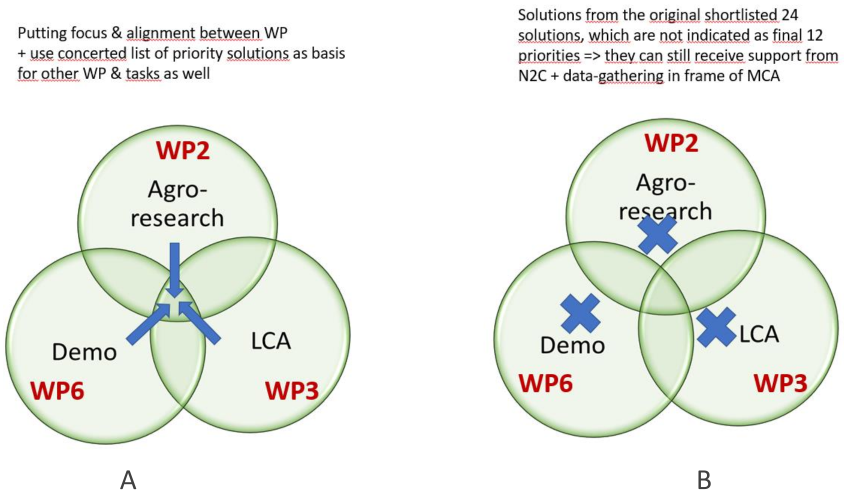

Figure 3. Proposed shortlisted solutions – A. re-align focus in the different WP-activities to maximally bring investigated solution to the center of the Venn-diagram, hence increasing the number of solution receiving active agro-technical research, environmental assessment and testing of scalability; B. continue support for other shortlisted solutions being investigated, but a clear signal to align focus on the prioritized solutions ; this continued support of those solutions that were non-prioritized to avoid that ongoing investigations within the scope of Nutri2cycle would be terminated prematurely by a 'full-stop'.

The preparatory work resulted in the following mapping of the status of the shortlisted solutions (Fig. 4). The LL numbers refer to the code ID as listed in the original D.2.1. Longlist. The colour code refers to the 5 research lines as indicated in the Grant Agreement. The upper circle refers to the outcome of the WP2 survey relating to active agro-research and within-consortium competence & experience; the left circle to the outcome of the WP6 survey relating to TRL, scalability and access to relevant / pilot scale infrastructure ; the right circle refers to the 'traffic light' exercise carried out in WP3 to scrutinize on the access to qualitative data on which basis reliable environmental impact can be carried out.

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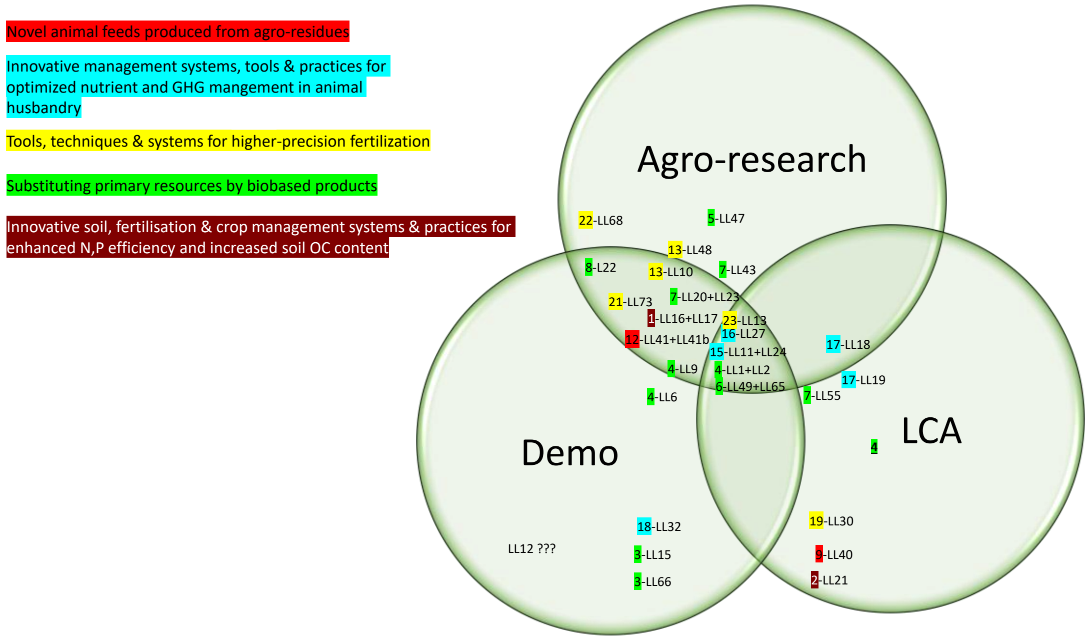
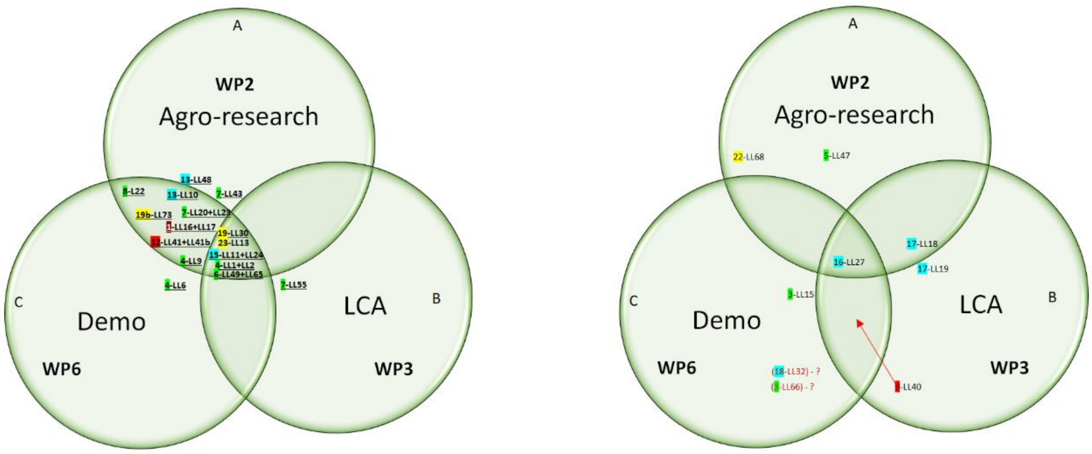


Figure 4. Distribution of the shortlisted solutions under investigation in Nutri2Cycle, using their original LL-code number and colour-coded per each of the 5 research lines.

Following intensive discussion this resulted in the re-alignment and prioritization as indicated in Fig. 5 – with on the left hand the prioritized solutions for further investigation and demonstration within Nutri2cycle and the right hand side those investigations for which the support does not instantly ends but of which it has been signaled that they are not in the core priority solutions being investigated within Nutri2cycle.



Priority list of solutions

Supported Continued research: NON-priority solutions

Figure 5. Allocation of priorities for shortlisted solutions as well as continued supported research that are not indicated as final priorities

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Translating the Venn diagram exercise into a scoring system, the results are given in Table 1.

Table 1. Scored overview of shortlisted solutions.

Research Line	SRL-identifier	LL-identifier	Agro-research (WP2)	Demo (WP6)	LCA (WP3)	Score
Innovative soil, fertilisation & crop management systems & practices for enhanced N, P efficiency and increased OC content	1	LL16+LL17	1	1	0	**2**
	2	LL21	0	0	1	**1**
Subsituting primary resources by biobased products	3	LL15	0	1	0	**1**
	3	LL66	0	1	0	**1**
	4	LL1+LL2	1	1	1	**3**
	4	LL6	0	1	0	**1**
	4	LL9	1	1	0	**2**
	5	LL47	1	0	0	**1**
	6	LL49+LL65	1	1	1	**3**
	7	LL20+LL23	1	1	0	**2**
	7	LL43	1	0	0	**1**
	7	LL55	0	0	1	**1**
	8	LL22	1	1	0	**2**
Novel animal feeds produced from agroresidues	9	LL40	0	0	1	**1**
	12	LL41+LL41b	1	1	0	**2**
Innovative management systems, tools & practices for optimized nutrient and GHG management in animal husbandry	13	LL48	1	0	0	**1**
	13	LL10	1	1	0	**2**
	15	LL11+LL24	1	1	1	**3**
	16	LL27	1	1	1	**3**
	17	LL18	1	0	1	**2**
Tools, techniques & systems for higher precision fertilization	17	LL19	0	0	1	**1**
	18	LL32	0	1	0	**1**
	19	LL30	0	0	1	**1**
	21	LL73	1	1	0	**2**
	22	LL68	1	0	0	**1**
	23	LL13	1	1	1	**3**

Following this exercise, all solutions were discussed at length in the consortium meeting d.d. 15/02/2021. In this discussion, solutions receiving scores of 2-3 had preference above the ones with only a score of 1. With one exception, being SRL16-LL27 "Use of an inoculate of microbiota and enzymatic pre-cursors to reduce ammonia emissions and optimize nutrient use efficiency in poultry manure". This solution demonstrates promising results, but was in itself (based on results so far) not strong enough to be put forward as one out of 12 priorities for the EU-27 at this stage. The reason

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why the solution was not finally chosen as a priority was because we have had problems developing the tests with the farms where the tests were going to be performed due to the associated COVID restrictions, so some tests are being performed at a lower TRL and not as much information would be available to perform a full LCA. In order to compensate for not taking on this solution amongst the final 12 priorities, we have made a review of this topic (open access paper). Please find the paper at the following link: https://link.springer.com/article/10.1007/s13399-022-02428-x

In addition, in order to defragment research efforts and better align closely related investigations, several solutions were merged together when drafting the final priorities.

1.3. Concluding selection priority list

The overview below represents the concluding priority list of solutions that were withheld following the abovementioned consortium meeting (Table 2). These solutions are grouped per 5 Research Lines, the prioritized Subresearch lines (SRL) and the Longlist solution (= individual studies) number. In addition, responsible partners are indicated.

Table 2. Concluding priority listed solutions resulting from the surveys carried out in WP2, WP3, WP6 – the subsequent Venn-diagram exercise and the consortium meeting (15/02/2021).

Research Line	SRL-N° (subresearch lines)	Long List (LL) identifier (< D.2.1.)	Sub-research Line (Shortlist Title) (< D2.2.)
1	13	10 ; 48	Anaerobic digestion strategies for optimized nutrient and energy recovery from animal manure
	15	24	Organic matter recovery from manure and associated valorisation strategies
2	1	16 ; 17	Practices for increasing soil organic matter content
3	19 & 21 merged	13 ; 30 ; 73	Precision farming coping with heterogeneous qualities of organic fertilizers in the whole chain
4	4	1 ; 2 ; 6 ; 9 ; 55	Substituting external mineral nutrient input from synthetic fertilisers by recycled organic based fertilizers in arable farming
	6	49 ; 65	P recovery from organic waste(water) streams via struvite crystalization
	7	20 ; 23 ; 43	Pig manure processing and replacing mineral fertilizers
	8	22	P recovery from animal bones
5	12	41 ; 41b	Floating wetland or algae plants grown on liquid agro-residues as a new source of proteins

2. Selection of Lighthouse demos from priority solutions

Following the abovementioned prioritization within Nutri2cycle, specific solutions were selected for organizing further cale-up and demo activities, making use of the criteria in Table 3.

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Table 3. Lighthouse demo selection criteria.

Criteria	Description
Active research	Demonstration protocol needs research component (field/pilot/operational scale trial set-up) and research in-progress in the frame of Nutri2Cycle.
Evidence of results	Technical activity and measurement of parameters are needed for the demonstration and communication to stakeholders. This involves with data availability, quality and competence to benchmark impact on closing CNP loops.
Scalability and regional distribution	The demonstration activity should upscale operational/market readiness (i.e. Technology readiness level (TRL)) and transnational applicability of selected solutions.
Agro-typology	The selected solutions should have demonstration capacity in the frame of Nutri2Cycle associated 8 agro-typologies (pig, poultry, cattle, cereals and maize, vegetables, orchards, agro-energy, and byproduct processing) under crop, animal and processing pillars.

The selected lighthouse demonstration activity solutions represent two solutions from research line (RL) 1, 2, 3 and 5, respectively, and five solutions from RL-4 (Fig. 6, Table 3). Based on the investigation type and capacity, each of the selected demo's is connected to at least one or more of the 8 agro-typologies (e.g. pig (5), poultry (1), cattle (2), cereals and maize (5), vegetables (3), orchards (1), agro-energy (2), and byproduct processing (12)) (Fig. 7(a)). All listed demo titles are well balanced across 8 agro-typologies covering three major pillars of Livestock (26%), Crop (29%) and Agro-processing (45%) (Fig. 7(b)). Lighthouse demos are distributed across seven partner countries (Belgium, Spain, Netherlands, Hungary, Italy, Ireland, and France) involving 10 partners.

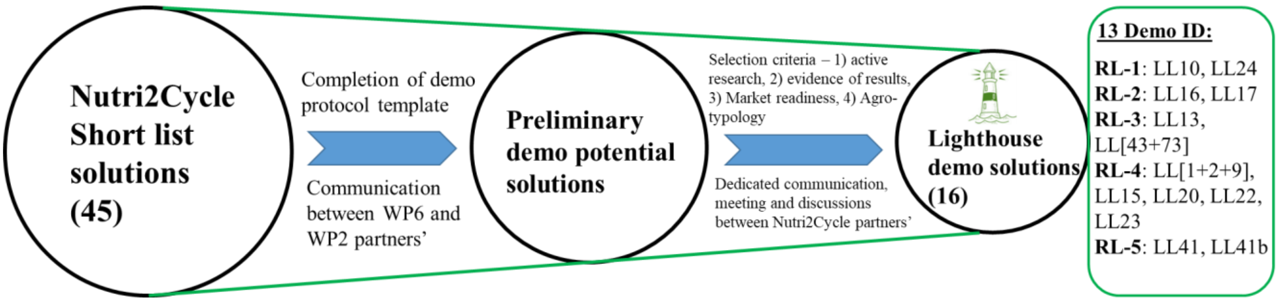

Figure 6. Illustration of Nutri2Cycle lighthouse demo selection. Selected demos are grouped into five research lines (RL) as per long list (LL) solution number within Nutri2Cycle WP2.

More information on investigated solution, link to research-line, link to agro-typology, TRL, partner country and PP as well as remarks concerning (non)selection are indicated in Table 4.

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Table 4. Selection for scale up into lighthouse demonstration.

Research Line (RL), Demo ID and Title	TRL	Agro-typology (Pillar)	Partner, Country	Remarks on demo selection
RL-1. LL10: Farm-scale anaerobic digestion of agro-residues/pig manure to increase local nutrient cycling & improve nutrient use efficiency	7 - 9	Agro-energy, Manure processing (Processing)	Inagro+Ghent, Belgium	Selected as lighthouse demo
RL-1. LL24: Adapted stable construction for separated collection of solid manure and urine in pig housing (followed by separate post-processing)	9	Pig, Manure processing (Livestock + Processing)	Ughent+Inagro Belgium	Selected as lighthouse demo because this solution can be developed as demo, evidence of farmers using this kind of infrastructure in Belgium.
RL-1. LL32: Annual Nutrient Cycling Assessment (ANCA)	8 - 9	Cattle farming (Livestock)	ZLTO, The Netherlands	Not lighthouse demo due to research component is not active.
RL-1. LL27: Use of an inoculate of microbiota and enzymatic pre-cursors to reduce ammonia emissions and optimize nutrient use efficiency in poultry	6<	Poultry (Livestock)	CARTIF, Spain	Not lighthouse demo, currently evidence is low for demo activity.
RL-1. LL11:Monitoring the best manure management practices in cattle farms, focusing on the use of recycled solid manure and digestate for bedding	6	Animal byproduct processing (Processing)	SOLTUB, Hungary	Not meeting Nutri2Cycle scope, this solution provides replacement for straw as bedding material, but not targetting nutrient recycling. Also, regulations in some EU countries do not allow this recycled solid manure to be used as bedding material.
RL-2. LL16: Using digestate, precision agriculture and no-tillage focusing on OM stocking in an area characterized by the lack of it.	9	Byproduct processing, Cereals & Maize (Processing + Crop)	UMIL, Italy	Selected as lighthouse demo
RL-2. LL17:Crop farmer using a variety of manure and dairy processing residues to recycle and build soil C, N, P fertility	6	Byproduct processing, Cereals & Maize, Cattle farming (Processing + Crop + Livestock)	Teagasc, Ireland	Selected as lighthouse demo
RL-3. LL13: Comparision of different precision technologies used in plant cropping system, having in focus the sensor technologies	6	Crop - cereals & maize, vegetables (Crop)	SOLTUB, Hungary	Selected as lighthouse demo. This demo has potential to be aligned with other precision demo in Germany, Belgium and The Netherlands.
RL-3. LL[43+73]: Trial potato growing with refined pig manure fractions	5 - 6	Pig, Manure processing, Vegetables (Processing + Crop + Livestock)	ZLTO, WUR, The Netherlands, UGhent, Belgium	Selected as lighthouse demo. This demo is a cross over of solutions from RL-3 (LL73) and RL-4 (LL43).
RL-4. LL[1+2+9]: Field trial on maize (2019), spinach (2020) and potatoes (2021) with recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry	7 - 9	Pig, Cereals & Maize, Vegetables, Manure processing (Processing + Crop + Livestock)	Inagro / Ghent University, Belgium	Selected as lighthouse demo. This demo is based on three longlist solutions combined (LL1+2+9).
RL-4. LL23: Pig manure refinery into energy (biogas) and fertiliser using a combination of techniques applicable at industrial pig farms	9	Pig, Agro-energy, Manure processing	UMIL, Italy	Selected as lighthouse demo
RL-4. LL20: Low temperature ammonium-stripping using vacuum	4	Pig, Manure processing (Livestock + Processing)	IRTA, Spain	Selected as lighthouse demo
RL-4. LL22: Formulated Bio-Phosphate trials for two comparative plants, elder and wheat	8 - 9	Animal byproduct processing, Cereals & Maize (Processing + Crop)	3R-BioPhosphate Ltd., Hungary	Selected as lighthouse demo
RL-4. LL15: The substitution of the mineral fertilizers with the biological fertilizers to optimize the organic carbon storage in soil and the NP cycling : two application cases in France.	6 - 7	Orchards & agroforestry, Organic (Processing + Crop)	CA17 - Chamber of agriculture of Charente-Maritime, France	Selected as lighthouse demo
RL-4. LL66: Application of digestate in large scale orchards	8 - 9	Orchards & agroforestry, agro-energy (Crop)	IPS, Croatia	Not active research and no trial started during lighthouse demo selection process.

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Table 4. (Continued) Selection for scale up into lighthouse demonstration.

Research Line (RL), Demo ID and Title	TRL	Agro-typology (Pillar)	Partner, Country	Remarks on demo selection
RL-4. LL6: The agronomic value of concentrate from evaporation as a nutrient-rich organic fertilizer in field cultivation of maize	4	Cereals & Maize (Crop)	Ugent, Belgium	Not active research.
RL-4. LL49: Nitrogen and phosphorus recovery from pig manure via struvite crystallization and design of struvite based tailor-made fertilizers	6 <	Pig, Manure processing (Livestock + Processing)	CARTIF, Spain	Not suitable for demo; Needs to be proven, TRL is lower than mentioned, not at the stage of demo yet in terms of producing struvite and production capacity. However, there will be product based demo based on work at Teagasc, linking to other replacement nutrient related demo.
RL-5. LL41b: #Algae grown on liquid agro-residues as a new source of proteins	4	byproduct processing, animal feed	Ugent, Belgium	Selected as lighthouse demo
RL-5. LL41: Floating wetland plants grown on liquid agro-residues as a new source of proteins	6	byproduct processing, animal feed (Livestock + Processing)	Ughent+Inagro Belgium	Selected as lighthouse demo

In addition, another solution (LL57) under RL 4 has further been considered to be included as a lighthouse demo due to its capacity for demonstration activity and availability of active and quality research components in the field trial set up. Therefore, a total of 14 lighthouse demo solutions (see Table 5) have been carried forward to meet the objectives of WP6.

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Table 5. Final list of 14 lighthouse demo solutions.

Research Line (RL), Demo ID and Title	TRL	Agro-typology (Pillar)	Partner, Country
RL-1. LL10: Farm-scale anaerobic digestion of agro-residues/pig manure to increase local nutrient cycling & improve nutrient use efficiency	7 - 9	Agro-energy, Manure processing (Processing)	Inagro+Ghent, Belgium
RL-1. LL24: Adapted stable construction for separated collection of solid manure and urine in pig housing (followed by separate post-processing)	9	Pig, Manure processing (Livestock + Processing)	Ughent+Inagro Belgium
RL-2. LL16: Using digestate, precision agriculture and no-tillage focusing on OM stocking in an area characterized by the lack of it.	9	Byproduct processing, Cereals & Maize (Processing + Crop)	UMIL, Italy
RL-2. LL17:Crop farmer using a variety of manure and dairy processing residues to recycle and build soil C, N, P fertility	6	Byproduct processing, Cereals & Maize, Cattle farming (Processing + Crop + Livestock)	Teagasc, Ireland
RL-3. LL13: Comparision of different precision technologies used in plant cropping system, having in focus the sensor technologies	6	Crop - cereals & maize, vegetables (Crop)	SOLTUB, Hungary
RL-3. LL[43+73]: Trial potato growing with refined pig manure fractions	5 - 6	Pig, Manure processing, Vegetables (Processing + Crop + Livestock)	ZLTO, WUR, The Netherlands, UGhent, Belgium
RL-4. LL[1+2+9]: Field trial on maize (2019), spinach (2020) and potatoes (2021) with recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry	7 - 9	Pig, Cereals & Maize, Vegetables, Manure processing (Processing + Crop + Livestock)	Inagro / Ghent University, Belgium
RL-4. LL15: The substitution of the mineral fertilizers with the biological fertilizers to optimize the organic carbon storage in soil and the NP cycling : two application cases in France.	6 - 7	Orchards & agroforestry, Organic (Processing + Crop)	CA17 - Chamber of agriculture of Charente-Maritime, France
RL-4. LL20: Low temperature ammonium-stripping using vacuum	4	Pig, Manure processing (Livestock + Processing)	IRTA, Spain
RL-4. LL22: Formulated Bio-Phosphate trials for two comparative plants, elder and wheat	8 - 9	Animal byproduct processing, Cereals & Maize (Processing + Crop)	3R-BioPhosphate Ltd., Hungary
RL-4. LL23: Pig manure refinery into mineral fertilizers by using a combination of techniques applicable at industrial pig farms	9	Pig, Agro-energy, Manure processing	UMIL, Italy
RL-4. LL57: Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop	9	Pig, Poultry, Cereals & Maize, Cattle farming (Processing + Crop + Livestock)	ISA, Portugal
RL-5. LL41b: #Algae grown on liquid agro-residues as a new source of proteins	4	byproduct processing, animal feed	Ugent, Belgium
RL-5. LL41: Floating wetland plants grown on liquid agro-residues as a new source of proteins	6	byproduct processing, animal feed (Livestock + Processing)	Ughent+Inagro Belgium

The following graphs (Fig. 7) illustrate the spread of the selected demonstration activities and how they are linked to agro-typology, main agro-pillars (crop, animal, processing).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

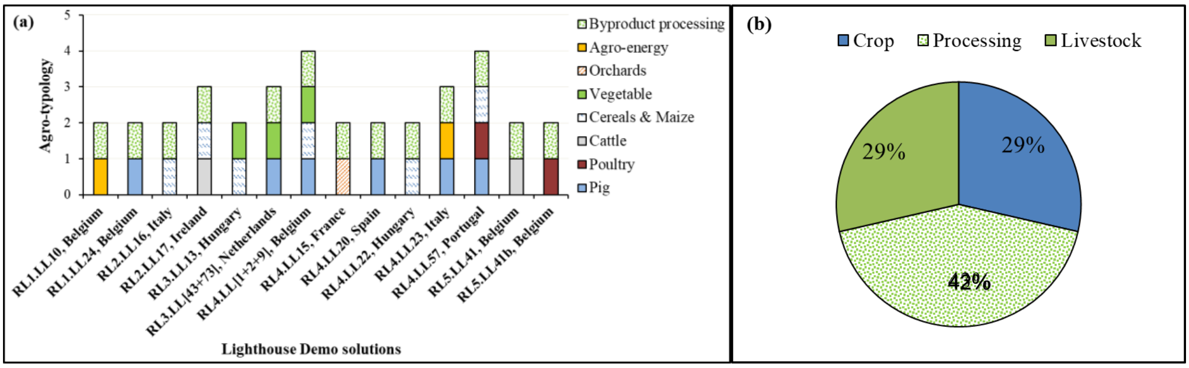
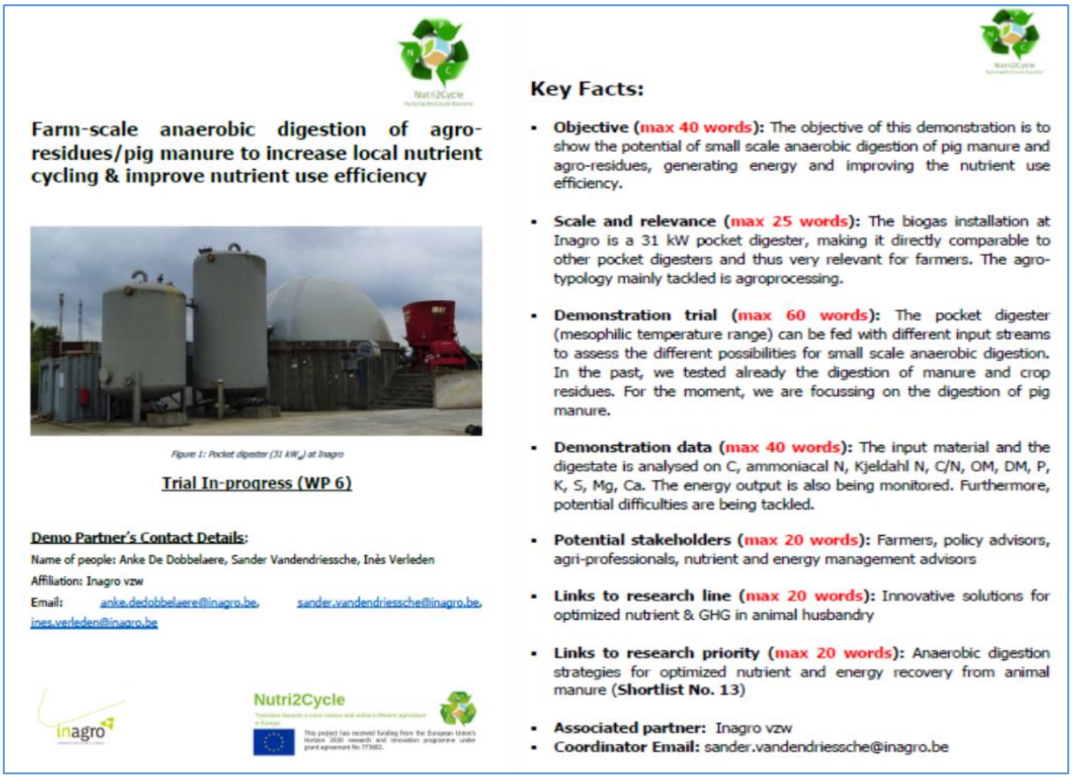


Figure 7. (a) Illustration of Nutri2Cycle lighthouse demo's agro-typologies and (b) Distribution of demo's across three major pillars of livestock, crop and agro-processing.

3. Organization of scale-up and demonstration activities (Lighthouse demos)

At the partner meeting in M12 in Ghent, this was thoroughly discussed and it was decided to develop a demo protocol template. Accordingly, a demonstration protocol template (Figure 8) was developed to capture the objective, scale, intended data collection, and interest of stakeholders in potential demos. This protocol was circulated and completed by interested Nutri2Cycle partners by M16. This was done in close collaboration with WP2.



Farm-scale anaerobic digestion of agro-residues/pig manure to increase local nutrient cycling & improve nutrient use efficiency

Figure 1: Pocket digester (31 kW) at Inagro

Trial In-progress (WP 6)

Demo Partner's Contact Details:

Name of people: Anke De Dobbelaere, Sander Vandendriessche, Inès Verleden

Affiliation: Inagro vzw

Email: anke.dedobbelaere@inagro.be, sander.vandendriessche@inagro.be, ines.verleden@inagro.be

Key Facts:

- **Objective (max 40 words):** The objective of this demonstration is to show the potential of small scale anaerobic digestion of pig manure and agro-residues, generating energy and improving the nutrient use efficiency.
- **Scale and relevance (max 25 words):** The biogas installation at Inagro is a 31 kW pocket digester, making it directly comparable to other pocket digesters and thus very relevant for farmers. The agro-typology mainly tackled is agroprocessing.
- **Demonstration trial (max 60 words):** The pocket digester (mesophilic temperature range) can be fed with different input streams to assess the different possibilities for small scale anaerobic digestion. In the past, we tested already the digestion of manure and crop residues. For the moment, we are focussing on the digestion of pig manure.
- **Demonstration data (max 40 words):** The input material and the digestate is analysed on C, ammoniacal N, Kjeldahl N, C/N, OM, DM, P, K, S, Mg, Ca. The energy output is also being monitored. Furthermore, potential difficulties are being tackled.
- **Potential stakeholders (max 20 words):** Farmers, policy advisors, agri-professionals, nutrient and energy management advisors
- **Links to research line (max 20 words):** Innovative solutions for optimized nutrient & GHG in animal husbandry
- **Links to research priority (max 20 words):** Anaerobic digestion strategies for optimized nutrient and energy recovery from animal manure (**Shortlist No. 13**)
- **Associated partner:** Inagro vzw
- **Coordinator Email:** sander.vandendriessche@inagro.be

Figure 8. Demonstration protocol template with an example of completed version for a potential demo solution LL10 - Farm-scale anaerobic digestion of agro-residues/pig manure to increase local nutrient cycling & improve nutrient use efficiency.

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4. Data acquisition of investigated solutions

In order to further consolidate on data generation and acquisition within the Nutri2Cycle project, an additional report not originally foreseen in the initial work plan, has been added to the work plan (D.2.6.).– In this report, ongoing agro-technical research in the project focuses on collecting and compiling quantified data. In frame of this new report, University of Milano aims at collecting uniformly all data by surveying each Nutri2Cycle partner involved in agro-technical research (WP2) to fill in five tables covering economic, technical, environmental and social dimensions, i.e. provide a minimum data set represented by 40 parameters, to be completed based on feedback received from WP3-WP5. This data set has been set up in close alignment with WP3-WP5 leaders and partners. The data gathering is moderated by the 5 Research Line leaders associated to the agro-technical research. The database will keep track of newly generated results on functional studies followed by their respective RL leaders.

Data collection has been applied to the total 45 (LL) single solution/investigations reported in the Shortlist of suitable solutions (D.2.2), but only for those solution/investigations funded by Nutri2Cycle itself, providing this data was mandatory. This implies that – together with the current prioritization exercise as reported in the current deliverable – more detailed quantified data will be collected and reported for the targeted investigations being carried out in frame of Nutri2cycle.

For the other solutions/investigations not included in the shortlist solution, only technical, environmental data is available as those solutions are not the subject of active investigation with in the Nutri2cycle project.

5. Leverage funding for shortlist and priority solutions under investigation

The Nutri2cycle project has enjoyed access to large European community of front-running entrepreneurs, farmers and farmer organizations as well as a substantial scientific network. In this, the Nutri2Cycle project could also build on past achievements both by consortium members as well as the broad circle of experts and stakeholders around them. This has resulted for example in access to infrastructure suitable for demonstration of solution at relevant scale, together with such external parties. This has allowed the project to develop an extensive Lighthouse Demo Network without the need and necessity to invest heavily in hardware or equipment from the project itself (see D.2.6 for funding details of the investigated solutions). But also in the frame of researched solutions from the short- and priority list, the consortium has been able to make links to other projects as well as individual researchers willing to collaborate within the framework of Nutri2Cycle solutions to be further investigated. This is in addition to the (Joint) PhD network and other junior and senior researchers employed directly by the Nutri2Cycle project. In the upcoming reporting period, an extensive overview of research linked to Nutri2Cycle by direct employment and deployment of researchers within the project will be foreseen as well as an overview of the extensive network and acquired leverage funding of extensive initiatives that contribute towards the Nutri2Cycle objectives and generated impact.

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6. Conclusions

Prioritizing and shortlisting solutions for further research embodied one of the pivot points in Nutri2Cycle. In this Deliverable, each shortlisted innovation investigated in WP2 was further reduced to "priority shortlist" for further in-depth investigation (WP3,4,5) and upscaling (WP6).

More specifically, anaerobic digestion (biogas) innovations related to manure digestion have been selected, as well as strategies that promote the recovery and use of animal manure for soil organic matter build-up. The project also recognizes and acknowledges the need to combine precision farming principles to deal with heterogeneous composition and quality of some organic fertilizers. The project has also identified major leaps can be made in the field of synthetic chemical fertilizers by mineral nutrients recovered from wastewater streams, for example stripping/scrubbing for nitrogen recovery and struvite crystallization for phosphorus recovery. On the topic of nitrogen recovery – Nutri2Cycle is one of the main drivers and advocates in Europe to establish a framework around the so-called RENURE ("recovered nitrogen from manure") type products. On the topic of P recovery, the project also pays due attention for the vast potential of P recovery from animal bones (when processing animal byproducts from slaughterhouse waste). Finally, in the frame of replacing feed protein imports into the European continent in order to feed our domestic animal production the Nutri2cycle project examines and promotes two priorities related to novel sources of protein cultivated on nutrient rich wastewater streams : duckweed and micro-algae.

It is important to also note – that although the priority listing of solutions warranting concerted focus, the consortium also acknowledged that running assessments (e.g. running LCA investigation on insect breeding for novel protein production on agro-residues, to give just one example) on any of the other shortlisted solutions are still supported from the project. That means in practice that although the funneling of solutions from longlist over shortlist to priority list, resulted in a reduced number of solutions to further investigate, ongoing research in the other solutions is not thrown away and escorted to good closure of those activities.

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