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DI MILANO

Nutri2Cycle
Nurturing the Circular Economy

Multicriteria assessment for innovative solutions to nutrient recycling

GRUPPO RICICLA

Università degli Studi di Milano

Supervisor: Professor Fabrizio Adani - DiSAA - Università degli Studi di Milano

Axel Herrera Ph.D. Student – Cycle XXXIV

DiSAA
DIPARTIMENTO
di SCIENZE
AGRARIE e
AMBIENTALI

NUTRI2CYCLE

Suggest changes in farm systems management and/or the introduction of innovative technologies at farm level able to get “solutions” for C, N, P closing loops, including GHG emission reduction.

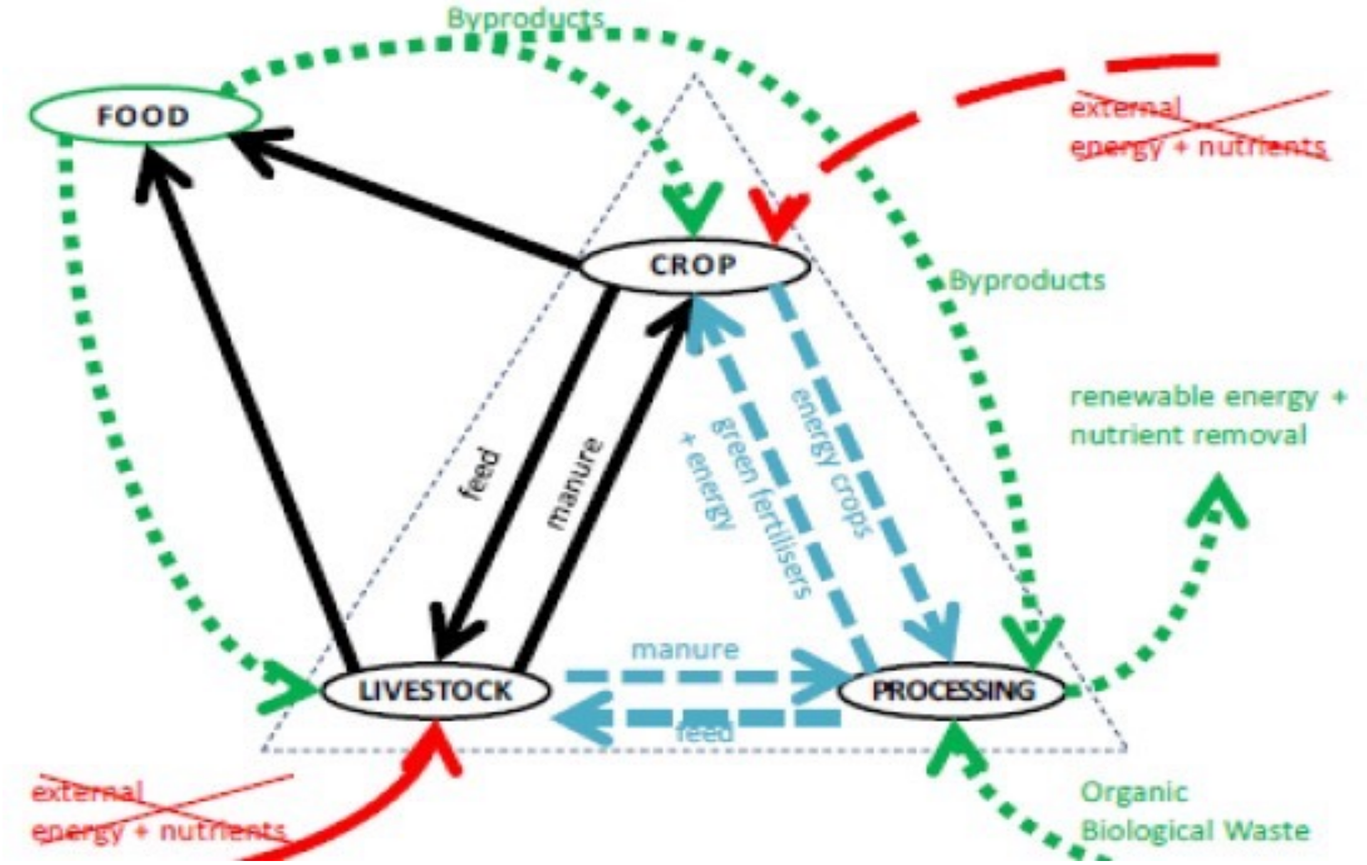


Figure 1. Triangle model for reconnecting nutrient and carbon flows between conventional agro-pillars

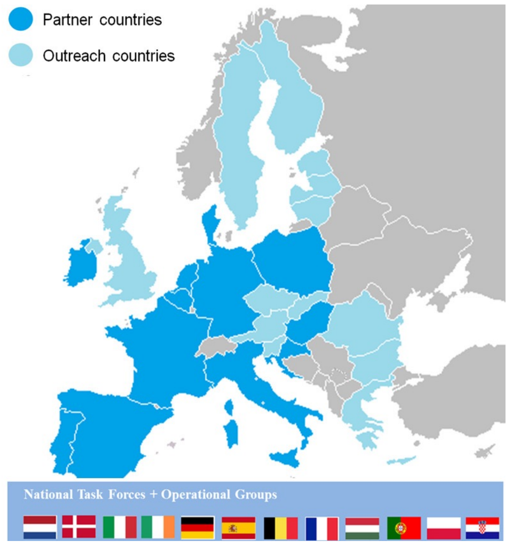


Figure 1.1. 12 participating countries AND outreach strategy for other EU member states.

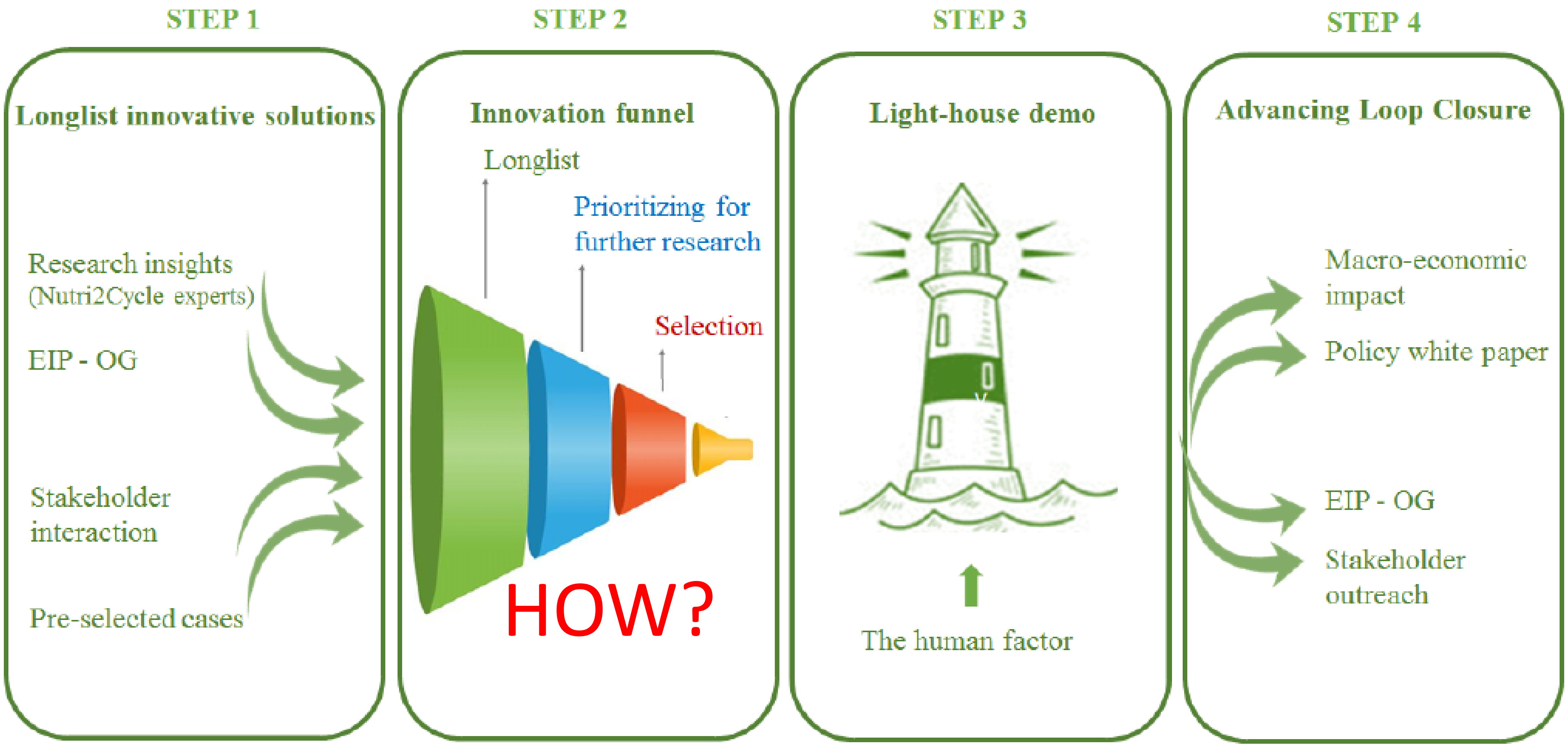


Figure 2. The NUTRI2CYCLE approach for more efficient nutrient loops at the local, regional and European scale

MULTI-CRITERIA DECISION MAKING - MCDM

"It has become more and more difficult to see the world around us in a one-dimensional way and to use only a single criterion when judging what we see" (Milan Zeleny 1982).

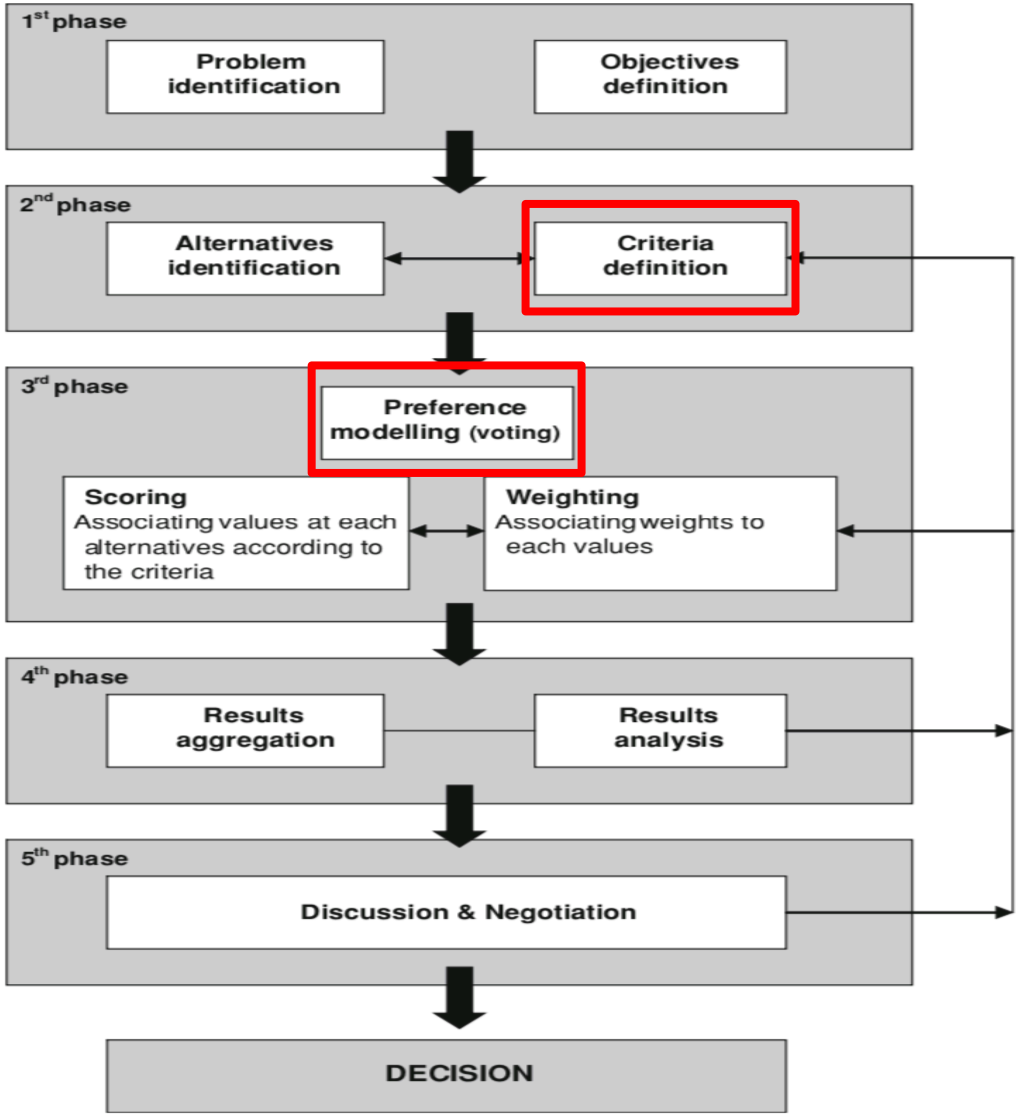
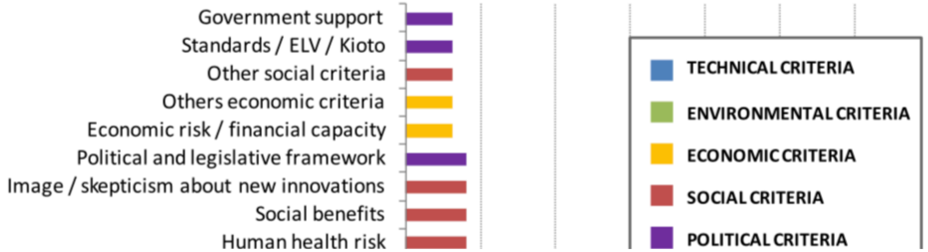
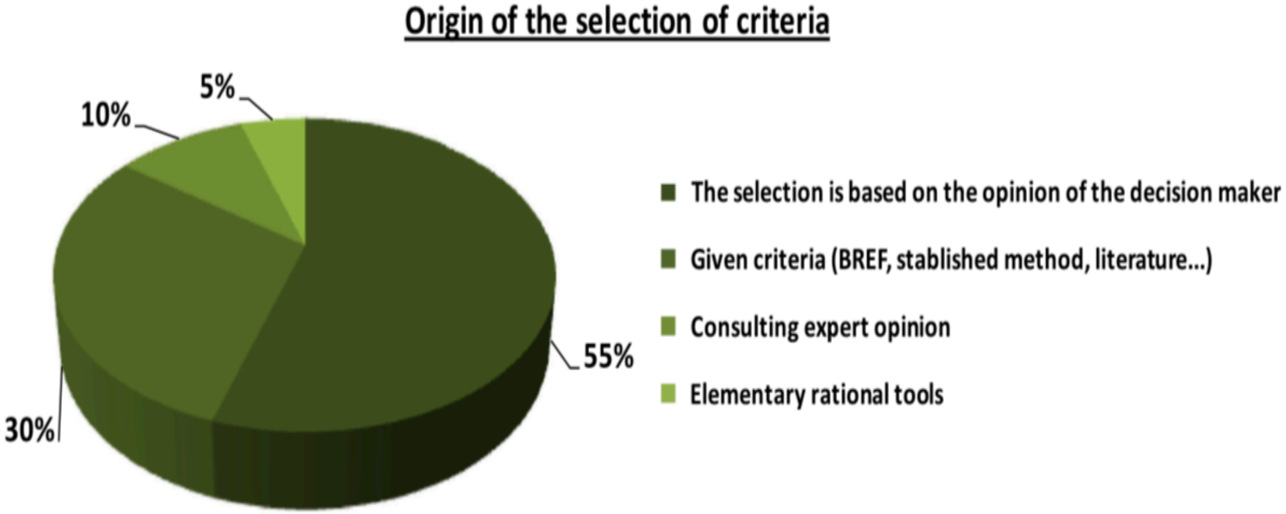
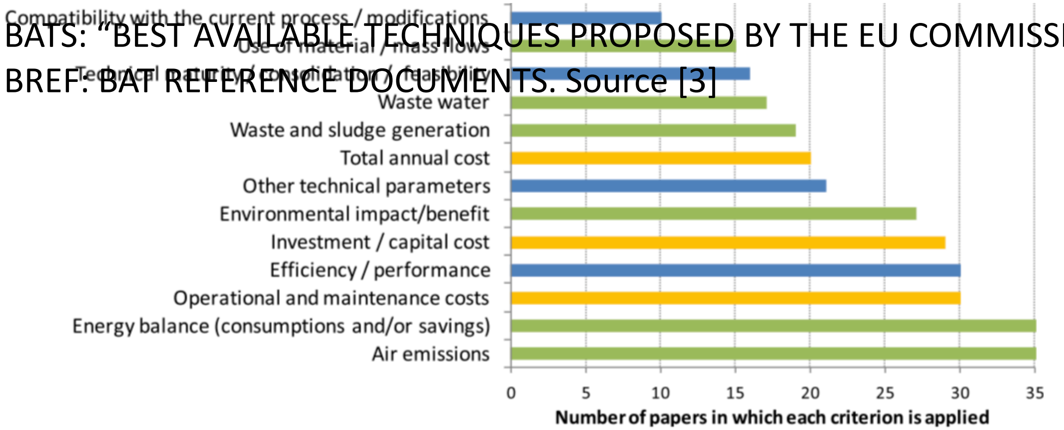


Figure 3. Typical structure of the MCA. Source: [9]







BATS: "BEST AVAILABLE TECHNIQUES PROPOSED BY THE EU COMMISSION", BREF: BAT REFERENCE DOCUMENTS. Source [3]

MCDM - Methods

Review

A holistic review of applied methodologies for assessing and selecting the optimal technological alternative from a sustainability perspective

CrossMark

V. Ibáñez-Forés, M.D. Bovea*, V. Pérez-Belis

Department of Mechanical Engineering and Construction, Universitat Jaume I, Av. Sos Baynat s/n, 12071 Castellón, Spain

The model works with much subjectivity. There are subjectivities in the preference scale for the criteria, not only because it is a subjective value but also in the scale by itself. There is subjectivity in applying the preferences scale in alternatives selection. Finally, the fact that two different persons can get different values for the same problem, casts a doubt about the reliability of this method. See also Dyer (1990).

The higher use of MAVT methods —in contrast to MOMP, non-classical and distance-to-target MCDA methods— seems to be linked to (i) the need for complex mathematical implementation in non-classical methods, (ii) the requirement of programming skills in MOMP methods, and (iii) the underuse of distance-to-target methods in the field of energy systems. Within the MCDA tools reviewed, and specifically within the distance-to-target methods, DEA arises as a trade-off solution between soundness and practi-

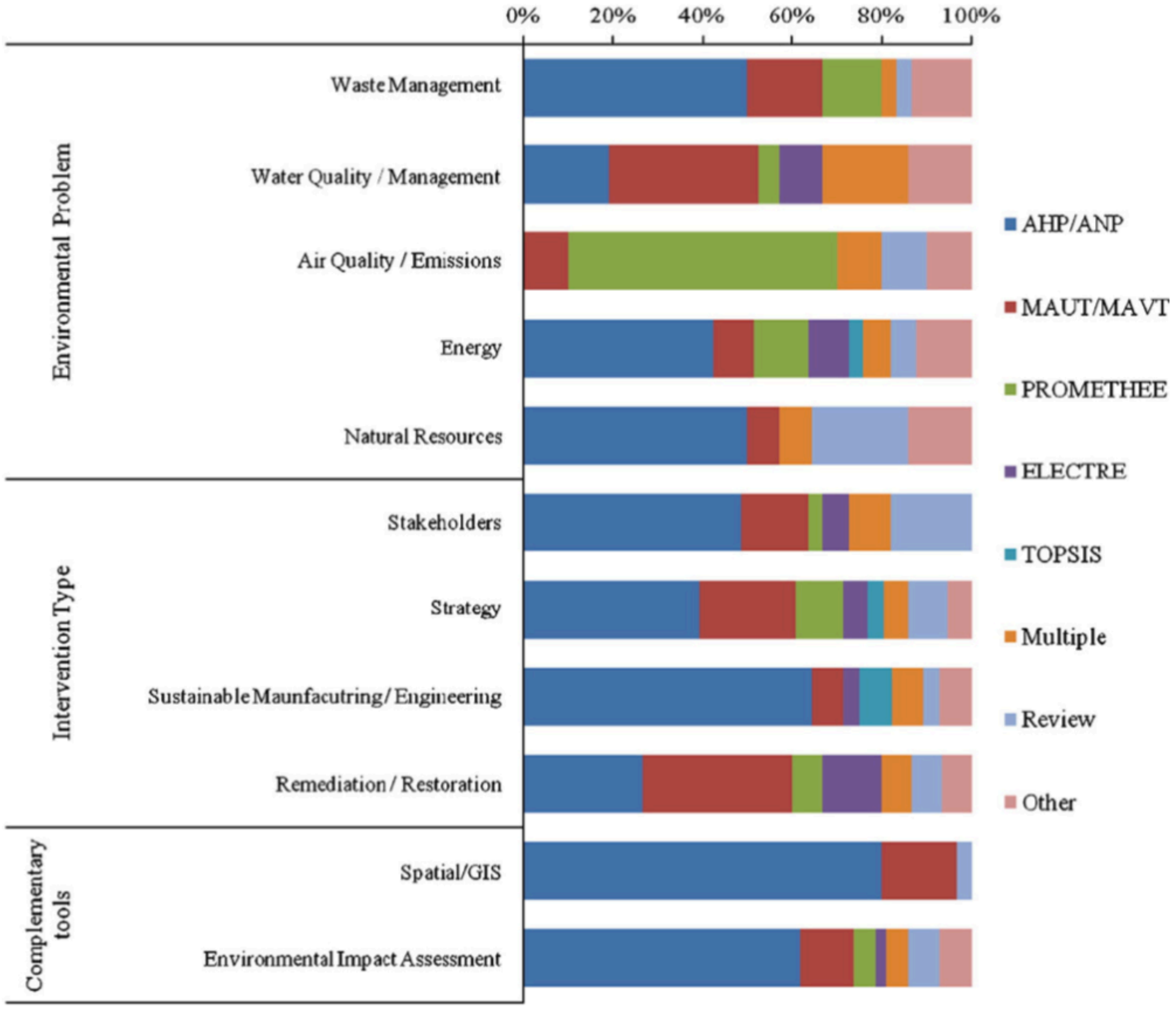


Figure 4. Percentage distribution of MCDA methods by applications areas. Source: [7]

MCDM - METHODS

Characteristic	ELECTRE I, II, III, IV, IS an TRI	PROME THEE I, II,I II and IV	AHP	MAUT	Linear Programming
Comprehension difficulty	High	Medium	Medium	Low	High
Available software	Yes	Yes	Yes	Yes	Yes (several)
Effect on alternatives selection by individual objectives	No	No	No	No	Yes
Capacity, measured as number of projects that it can handle	Small number of alternatives	Small number of alternatives (Bouyssou 1990)	Small number of alternatives	Small number of alternatives	Practically unlimited
Does the method allow working with multiple objectives?	Yes	Yes	Yes	Yes	No (except in some small problems or unlimited using SIMUS)
Does the method allow establishing technical precedence of projects?	No	No	No Yes (with ANP)	No	Yes
Is it possible to pre-select a determined alternative?	No	No	No	No	Yes
Does the method allow for binary selection? (0 or 1) (to select or not an alternative)	No	No	No	No	Yes
Does the method allow for alternatives ranking?	Yes	Yes, ELECTRE II	Yes	Yes	Yes (albeit there is no guarantee because the Solver may offer a unique solution, however this is possible with SIMUS)
Does the method allow for excluding alternatives (Example: If A is chosen then B can't)?	No	No	No	No	Yes

Table 1. Main working characteristics of different common models on MCDM. Source: [2]

(continued)

Multi criteria decision making methods

- **Multi objective mathematical programming (MOMP)**
  - Multi objective linear programming
  - Goal programming
  - Data envelopment analysis
  - …
- **Multi attributive utility theory (MAUT)**
  - Multi attributive utility theory
  - Analytic hierarchy process (AHP)/analytic network process (ANP)
  - …
- **Outranking**
  - Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)
  - Elimination and Choice Expressing Reality (ELECTRE)
- **Non-classical approaches**
  - Fuzzy set theory
  - Grey relational analysis

LCA – LIFE CYCLE ASSESSMENT

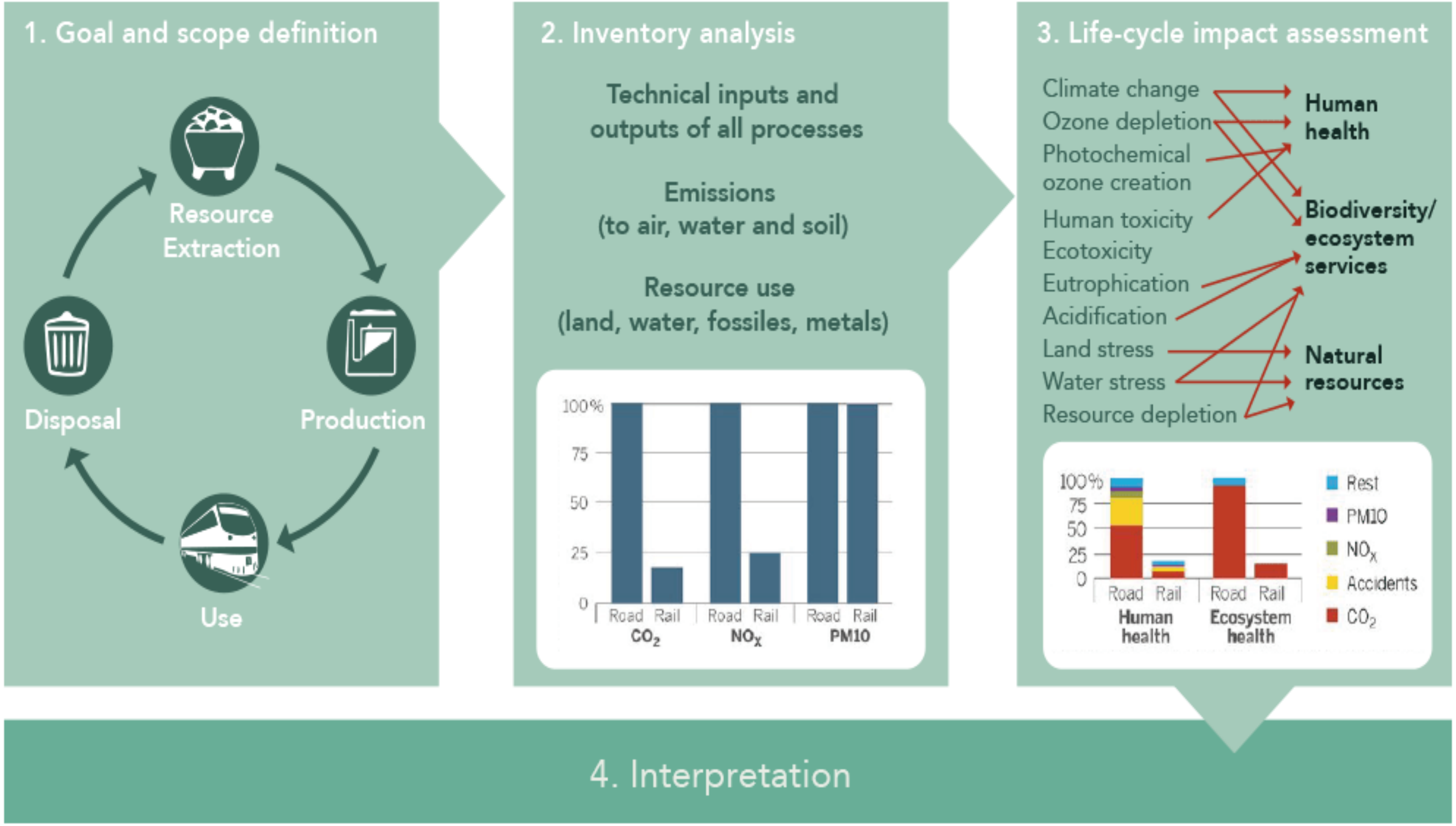
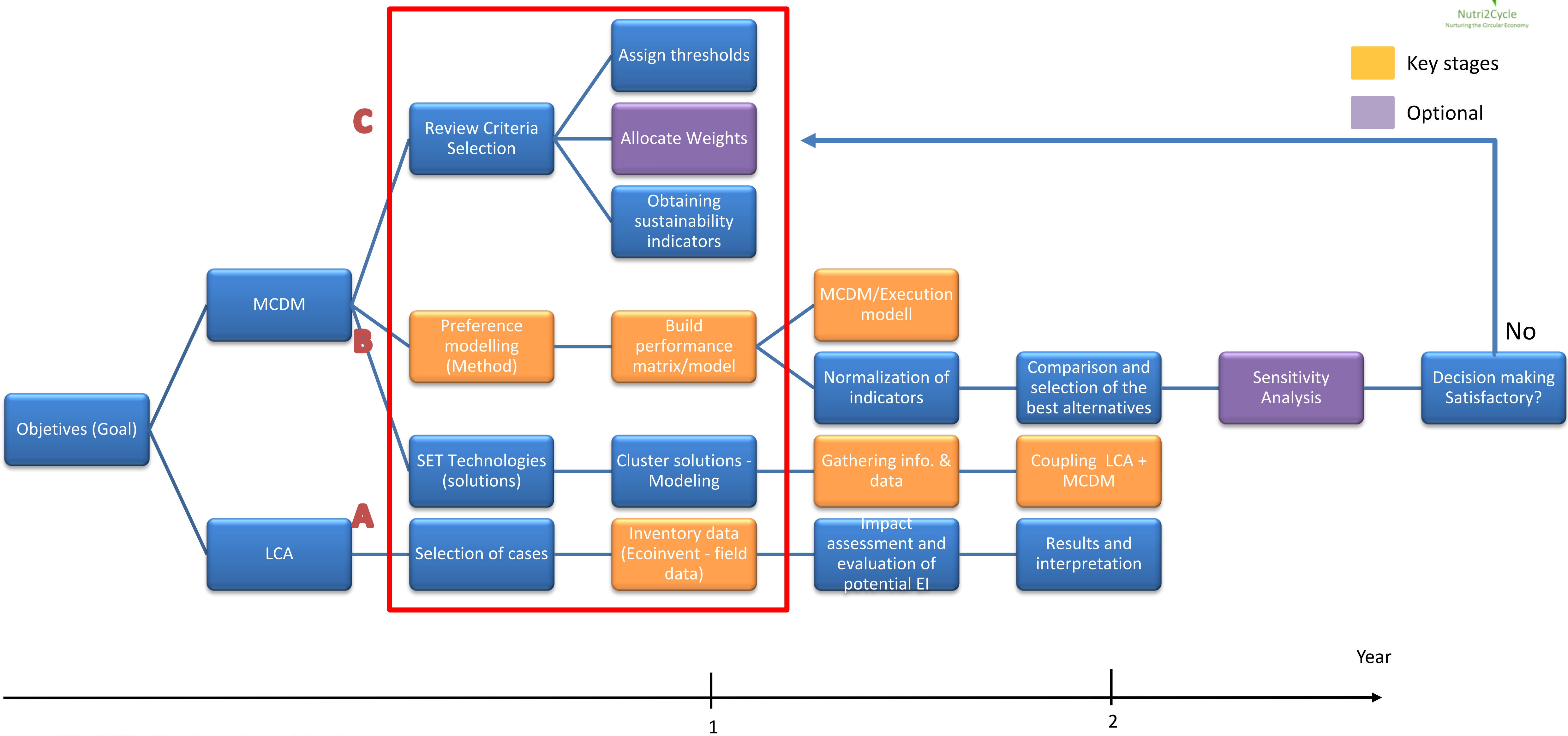


Figure 4. Standard methodology framework for LCA set by ISO14040. Source: [11]

- “FROM CRADLE TO GRAVE”
- Considers all the processes that have permitted to obtain a specific product, and all the processes concerning the extraction, treatment and by-products disposal of the raw materials needed.
- Quantitative methodology
- Standardized ISO 14040/44
- Intended for comparison and not absolute evaluation.

GENERAL METHODOLOGY FOR ASSESSING AND RANKING TECHNOLOGICAL SOLUTIONS UNDER MCDM



A – Shortlist; Set of technological Innovations

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RESEARCH LINES

1. **Innovative management systems, tools & practices for optimized nutrient and GHG management in animal husbandry**
2. **Innovative soil, fertilization & crop management systems & practices for enhanced N, P efficiency and increased soil OC content**
3. **Tools, techniques & systems for higher-precision fertilization**
4. **Bio based fertilizers (N, P) and soil enhancers (OC) from agro-residues**
5. **Novel animal feeds produced from agro-residues**

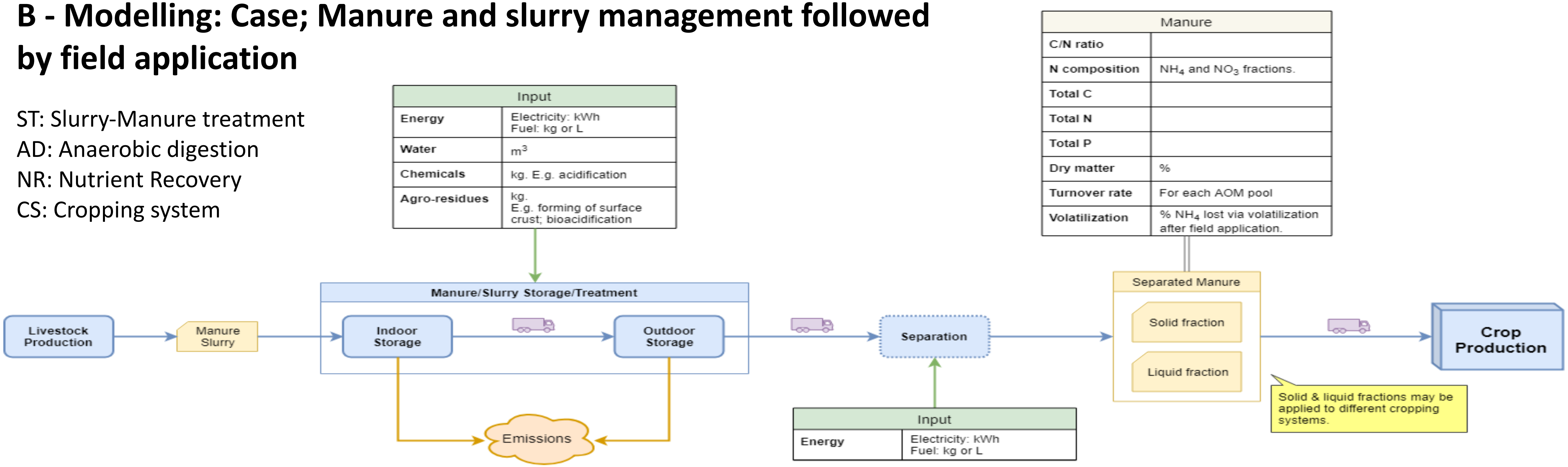
1	10	6
2	4	2
3	7	5
4	18	6
5	6	5

SOLUTIONS **SUB-RESEARCH LINES**

76 → 45 → 24

B - Modelling: Case; Manure and slurry management followed by field application

ST: Slurry-Manure treatment
AD: Anaerobic digestion
NR: Nutrient Recovery
CS: Cropping system



RL	#	Title	Summary	ST	AD	NR	CS	TRL
1	17	Crop farmer using a variety of manure and dairy processing residues to recycle and build soil C, N, P fertility	Recycling of nutrients from animal farmers and intensive grain users such as poultry to cropping land. Additionally use of dairy processing residues in a crop system.	X			X	6
1	71	Practices for increasing soil organic matter content in Dutch soils	For the arable sector: improved crop rotation, minimum tillage, additional application of organic matter (e.g. compost). For the dairy sector: maintaining permanent grassland, maize sown in strips in grassland, and species rich grassland.	X			X	7
4	8	Acid leaching of P from organic agro-residues in order to produce OM-rich soil enhancers and P-fertilizers	Slurry acidification using inorganic acids. Focus is on decoupling of C and P from waste streams (reduce P in solids).	X			X	6
4	11	Recycling fibres of manure as organic bedding material for dairy cows	Separation of solid-liquid fractions. Liquids are used for fertilisation. Solids are used for bedding material and later as fertiliser/soil enhancer.	X			X	6
4	7	Acidification as a tool to reduce ammonia emission from manure (storage)	Slurry acidification using inorganic acids.	X			X	4
4	19	Slurry bioacidification using org. waste products to reduce NH3 volatilisation and increase fertiliser value	Bioacidification by addition of organic carbohydrates.	X			X	5

C - Criteria selection

Indicators (minimum set)

1	Technical	**Technological Innovation**	1 - 10
2	Technical	**Substrate compositions**	%
3	Technical	**Transport**	km
4	Technical	**Energy consumption**	• Electricity (kWh) • Fuel (L diesel) • Heat (kJ)
5	Technical	**Water consumption**	m3/month - year + (Type)
6	Technical	**Chemical consumptions**	Kg/unit of product , kg/ha for crops
7	Technical	**Recovery efficiency**	N-recovered/N-input (%)
8	Technical	**Treatment capacity**	ton per year
9	Technical	**Energy production**	• Biogas (m3/day or month) • Heat generated from biogas (kJ/day or month) • Electricity generated from biogas (kWh/day or month)
10	Economic	**CAPEX**	€
11	Economic	**OPEX**	€/month or year
12	Economic	**Revenue**	€/month or year
13	Environmental	**GHG emissions**	kg CO2-equivalent
14	Mixed	**Nutrient uptake efficiency**	N or P–uptake /N or P-provided (%)

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1	Technical	**Characterization of product**	• Total N (% or mg/g) • Total P (% or mg/g) • Total C (% or mg/g) • N composition (NH4 & NO3 fractions; %) • C:N ratio • Dry matter (%)
2	Technical	**Characterization of field management**	
3	Technical	**Cultivated area**	ha
4	Technical	**Crop rotations**	Crop names
5	Technical	**Tillage**	Plough/Rotovation/No-tillage
6	Technical	**Characterization of fertilizers and application**	• Type: Mineral or organic • Rate of application: Total N, P, K (kg/ha) NH4 & NO3 fractions (%) For organic fertilizers: Total C, N content (% of DM) C:N ratio Dry matter (%)
7	Technical	**Field management activities**	Dates of: Sowing Fertilising (& method) Harvesting Irrigation (mm/ha)
8	Technical	**Crop yield estimation**	Grains (kg DM/ha, kg 85% DM equiv/ha, kg FW/ha) Residues left in field (kg/ha)
9	Technical	**Soil properties**	• Organic matter (%) • N and P content (%) • Texture • pH
10	Mixed	**Future Impact**	How will the technology/product further develop?
11	Legal	**Potential barriers**	Barriers for uptake due to legislation
12	Legal	**Potential positive impact**	Some techniques/products may be advantaged due to changing legislation.
13	Environmental	**Ammonia emission**	Ammonia emitted/N-provided (%)
14	Environmental	**Acidification potential**	kg SO2-equivalent
15	Environmental	**Leaching**	Leached Nutrients/Nutrient Provided (%)

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FUTURE PERSPECTIVES

- Quality and consolidation of data collected from the technologies.
- Immersive work with subtask leaders of each research line in the way of setting up particular criteria proper and reachable of the group of technologies of each RL.
- The selected model for the multi-criteria evaluation for processing the data is still under consideration due to the offer of other sizeable and robust methods found in recent studies and from the feedback of internal experts as well.
- The thresholds have not been defined, what can be a reference point, because a standard value is very subjective to different points of view or judge of each expertise in the area in regard.

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Thank you very much for your attention

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