RMT Elevages et environnement

Multi-objective formulation, a method to formulate eco-friendly and economic feed for monogastrics

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Introduction (1/2)

Livestock *vs.* environment:

- climate change (≈15% of greenhouse gas emissions)
- land use (≈35% of croplands are used for animal feed)
- eutrophication (in regions with high animal density)

Feed production:

- 65-70% of production cost in pigs and broilers
- main contributor to many LCA* impacts:
  climate change (50-85%), eutrophication (64-97%), energy use (70-96%), land occupation (≈100%)

Basset-Mens et al., 2005; Boggia et al., 2010; Dourmad et al., 2014; FAO, 2006, 2013; InterPIG, 2013; Leinonen et al., 2012a,b; Prudêncio da Silva et al., 2014; van Horne & Bondt, 2013;

***LCA:** Life Cycle Assessment

Introduction (2/2)

- **Least cost feed formulation (LCF):**
  - **the cheapest**!
  - but does **not** consider the environmental impacts
- **Least environmental impact feed formulation:**
  - effective to **minimize one single impact**
  - but generally **increases feed cost and possible trade-offs:**
    e.g. least CC → feed cost: +30% ; acidification: +20% (Mackenzie *et al.*, 2016)

How to formulate diets with:

- lower enviromental impacts compared to LCF
- limited trade-offs between impacts
- a limited increase of feed cost

How multi-objective formulation (MOF) works? (1/2)

- **Formulation constraints on:**
  - nutritional characteristics (energy, lysine, phosphorus…)
  - feedstuffs incorporation (maximum oil %, minimum of cereals…)
  - environmental impacts ≤ 105% of impacts of least-cost formula
- **A single objective function to be optimized:**

$$MIN\left[\left((1-\propto)\times\frac{Price_{MOF}}{Price_{LCF}}\right)+\propto\times\left(\frac{2}{5}\times\frac{CC_{MOF}}{CC_{LCF}}+\frac{1}{5}\times\frac{LO_{MOF}}{LO_{LCF}}+\frac{1}{5}\times\frac{PD_{MOF}}{PD_{LCF}}+\frac{1}{5}\times\frac{NRE_{MOF}}{NRE_{LCF}}\right)\right]$$

with 0 ≤ α ≤ 1

Considered impacts:
Climate Change (CC), Land Occupation (LO), Phosphorus Demand (PD), Non-Renewable Energy Demand (NRE), Eutrophication (EU), Acidification (AC)

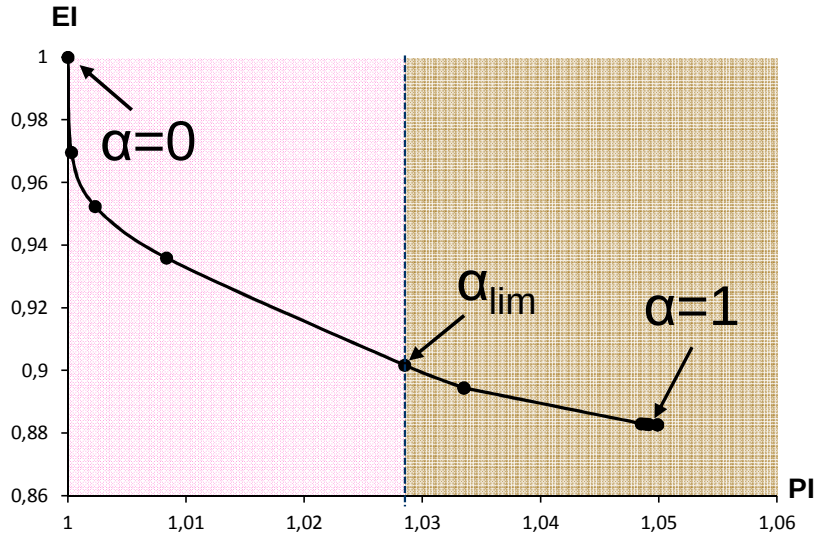
How multi-objective formulation (MOF) works? (2/2)

$$MIN\left[\left((1-\propto)\times\frac{Price_{MOF}}{Price_{LCF}}\right)+\propto\times\left(\frac{2}{5}\times\frac{CC_{MOF}}{CC_{LCF}}+\frac{1}{5}\times\frac{LO_{MOF}}{LO_{LCF}}+\frac{1}{5}\times\frac{PD_{MOF}}{PD_{LCF}}+\frac{1}{5}\times\frac{NRE_{MOF}}{NRE_{LCF}}\right)\right]$$

Price Index (PI) **Environmental Index (EI)**

- **$0 \leq \alpha \leq 1$:**
  - $\alpha = 0 \Rightarrow$ least-cost formulation
  - $\alpha = 1 \Rightarrow$ only environmental indicators
  - $0 < \alpha < 1 \Rightarrow$ infinite number of solutions

α_{lim}: last α where marginal EI ↘ is still > to marginal PI ↗ (in absolute value)

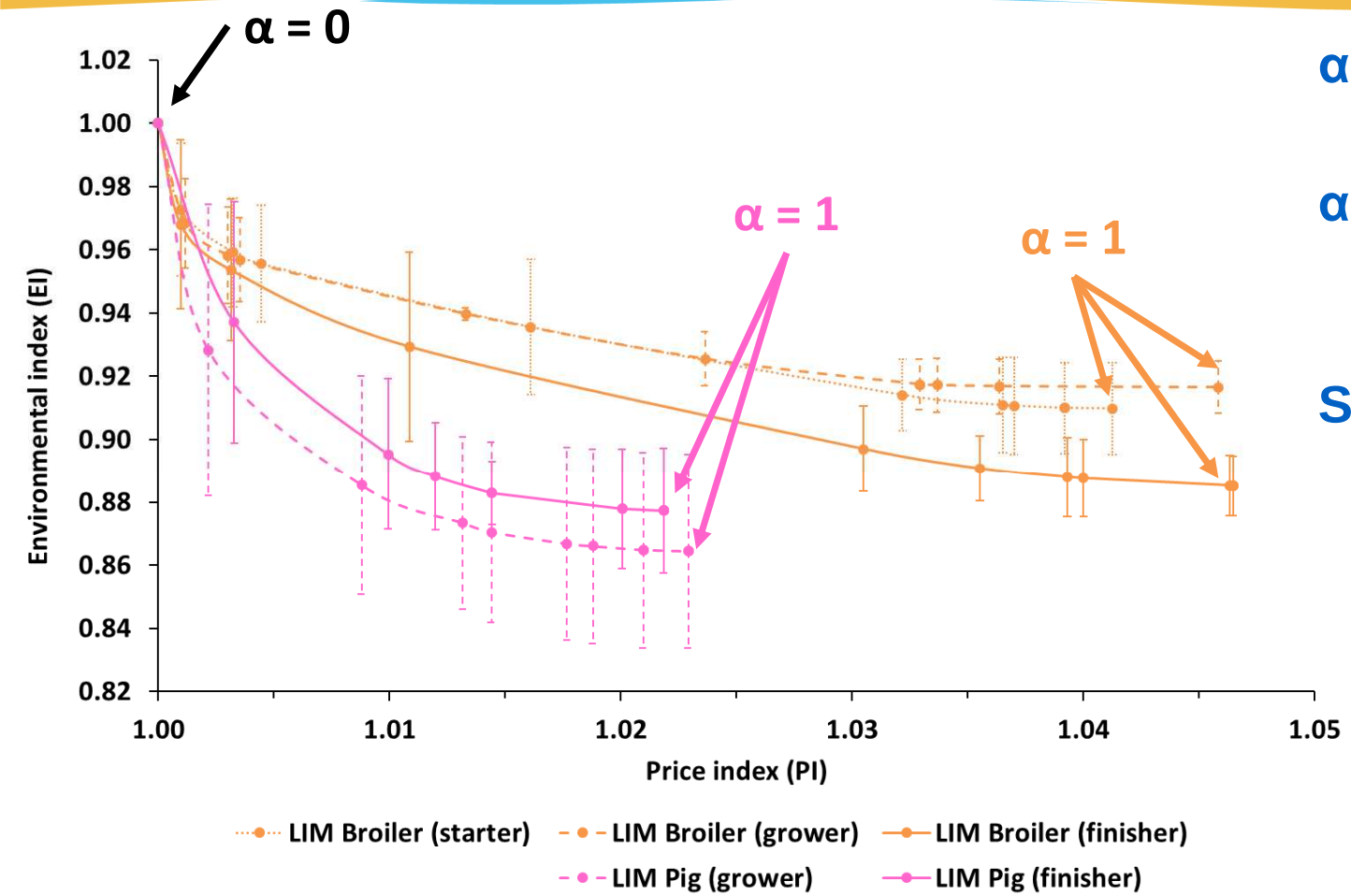


$\frac{-\delta EI}{\delta PI} > 1$ $\frac{-\delta EI}{\delta PI} < 1$

Data and scenarios

- **Environnemental impacts of feedstuffs:**
  - ECOALIM database (Wilfart *et al.*, 2016)
  - 6 LCA impacts: CC, LO, PD, NRE, EU, AC
- **Feedstuffs**
  - 4 price contexts: 2011, 2012, 2013, 2014
  - 2 availaibility contexts: limited (LIM, current context) *vs.* non- limited (NLIM)
- **Species:**
  - Pig: grower and finisher phases
  - Broiler: starter, grower and finisher phases

Evolution of environmental and price indexes with α



α ≤ 0.5:

- fast ↘ of EI & ↗ of PI

α > 0.5:

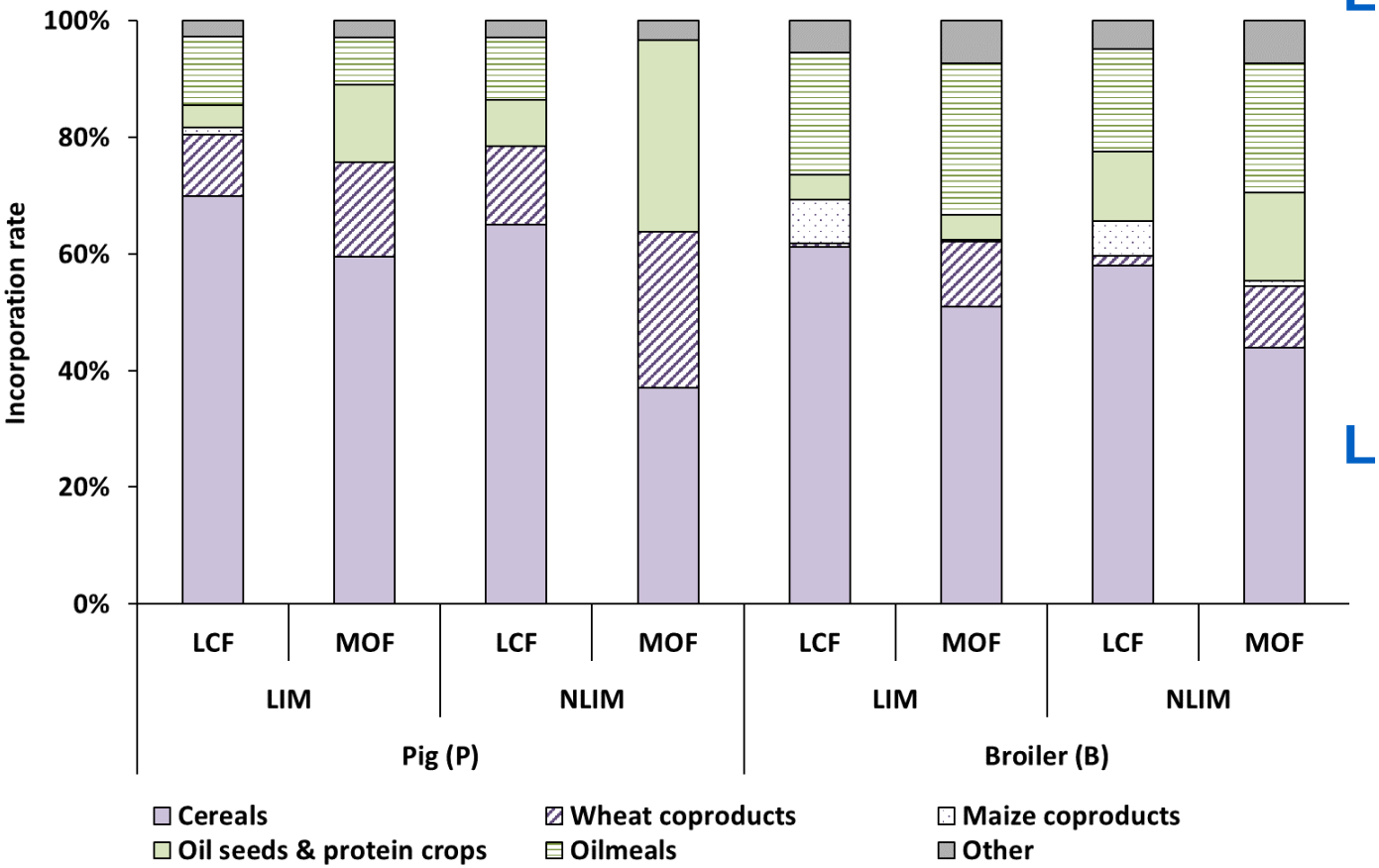
- slower evolution of EI & PI

Sensitivity of α_{lim}:

- price context
- nutritional characteristics of feed
- availability of feedstuffs

(e.g. 0.46 ≤ α ≤ 0.97 in broiler)

Average[1] feeds for $\alpha = \alpha_{lim}$



LCF → MOF:

- ↘ of cereals & ↗ of wheat coproducts (P & B)
- ↗ oil seeds & protein crops (P)
- ↘ oilmeals in P *vs.* ↗ in B (but with ↘ of soybean meal)
- ≈ no maize coproducts left (B)

LIM → NLIM (MOF):

- ↘ of cereals (P & B)
- ↗ wheat coproducts (P)
- ↗ oil seeds & protein crops (P & B)
- ↘ oilmeals (P&B) (no oilmeals left in B)

[1] **P:** 40% Grower + 60% Finisher; **B:** 6% Starter + 20% Grower + 74% Finisher

Price and impacts of average[1] feeds for $\alpha = \alpha_{lim}$

	Included in the objective function (OF)					NOT included in the OF	
	Price (€)	CC (kg CO_2-eq)	NRE (MJ)	PD (kg P)	LO (m^2.year)	AC (mol H^+)	EU (kg PO_4^{3-})
Pig							
LIM [2]	+1%	-14%	-13%	-6%	-13%	-7%	-11%
NLIM [3]	+4%	-23%	-14%	-25%	-16%	-17%	-17%
Broiler							
LIM [2]	+3%	-12%	-18%	-12%	+4%	-4%	-7%
NLIM [3]	+4%	-12%	-16%	-12%	+1%	-2%	-7%

[1] **Pig:** 40% Grower + 60% Finisher; **Broiler:** 6% Starter + 20% Grower + 74% Finisher.
[2] Compared to LIM-LCF.
[3] Compared to NLIM-LCF.

Consequences at farm gate: final price & impacts per kg of BW

	Included in the objective function (OF)					NOT included in the OF	
	Price [1] (€)	CC (kg CO_2-eq)	NRE (MJ)	PD (kg P)	LO (m^2.year)	AC (mol H^+)	EU (kg PO_4^{3-})
Pig [2]							
LIM [4]	+1%	-7%	-8%	-5%	-10%	-2%	-7%
NLIM [5]	+4%	-12%	-14%	-16%	-13%	-3%	-7%
Broiler [3]							
LIM [4]	+3%	-10%	-14%	-12%	+3%	-2%	-5%
NLIM [5]	+4%	-10%	-12%	-10%	+0%	-1%	-5%

[1] **Pig:** feed cost; **Broiler:** production cost.

[2] Breeding-fattening farm: FCR = 2.73 (fattening period); final BW = 118.1kg.

[3] Conventional broiler farm: FCR = 1.73; final BW = 1.83 kg.

[4] Compared to LIM-LCF. [5] Compared to NLIM-LCF.

Conclusions

- **Feed price & impacts considered together:**
  - simultaneous ↘ of several impacts
  - limited ↗ of feed cost
  - limited trade-offs between impacts
- **An efficient tool to ↘ impacts of pig & broiler productions**
  - limited ↗ of production cost
  - combination with ≠ feeding strategies (Espagnol *et al.*, EAAP 2017 Session 11)
- **Availability of feedstuffs:**
  - competition between productions on a territory (Espagnol *et al.*, EAAP 2017 Session 19)

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Thank you for your attention!

Any questions?

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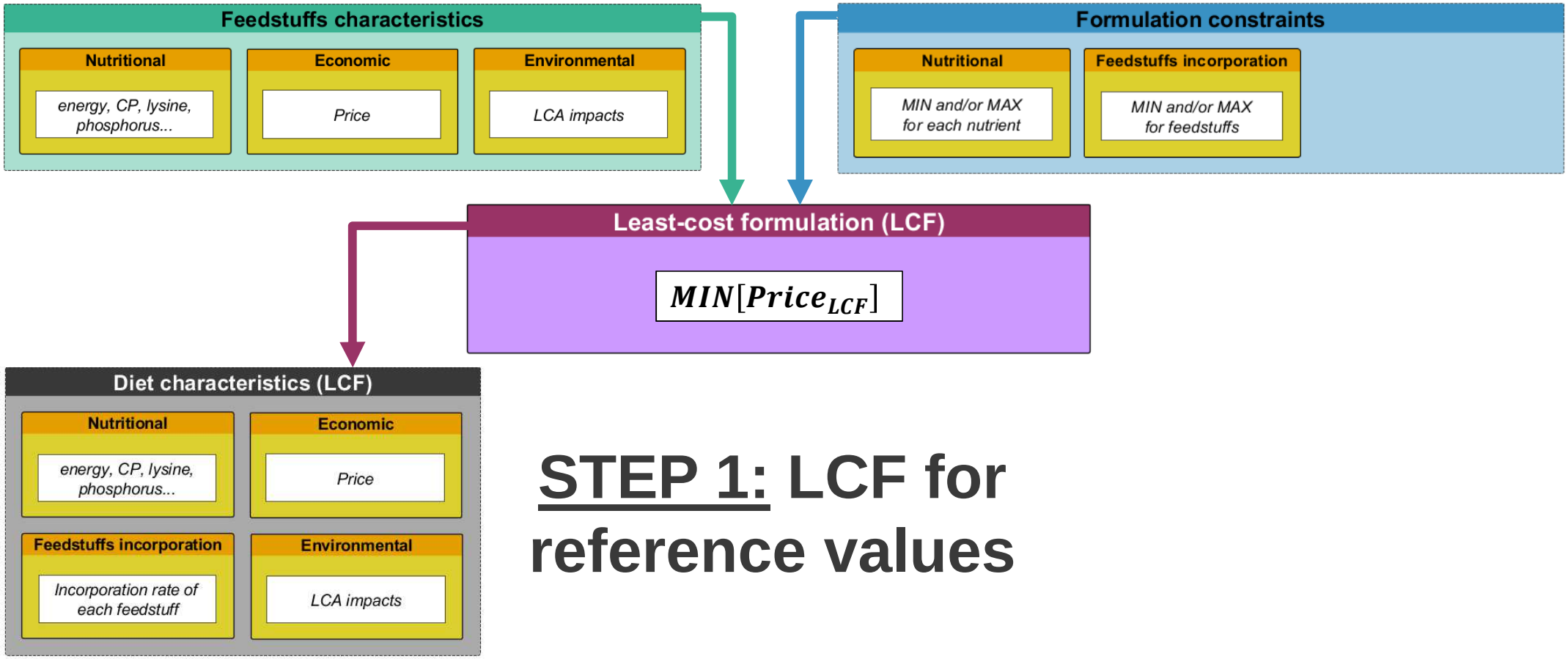
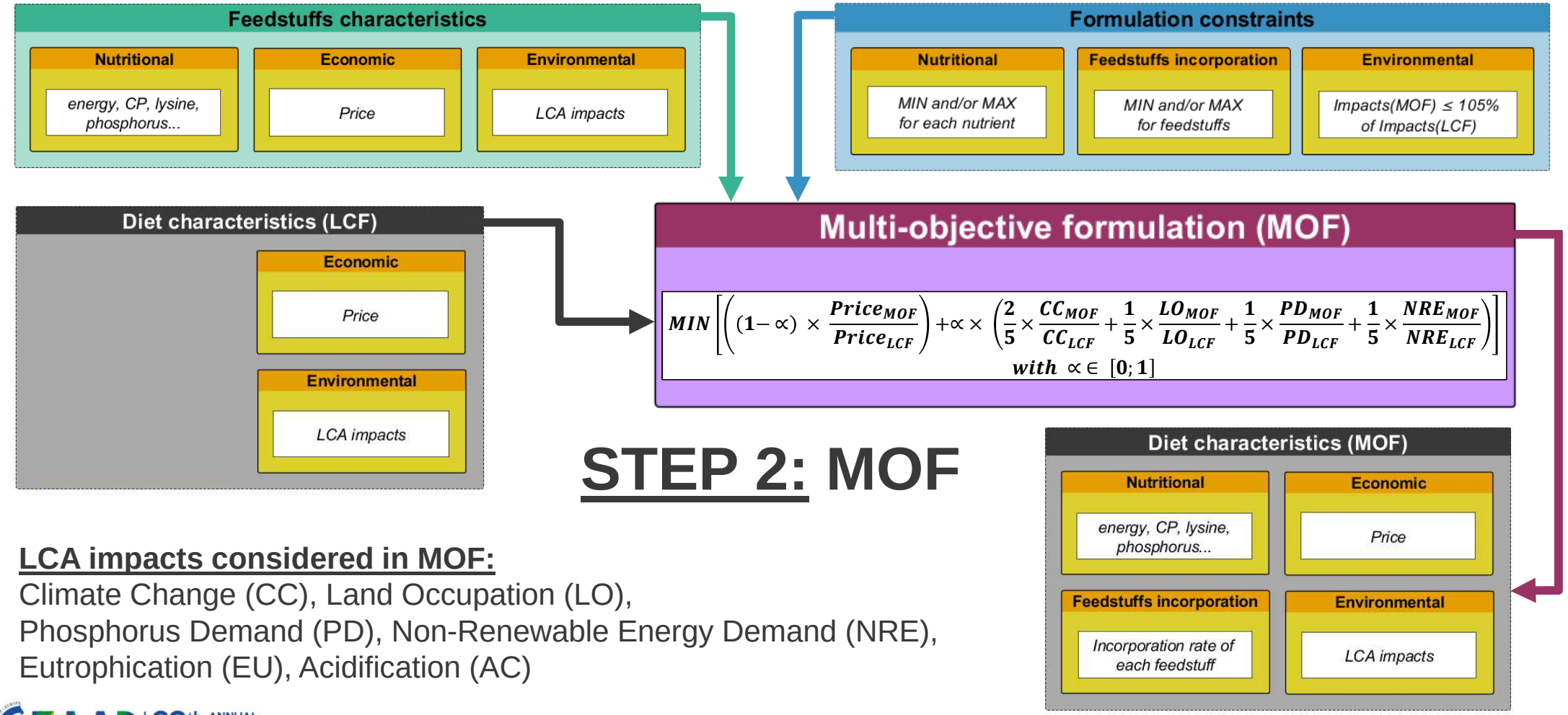
How multi-objective formulation works?



STEP 1: LCF for reference values

How multi-objective formulation works?



STEP 2: MOF

LCA impacts considered in MOF:

Climate Change (CC), Land Occupation (LO), Phosphorus Demand (PD), Non-Renewable Energy Demand (NRE), Eutrophication (EU), Acidification (AC)