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Increase in the REduction and REcovery of EXpired FOod

LCA analysis of waste food co-digestion, in the framework of i-REXFO LIFE project

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Dipartimento di Ingegneria



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www.irexfo.eu

Partner of





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Outline

i-REXFO concept

Transferability Tool

Application to pilot area



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WHY THE IREXFO PROJECT?

IN THE EU

(Estimates, 2012)

FOOD IS LOST OR WASTED THROUGHOUT THE ENTIRE SUPPLY CHAIN



from **agricultural production** to final household consumption



million tonnes

of food are wasted per
year

or



kg per person



170

million tonnes
of CO₂

emitted from production
and disposal of EU food
waste



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WHY



In developing countries
40% of losses occur during
harvest and **processing level**



In industrialized countries
40% of losses happen at the
retail or **consumer level**



Destroyed in
transport



Not bought at
a supermarket



Thrown away
by the consumer

Atti
Passa



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HOW

Raising Awareness

Donation, last minute meal, doggy bags

Optimization



Destroyed in
transport



Not bought at
a supermarket



Thrown away
by the consumer

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Pass



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HOW

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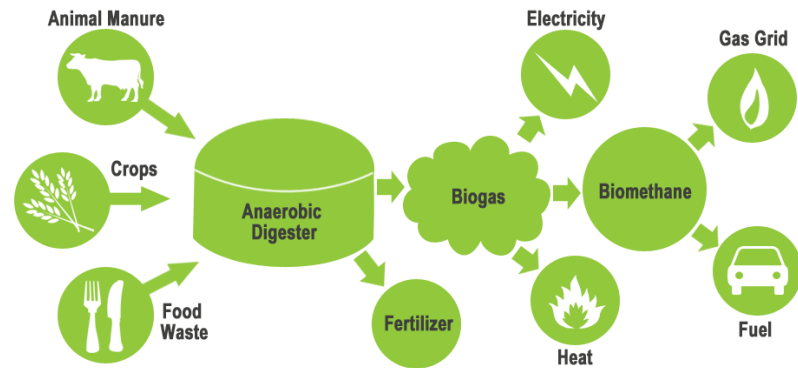
HOW

- When food becomes not suitable for human consumption, there are economic, logistic, legal and cultural barriers, which prevent its reuse:

animal feed



biogas – energy – fertilizer





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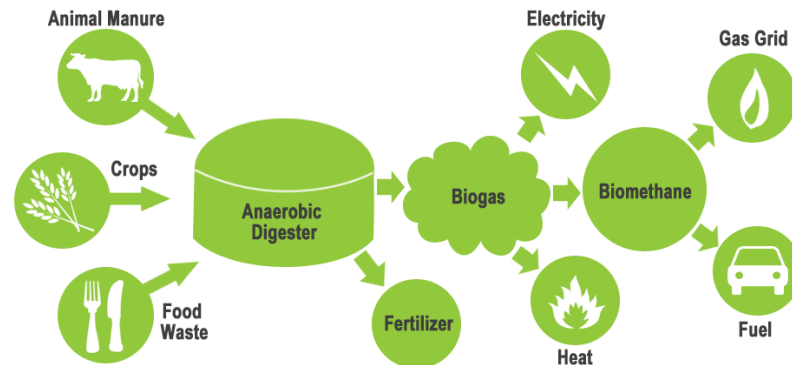
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i-REXFO

Increase in the **RE**duction and **RE**covery of **EX**pired **FO**od

i-REXFO is an innovative **BUSINESS MODEL** to reduce waste food □ It promotes actions to avoid waste food to be disposed in landfills and to produce bioenergy with the non edible fractions

iREXFO will provide an open source tool to transfer the Reduction of Expired Food (**REF**) chains and the Expired Food Energy (**EFE**) chains that will be tested in the Umbria region that is identified as a pilot case study

i-REXFO
increase in reduction and recovery of expired food

1 WHY

With one-quarter of the world population at risk of poverty and social exclusion, one-third of the food produced in the world gets lost or ends up in landfills. But there's more: The production of expiration food involves the use of **100 million m³ of water**, occupies **30% of the world's agricultural land area**, and releases **3.5 billion tonnes of climate-altering gases**. The direct economic consequences of all this waste amount to **750 billion dollars each year** (source: FAO).

According to FAO, food waste in industrialised countries are caused by a combination of factors:

- **consumers' behaviour**: incorrect shopping planning, poor understanding of best before and use by dates, excess purchases, and lack of the habit of storing and eating leftovers;
- **production-precurement-distribution chain** that does not give enough value to food that is near its expiration date, non-conforming products, and the donation of surplus;
- **a legal and authorization system** that helps not promote the reuse of food waste in the animal feed industry or, more recently, its use in biomass-fed biogas production plants.

2 OUR GOAL

The i-REXFO project aims at demonstrating that food waste can be reduced through an **innovative business model** that is both economically and environmentally sustainable.

i-REXFO is based on an **integrated model**, in which **expired food to energy (EFE)** valorisation supports the **Reduction of Expired Food (REF)** chain.

3 HOW

The project focuses on food waste produced by the food industry and farms, large-scale distribution, the catering industry (hotels, restaurants, bars, HORECA) and consumers. It does so through measures that reduce food waste and increase waste-to-energy valorisation.

Based on the **good practices in Europe (Denmark)**, i-REXFO has developed **open-source software** to plan and optimise the integrated model from a **technical, economic, and environmental point of view**.

The i-REXFO model **raises the awareness of consumers** and operators in the large-scale distribution and HORECA sectors, **promotes the sale and use of food** that is near its expiration date, **recycles aesthetically pleasing and increases biomass of surplus food** to charities and food banks. These measures are **backed by the collection and use of expired food** for the production of **biogas** in anaerobic digestion plants, which use the resulting digestate as a fertiliser, thereby completing the cycle. The i-REXFO model will be **demonstrated in Umbria** and then transferred to other countries (**Hungary**).

4 IMPACT

- **4,500 tonnes of CO₂ emissions avoided every year**;
- **3,400 tonnes of food waste** a year from the food industry, farms, shopping centres, and restaurants **that don't end up in landfills**;
- **580,000 m³ of water saved every year**;
- **2,800 MWh/year of energy produced from renewable sources**;
- **2,400 MWh in energy savings every year**;
- **1,100 ha a year in reduced soil consumption**;
- **100,000 aware consumers**, thanks to the project's campaigns and activities.

SHARE THE PROJECT

Twitter: @IREXFO

LinkedIn: I-REXFO

Facebook: I-REXFO



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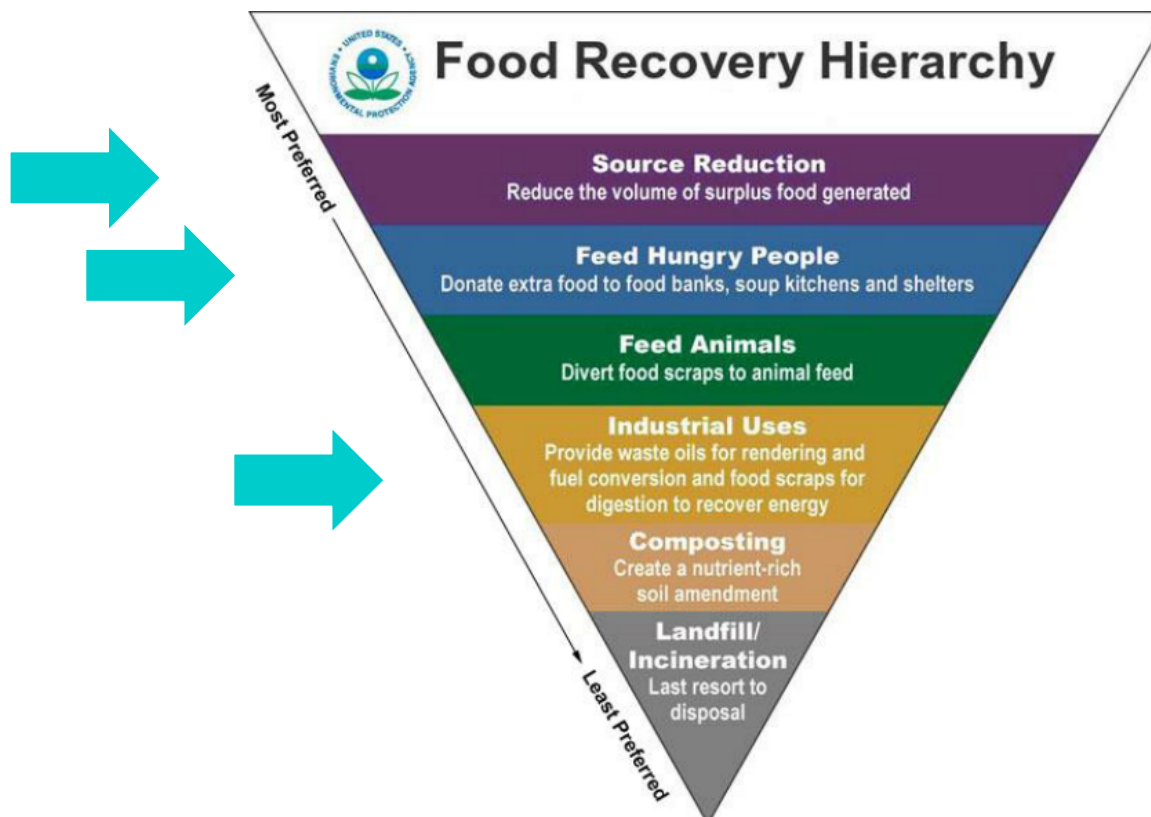


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i-REXFO

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i- REXFO objective is the reduction of the quantity of waste food which is disposed in landfill.





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The i-REXFO model

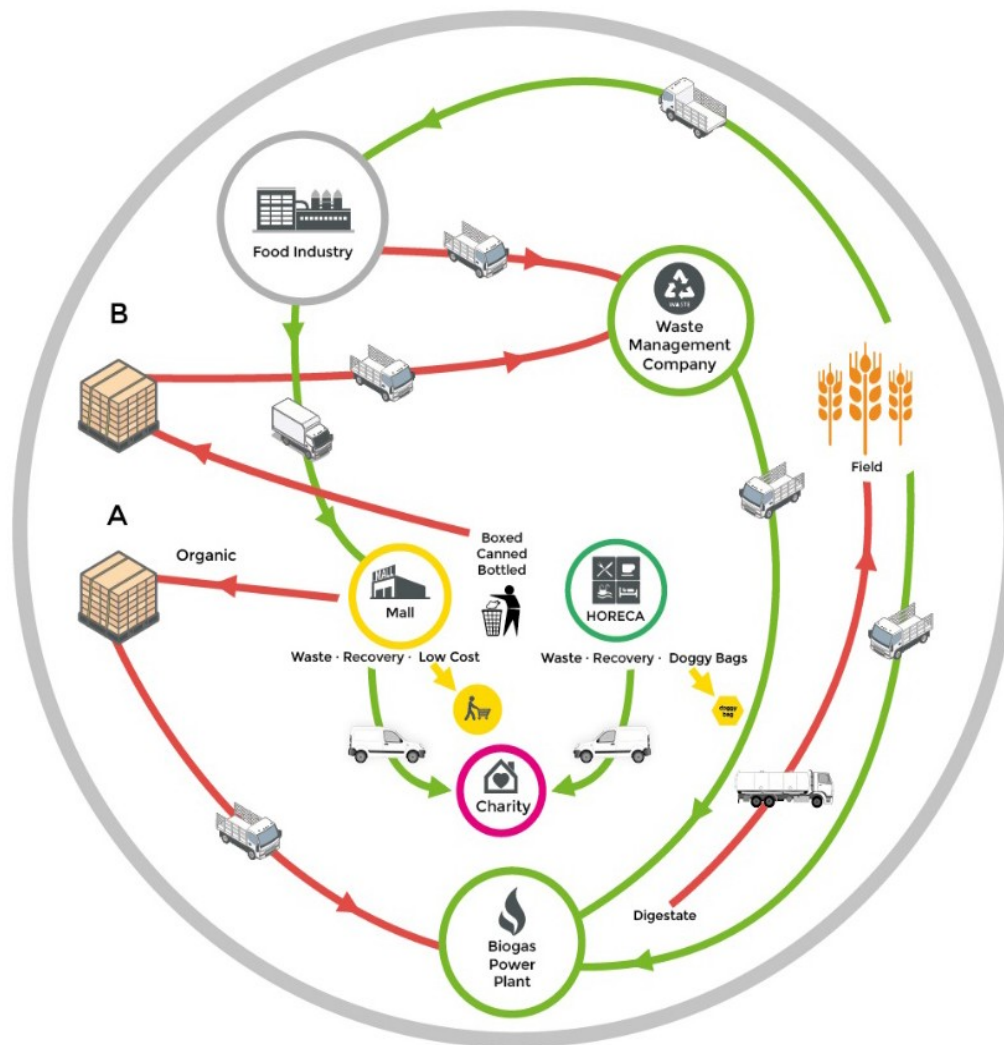
Circular diagram of the i-REXFO approach



Waste



Matter





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The i-REXFO model

Circular diagram of the i-REXFO approach

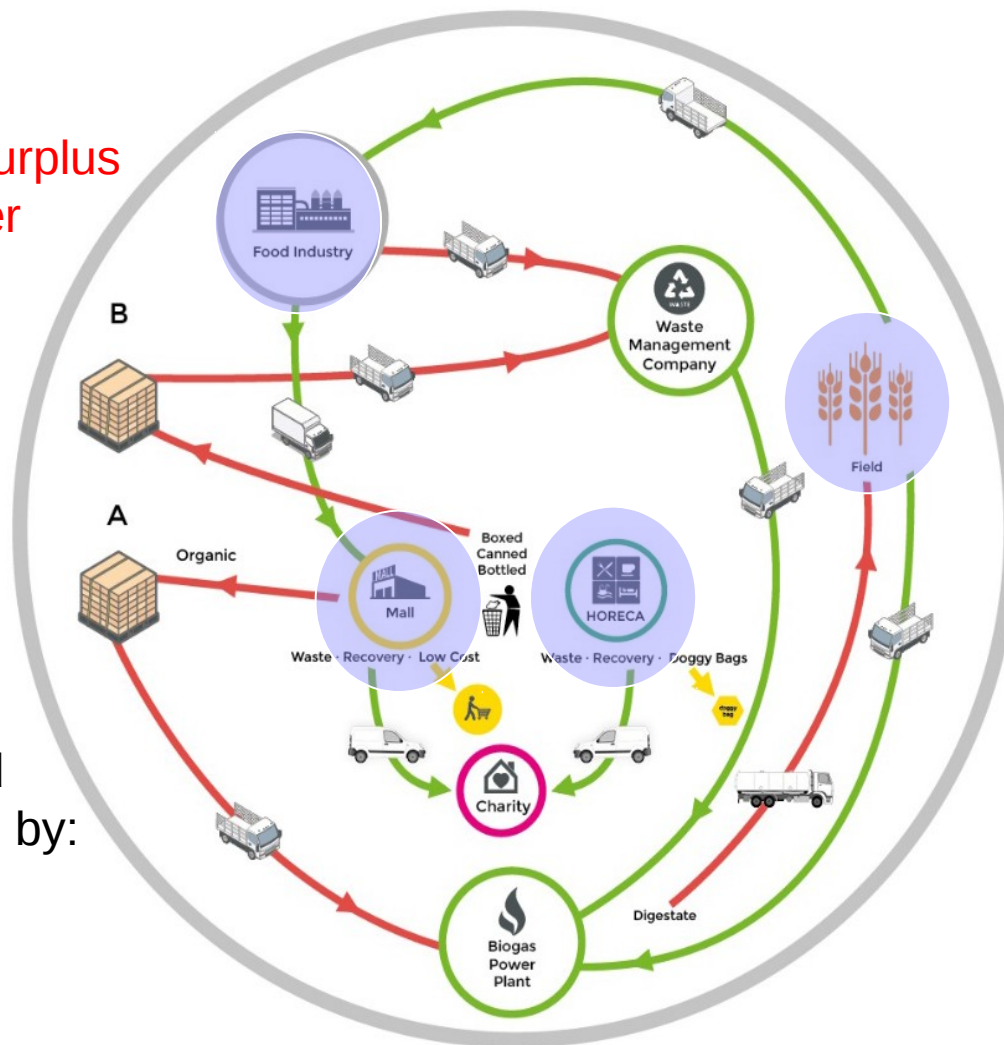


Waste and surplus food producer

Waste



Matter



Focused on food waste generated by:

- Food industry;
- Farms;
- Big retailers;
- HORECA sector;



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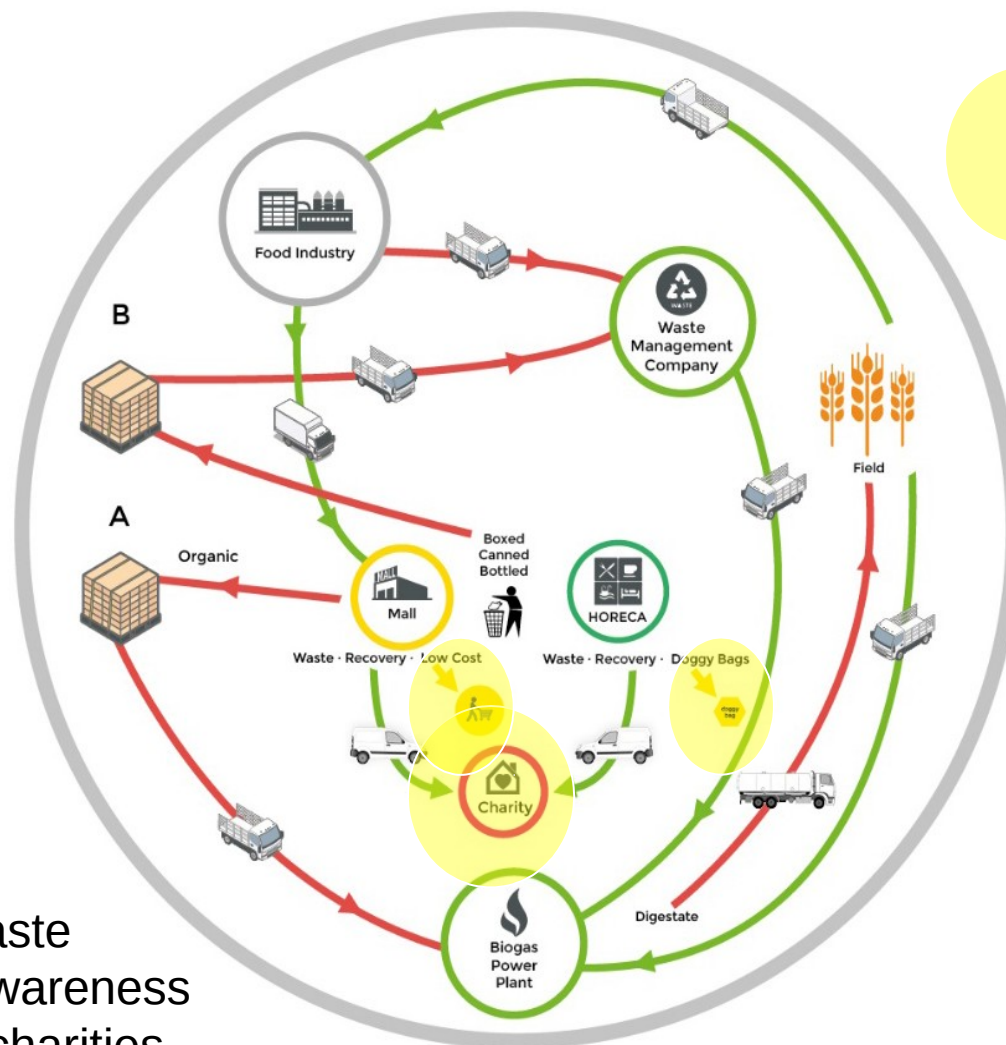
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The i-REXFO model

Circular diagram of the i-REXFO approach



Waste 
Matter 



Actions to

reduce food waste

- ☐ consumer awareness
- ☐ donation to charities
- ☐ last minute market & doggy bags



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Waste



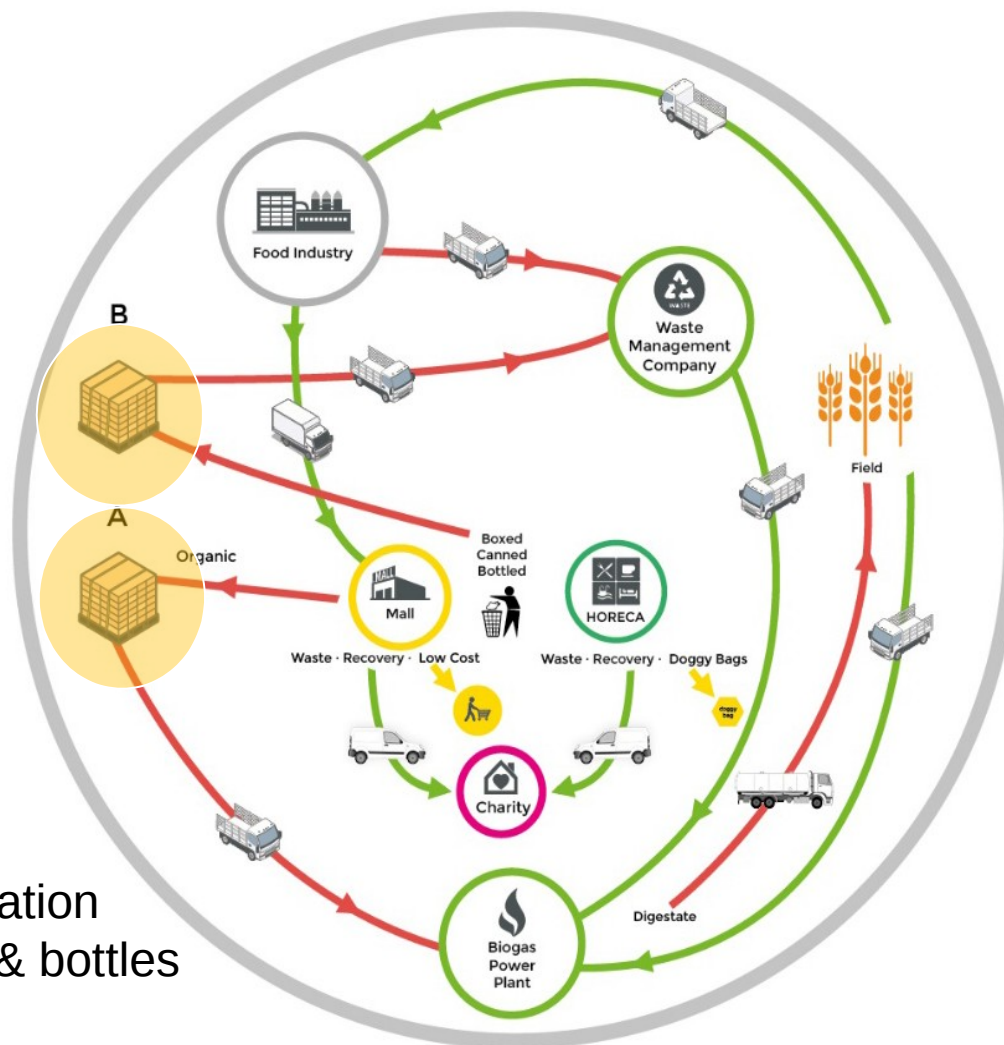
Matter



Wasted food
storage

Packaged food
Requires separation
of boxes, cans & bottles

Unpackaged food can go directly
to biogas production





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The i-REXFO model

Circular diagram of the i-REXFO approach

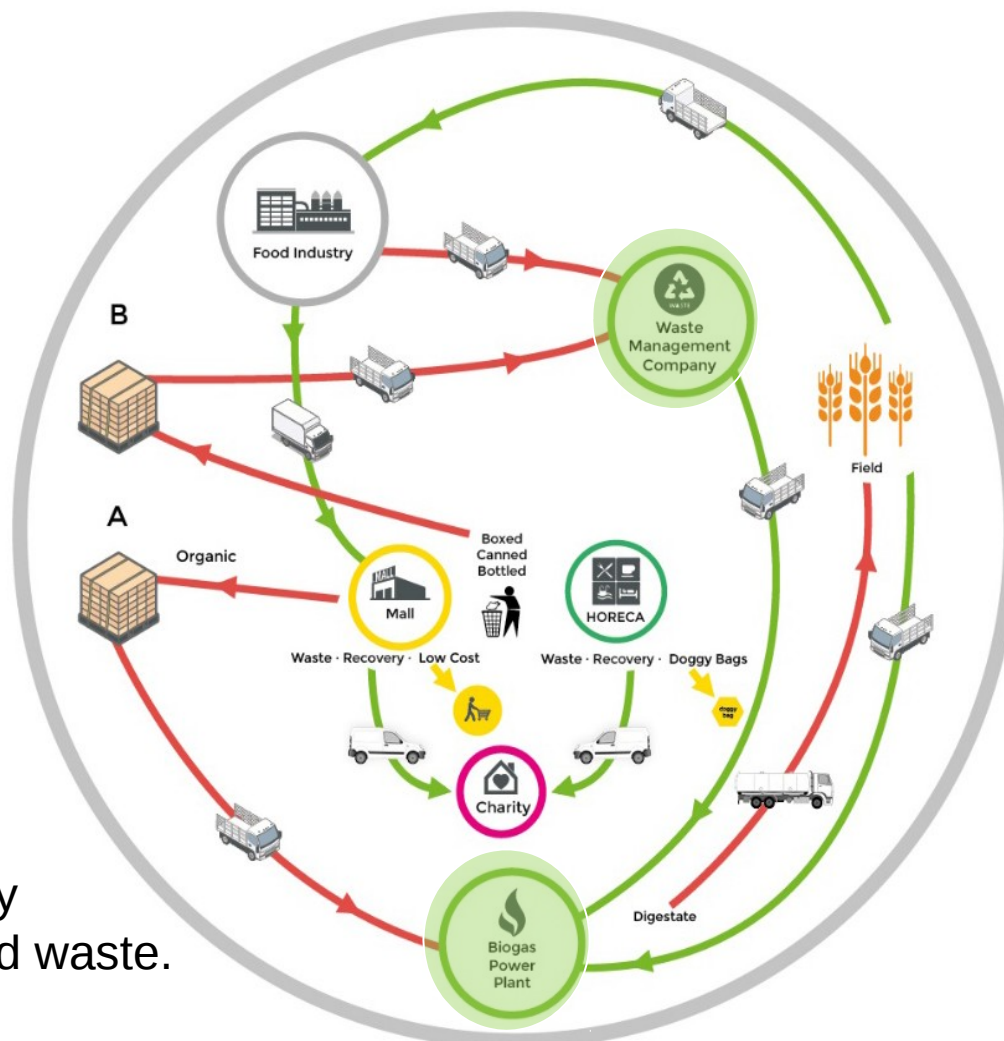


Waste 
Matter 

Waste food user

Selling bioenergy produced by food waste.

The iRexfo business model requires technical environmental and economic sustainability on the entire Life Cycle.





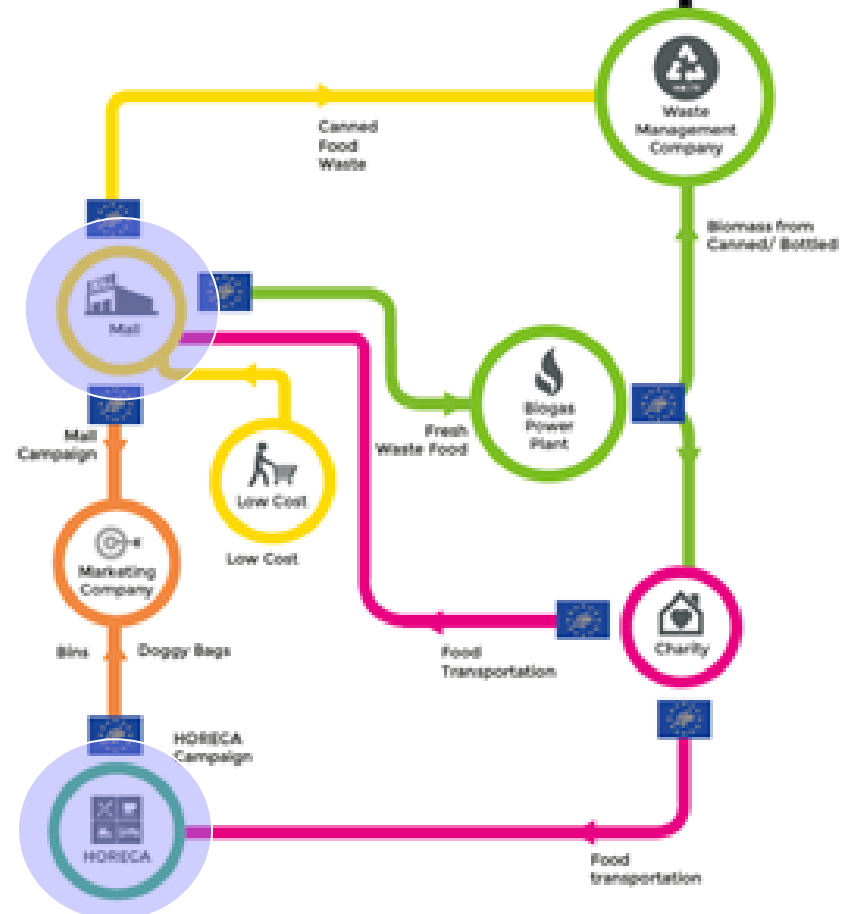
During the Life Project



Food industry



if (isatty(
 stdout)
 && !isatty(
 stderr))



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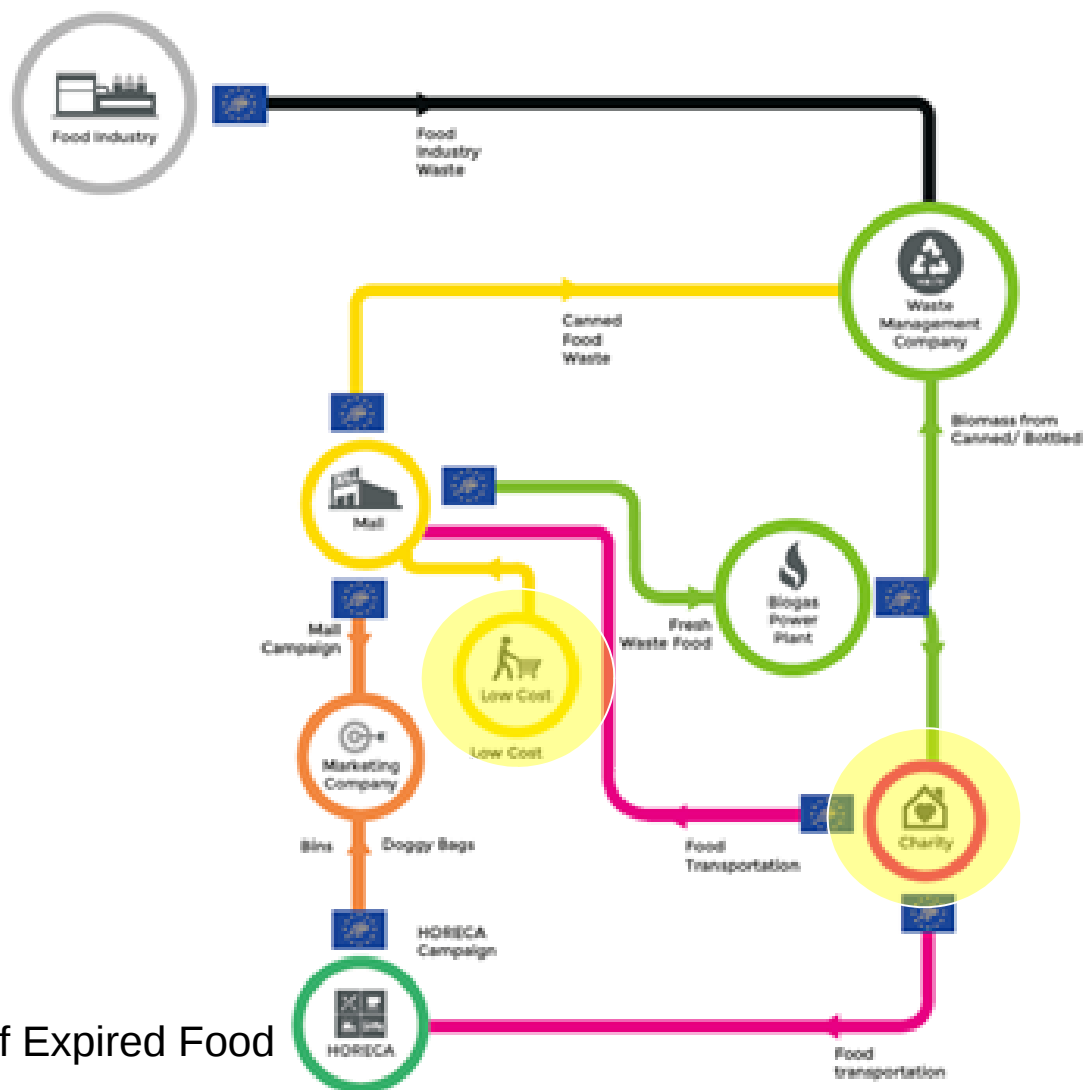
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Sostenibilità economica di i-REXFO

During the Life Project



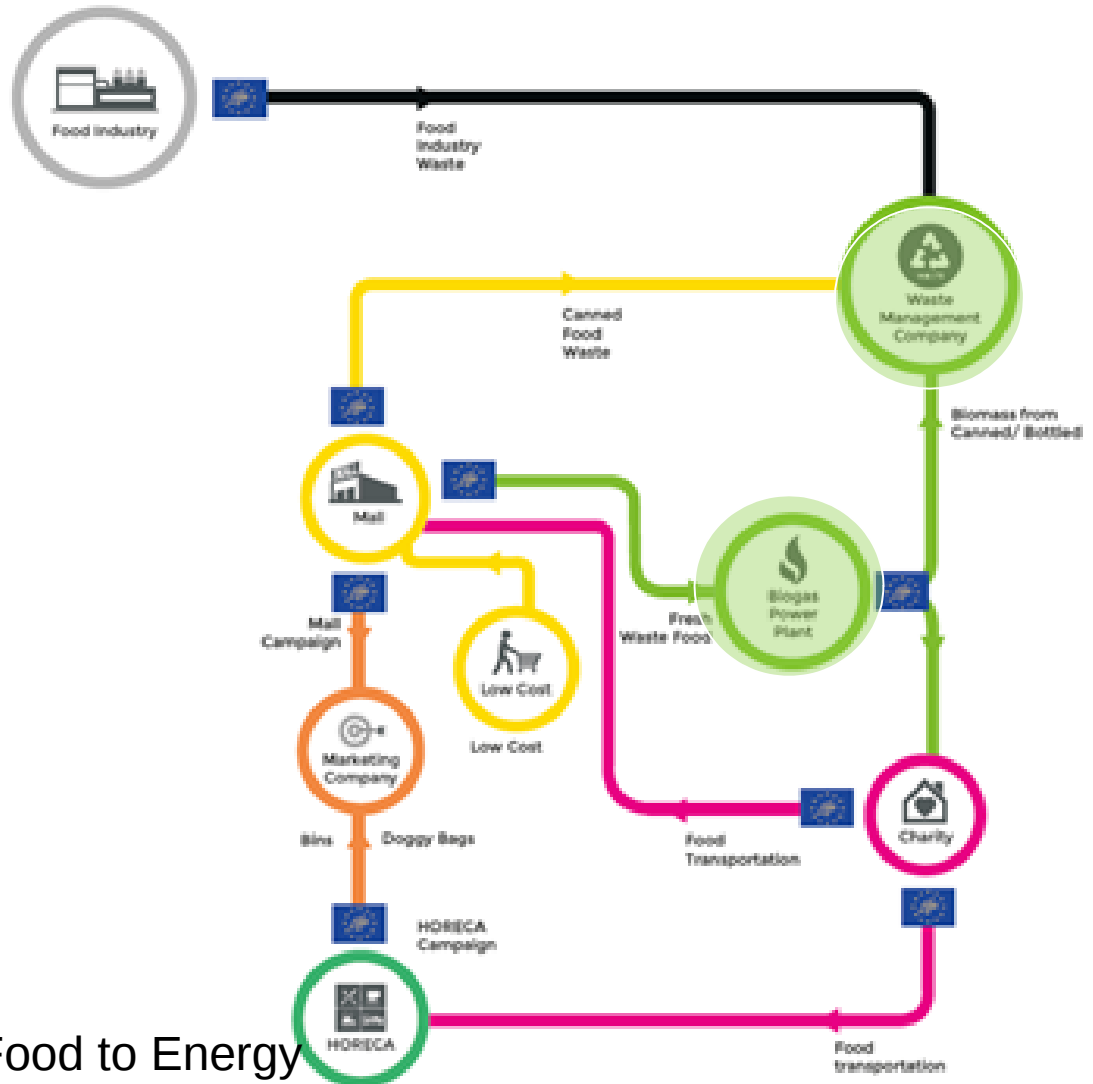
Surplus food
Users



REF chain – Reduction of Expired Food



During the Life Project



Waste Food Users



EFE chain – Expired Food to Energy



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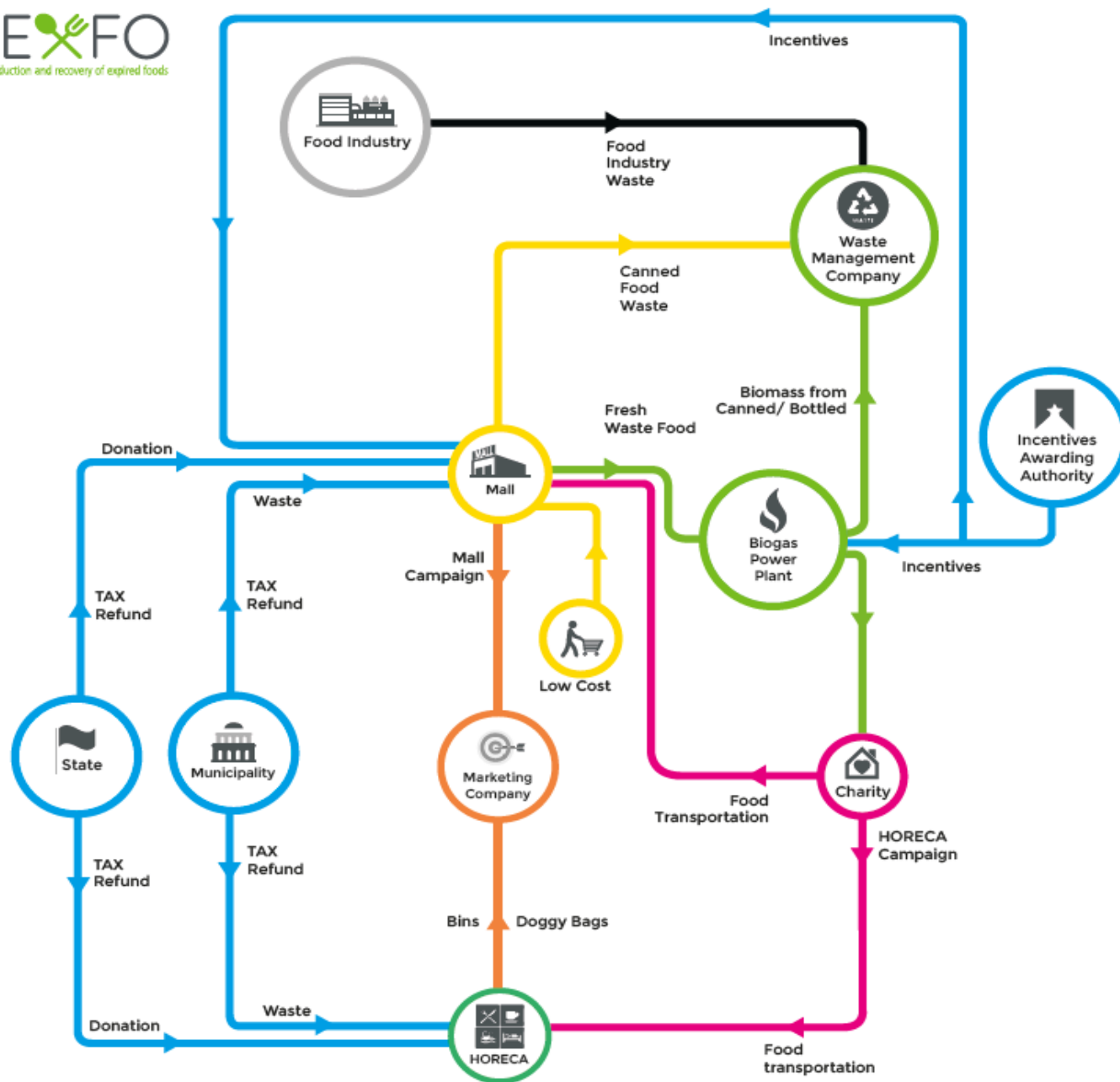


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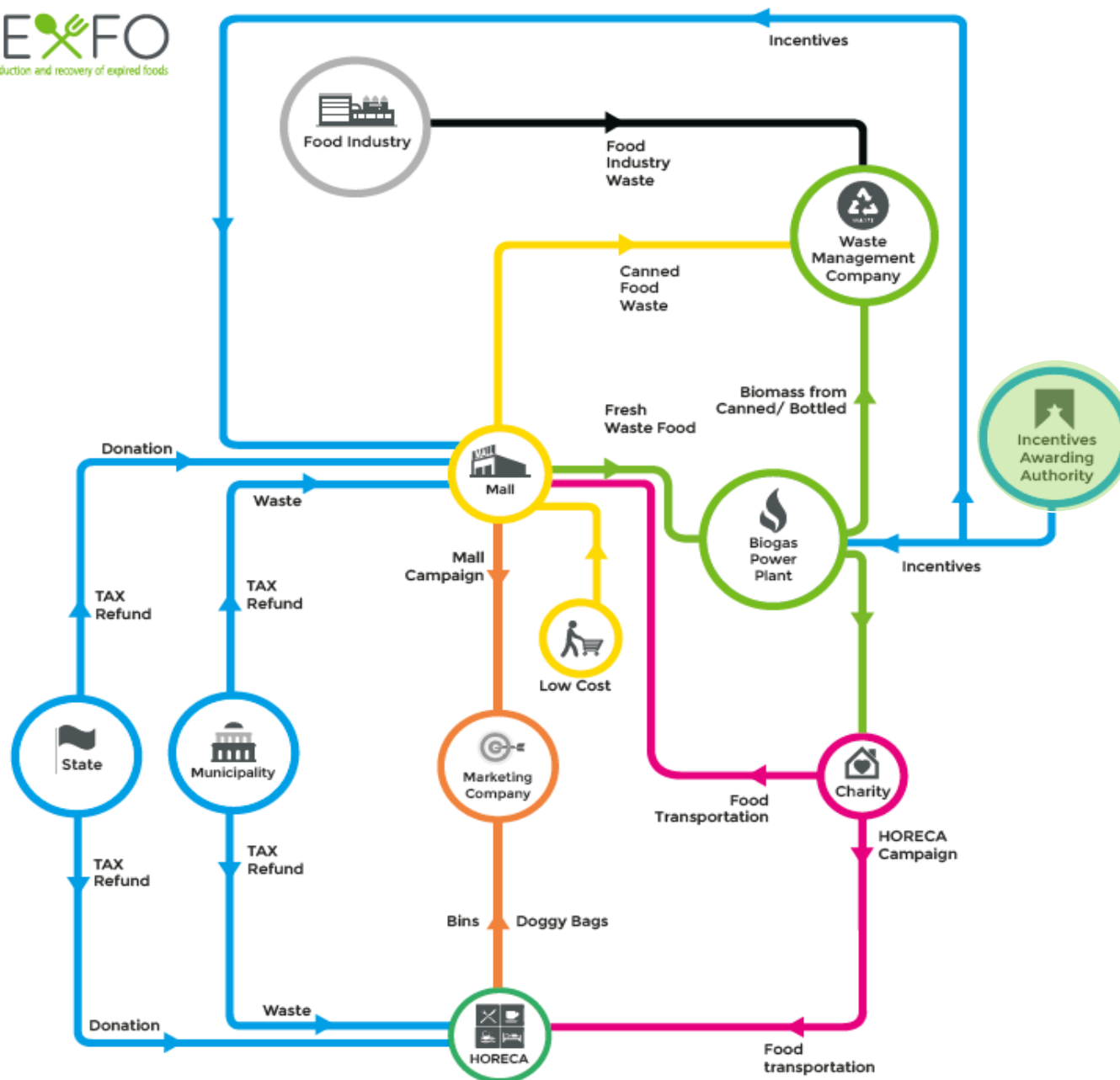


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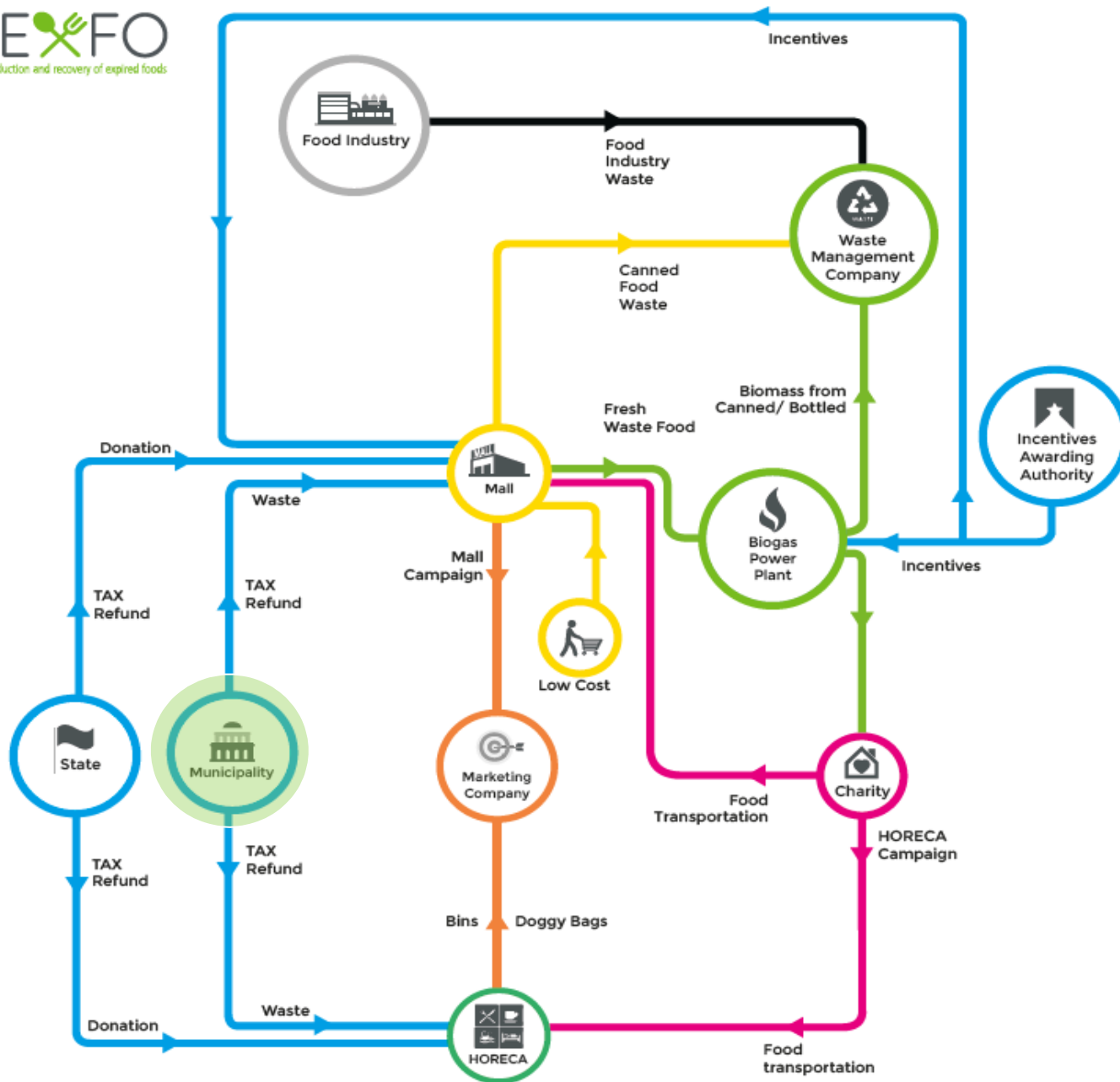


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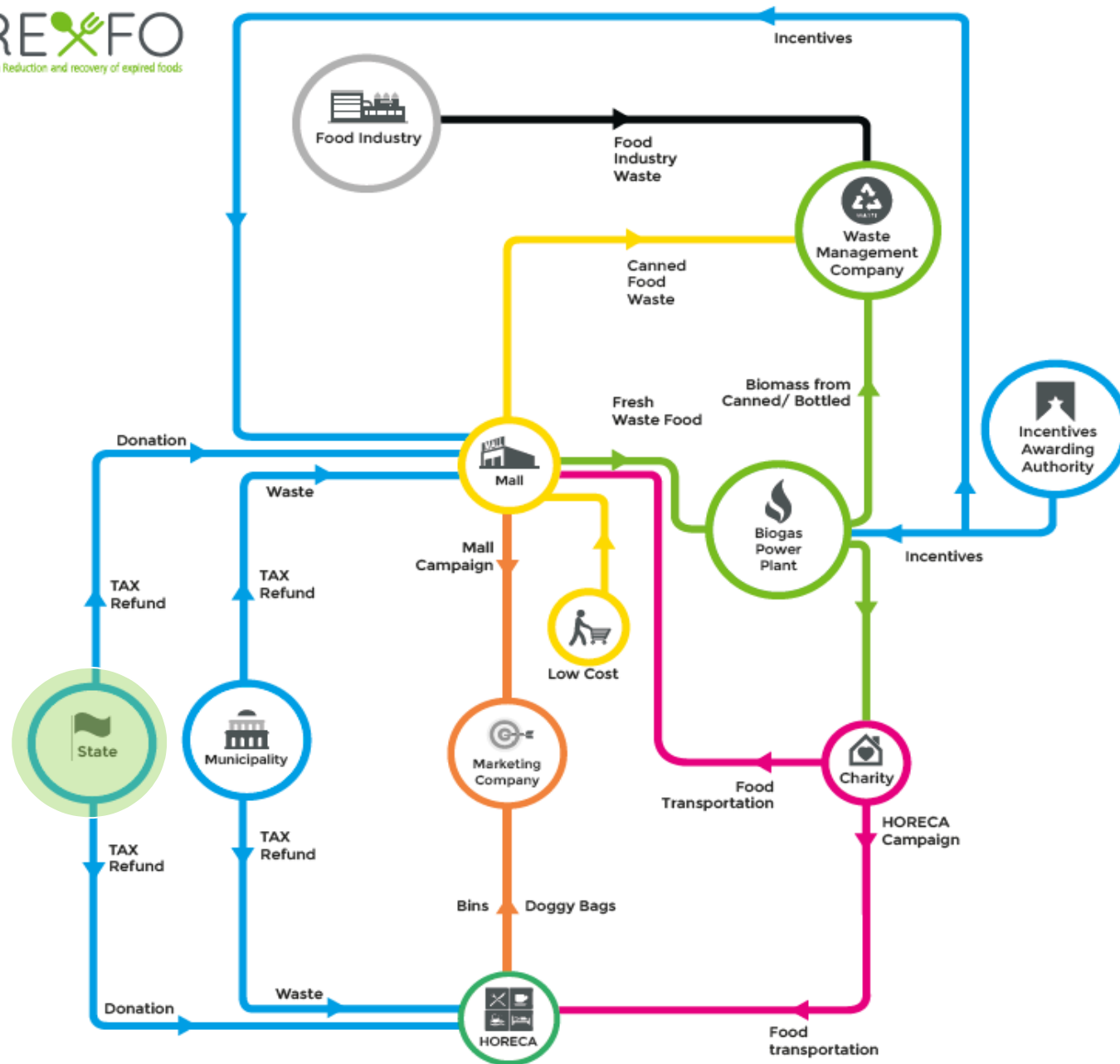


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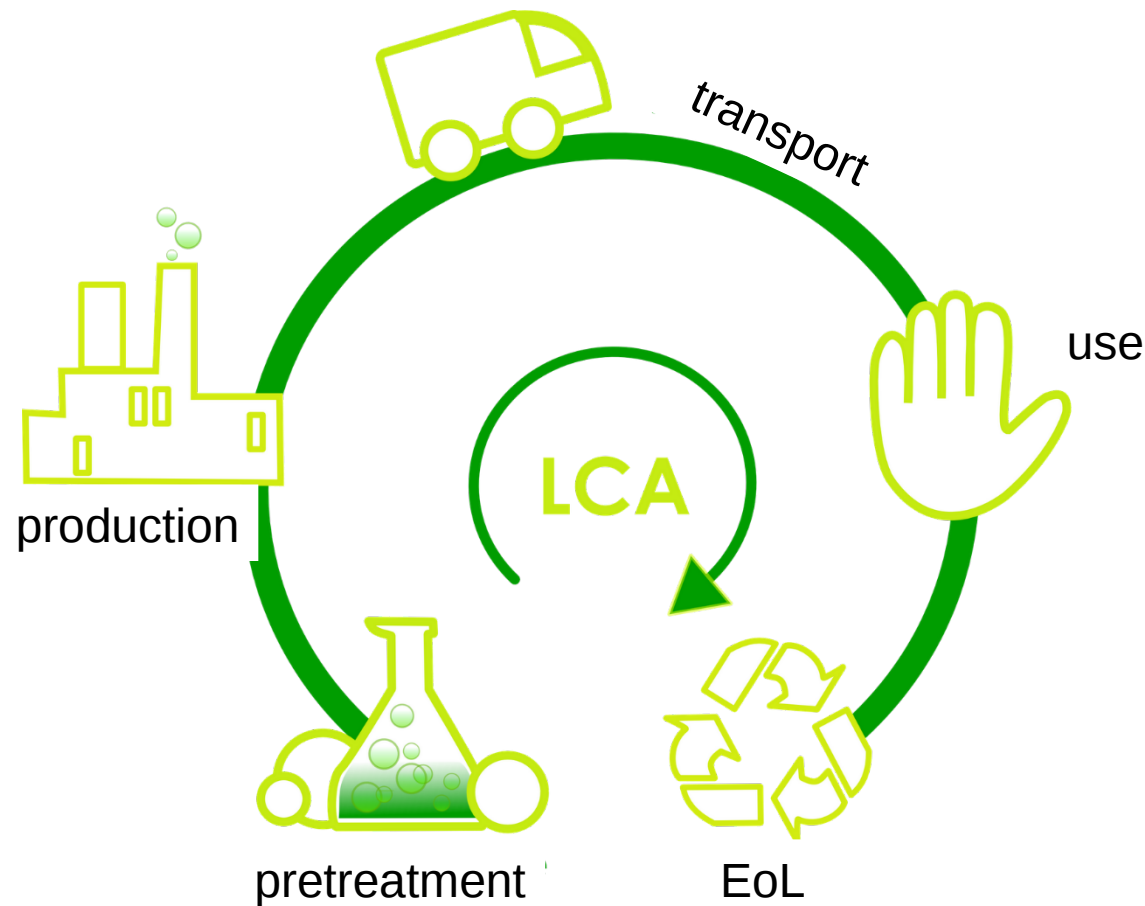


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iREXFO is optimised on a Life Cycle perspective



An OPEN SOURCE tool will optimize the:

- Technical performances;
- Economic performances;
- Environmental performances.



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i-REFO

Increase in the REduction and REcovery of EXpired FOod

1. Trasferability tool



+



Good practices: Denmark

4. Transfer - Hungary



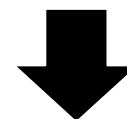
2. Design

Circular diagram of the i-REXFO approach

i-REXFO




Waste
Matter



3. Demo - Umbria



i-REXFO Partners

 University of Perugia (CO)



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	A + Srl. Outsourced marketing		Communication strategy in IT
	Biogáz Unió ZRT.		Transferability (EFE chain)
	Solidarietà Caritas Onlus		Pilot action on REF (charity)
	Associazione di Volontariato SAN MARTINO		Pilot action on REF (charity)
	ECOPARTNER srl		Pilot action on EFE Waste pre-treatment
	Hungarian Food Bank Association		Transferability (REF chain)
	Noesis snc		Reporting and administration
	Primetime Kommunikation A/S		Communication, good practice
	Regione Lombardia		Legislation and permit
	Azienda Agricola		Pilot action on E
	famila		gas
	Superconti		





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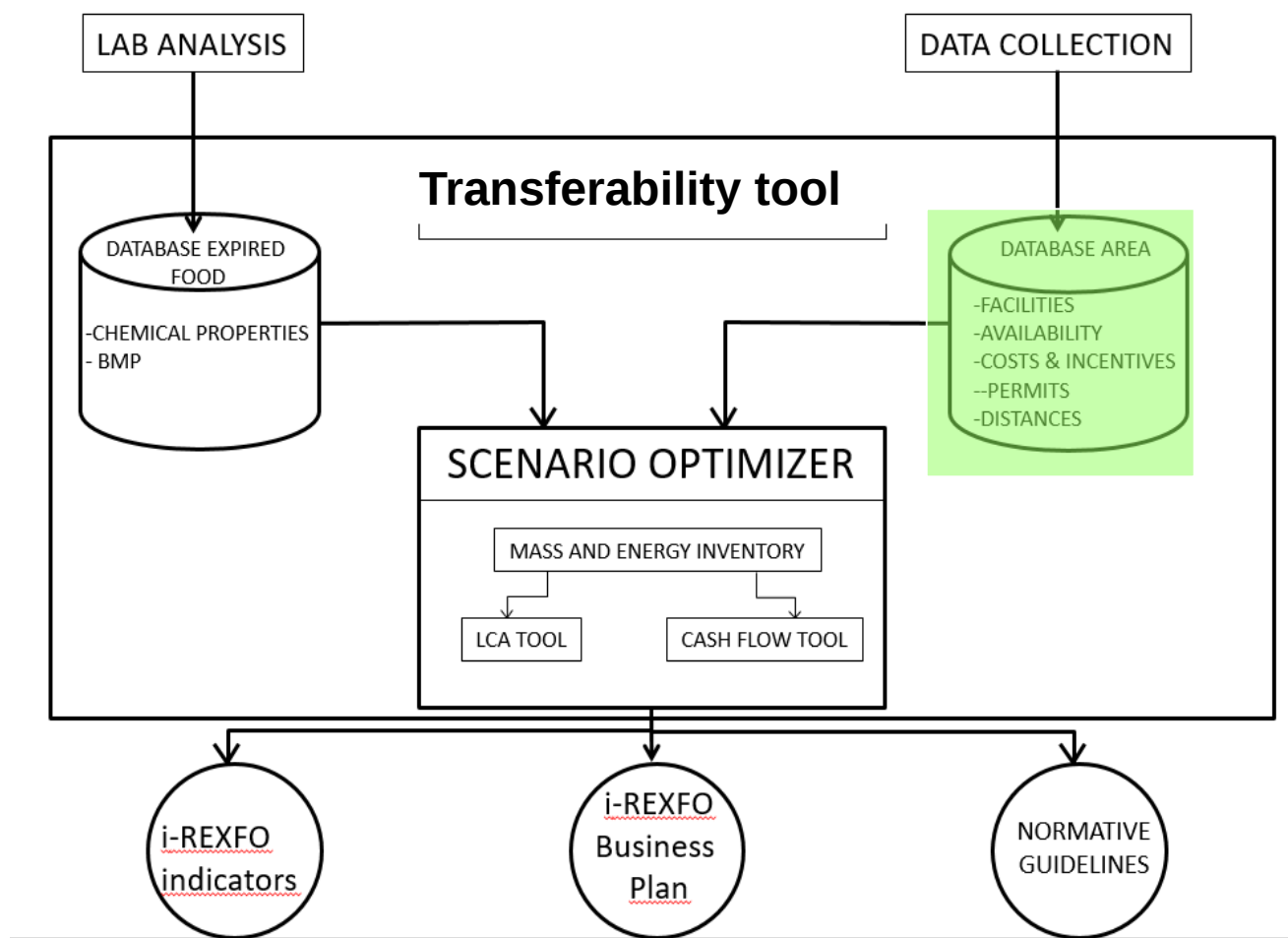


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Increase in the REduction and REcovery of EXpired FOod

1. The transferability tool





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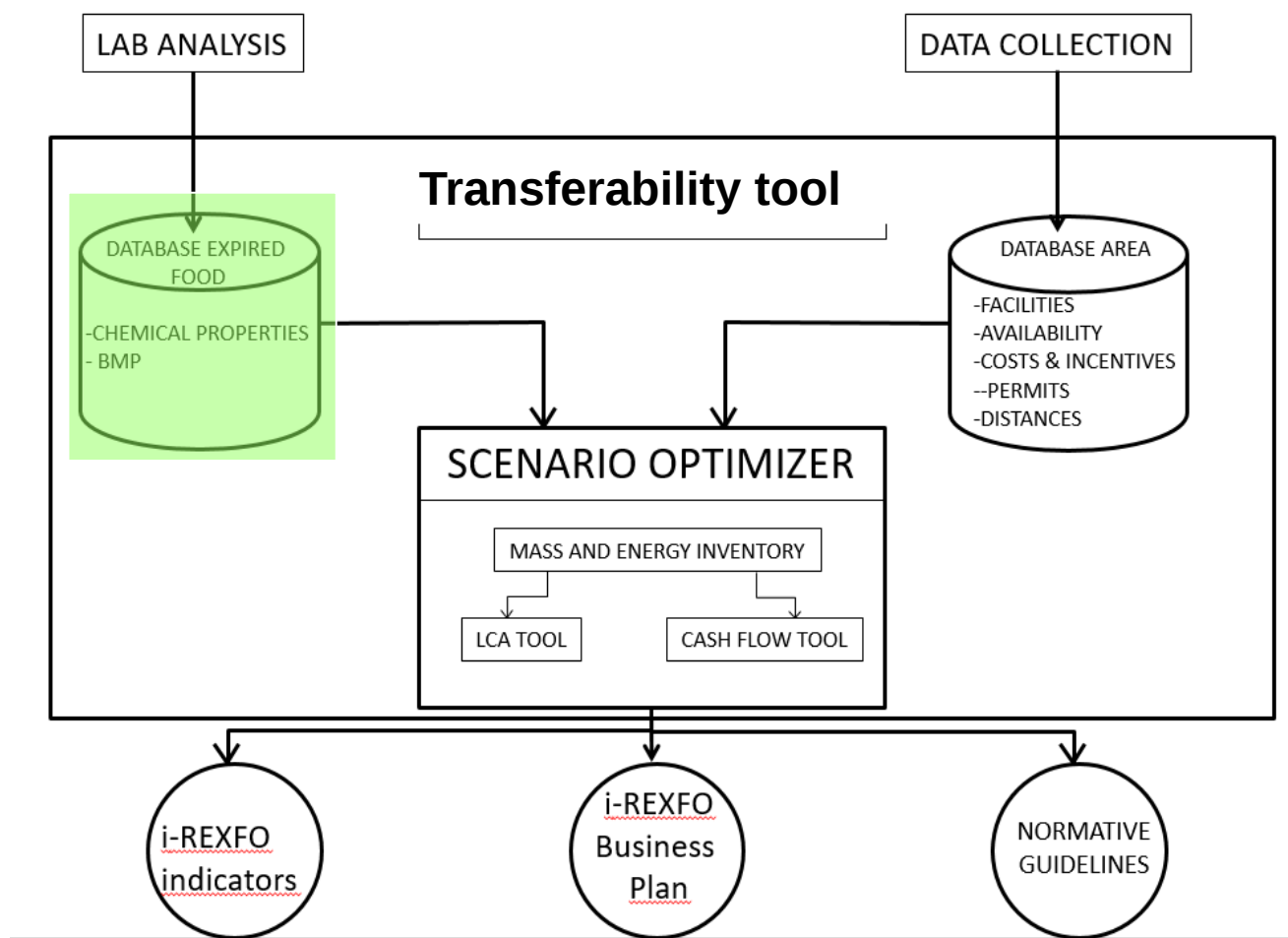


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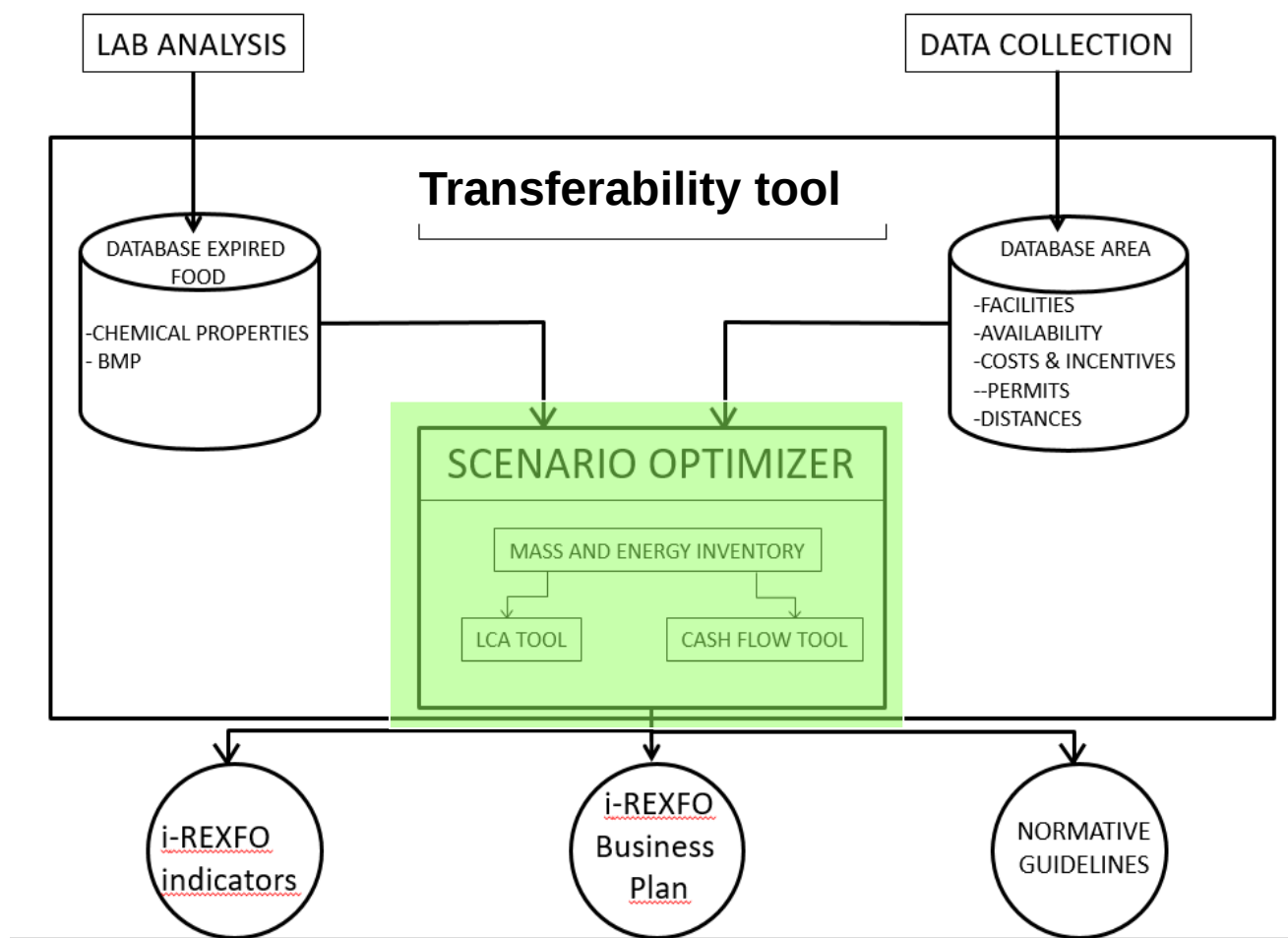


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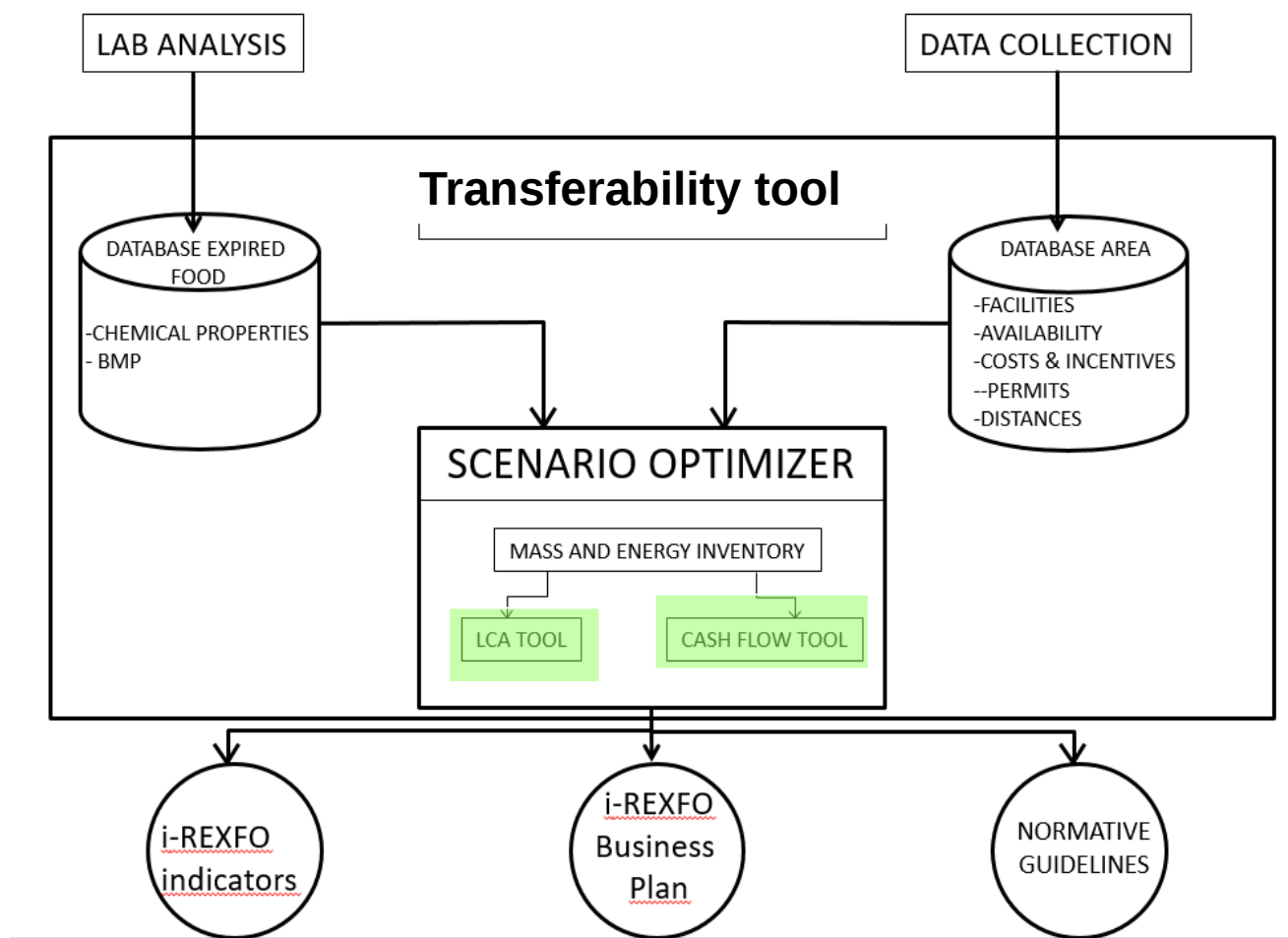


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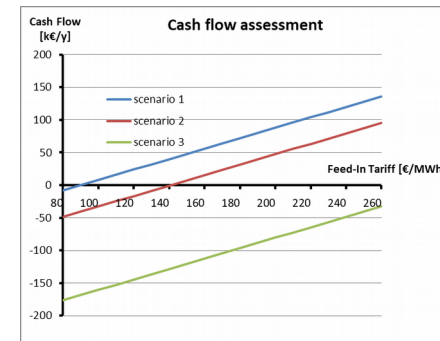
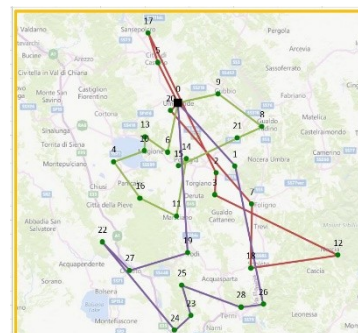
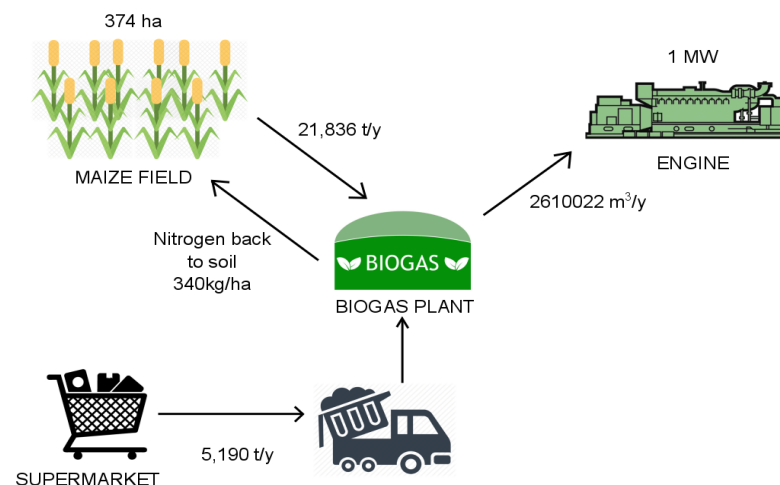
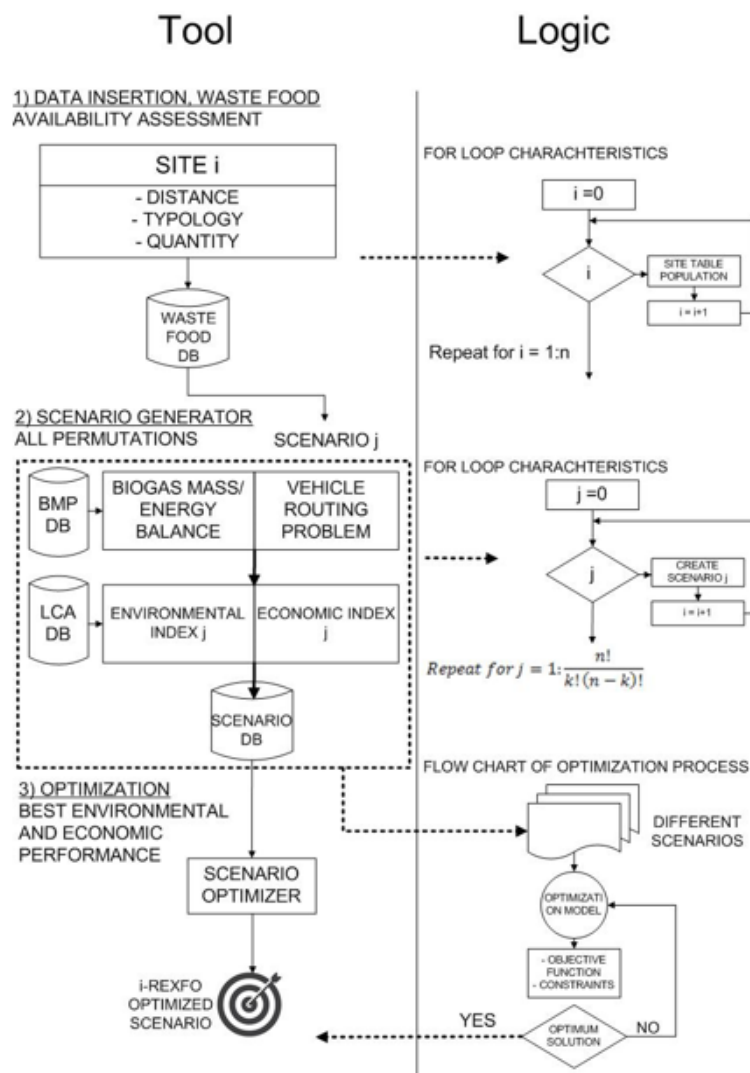


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i-REFO

Increase in the REduction and REcovery of EXpired FOod

2. DESIGN





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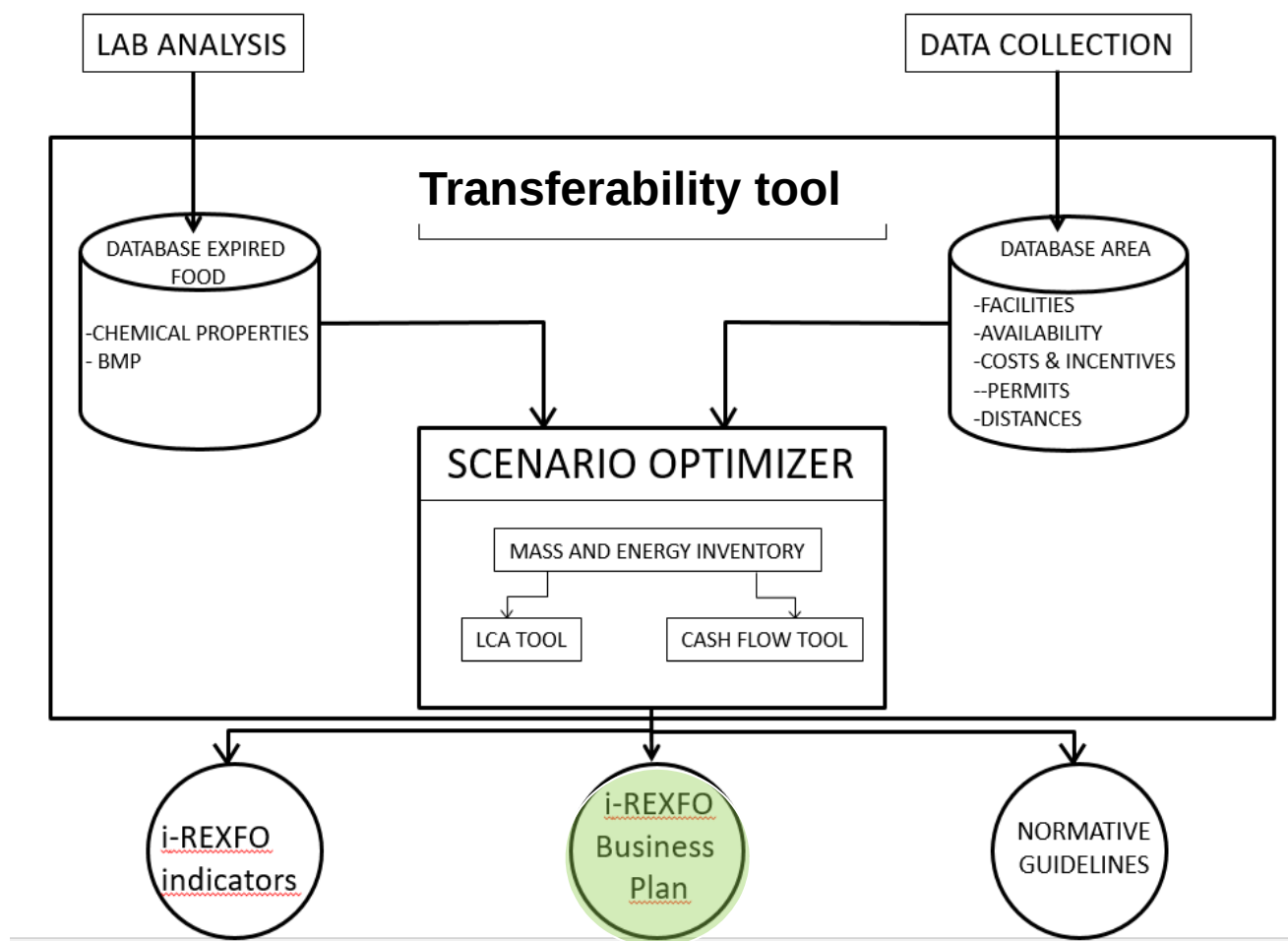


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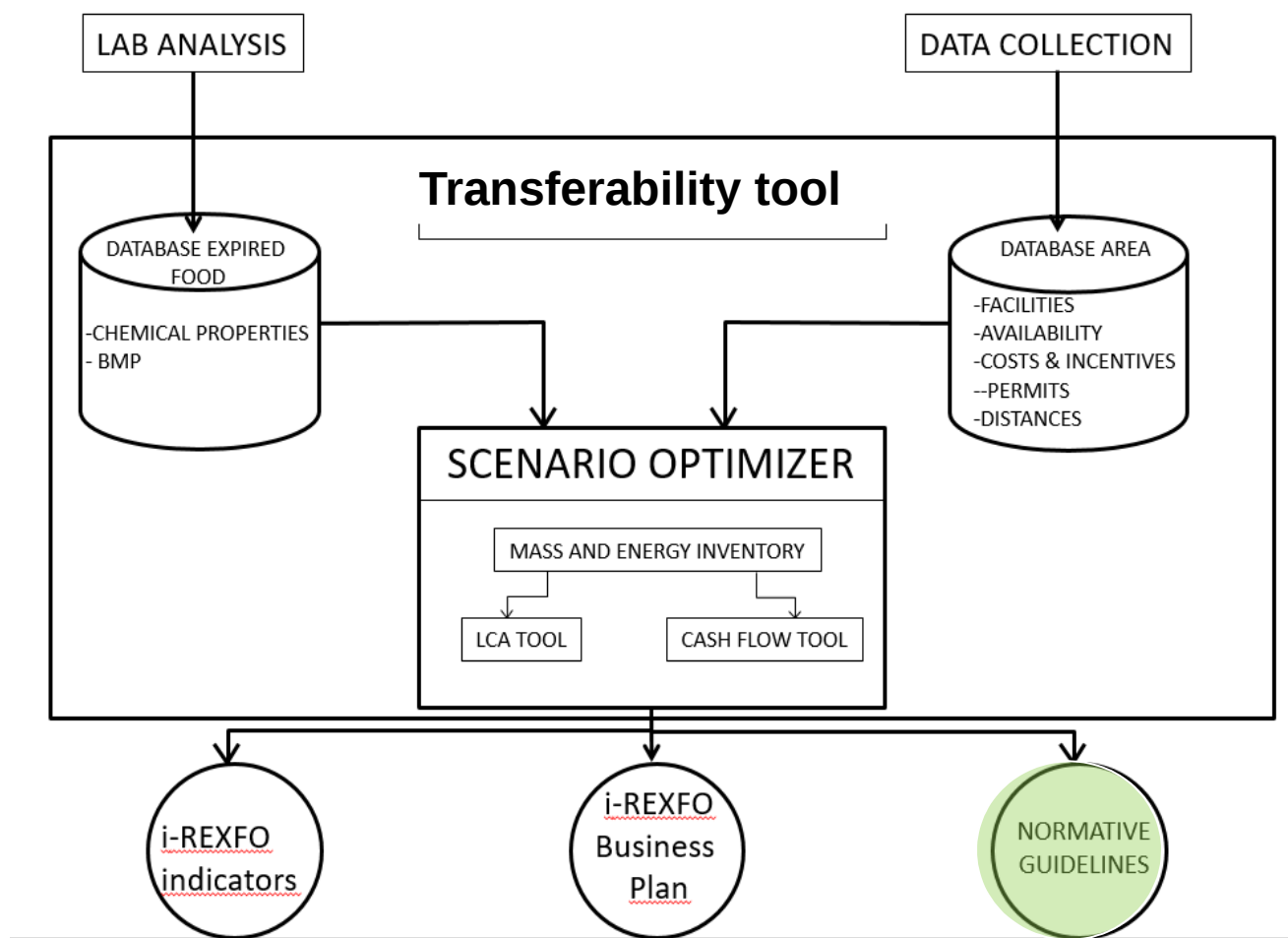


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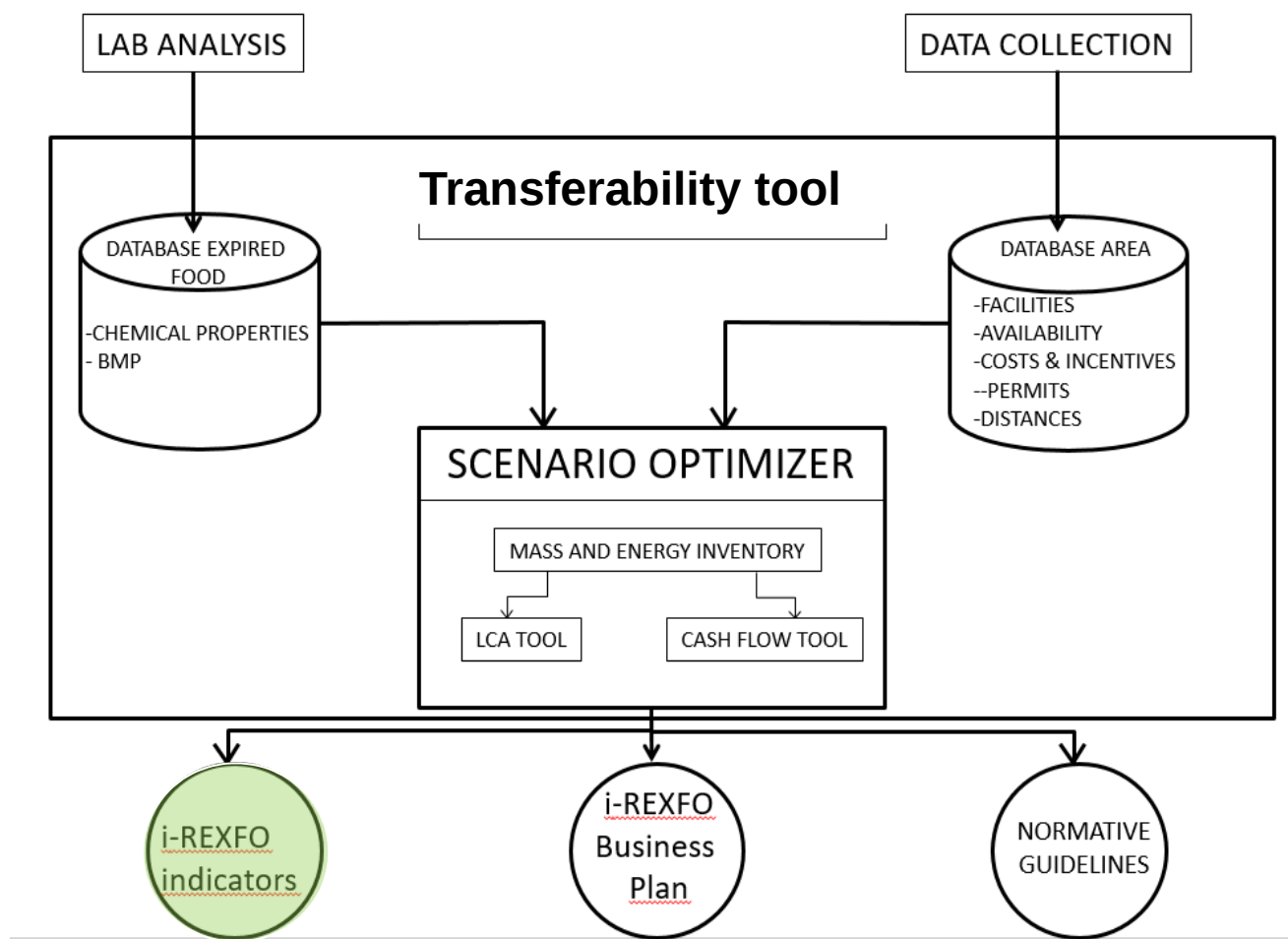


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Increase in Reduction and recovery of expired foods



i-REXFO EXPECTED RESULTS

- **CO2 reduction** **8.500 ton/year**
- **Waste Food Reduction** **3.400 ton/year**
- **Water Consumption Reduction** **480.000 m³/year**
- **Renewable Energy Production** **2.800 MWh/year**
- **Energy saving** **2.400 MWh/year;**
- **Land Occupation Reduction** **1.100 ha/year**
- **Awareness raised** **128.000 pax**
- **Changing behaviour** **25.000 pax**



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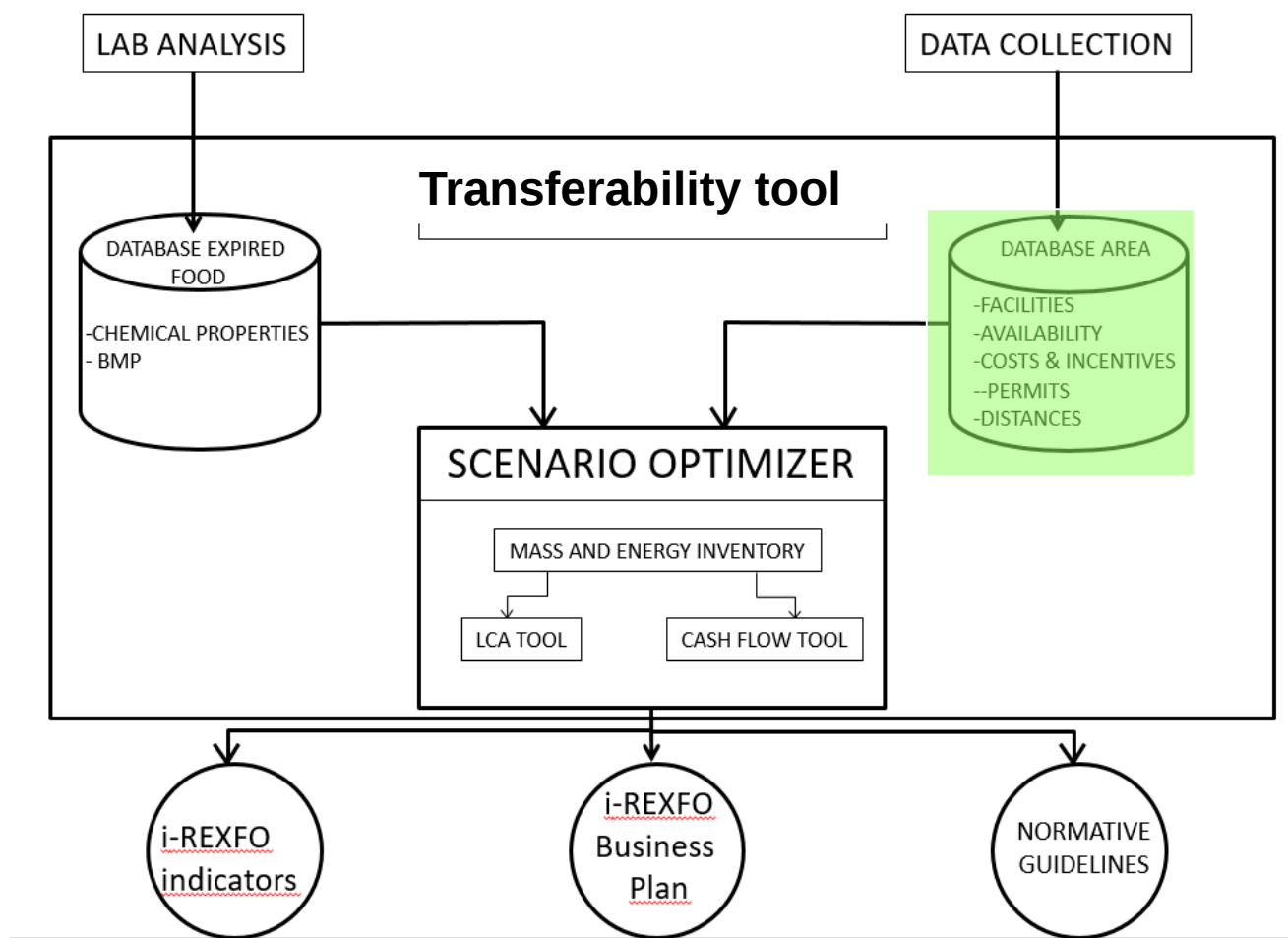


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Food waste and surplus availability

SCENARIO 1

Food waste

- 5 supermarkets in Umbria
- 18 food industries in Italy

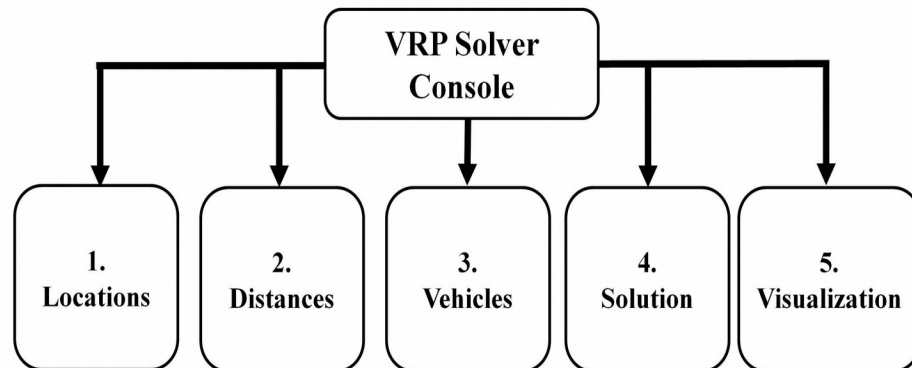
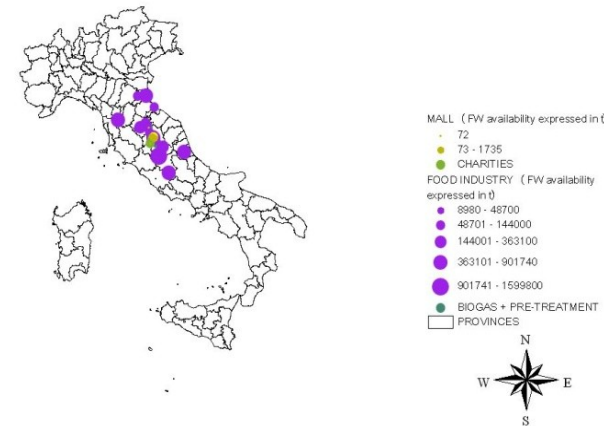
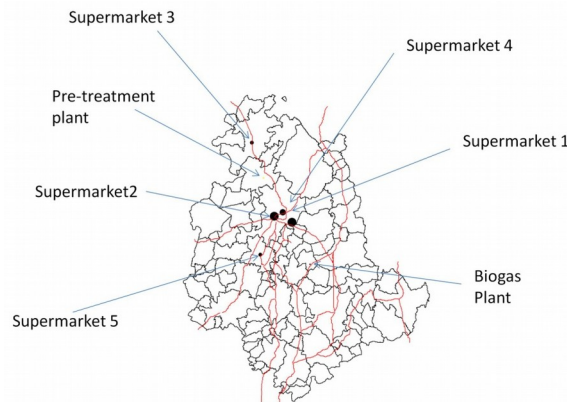
SCENARIO 2

Food waste

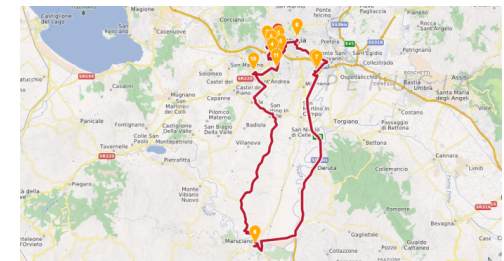
- 18 food industries

Food surplus

- 5 supermarkets in Umbria



Food waste collection for
Charity purposes (Perugia)





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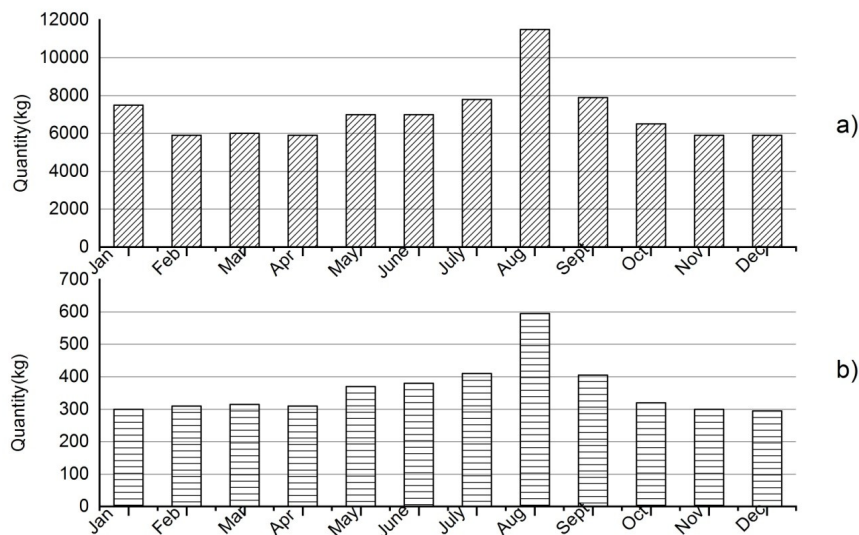
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Results: Supermarket waste production (projection year 2019)

Type of food waste	Supermarket A		Supermarket B	
	Mass (kg)	Percentage (%)	Mass (kg)	Percentage (%)
Fruit and vegetables	1,766	58	86,471	82
Meat and fish	479	16	13,770	13
Bread and sweets	1,723	56	350	0
Canned food	n.a.	-	3,866	4
Frozen food	315	10	1,241	1
Total	3042	100	105,698	100





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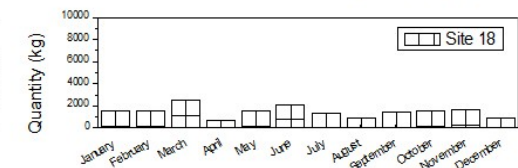
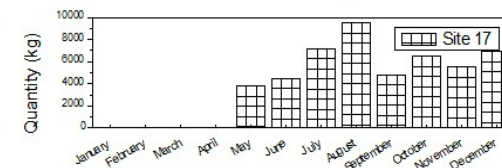
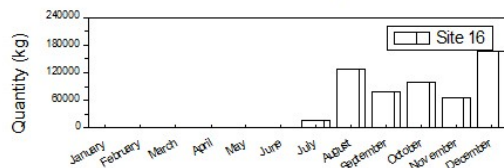
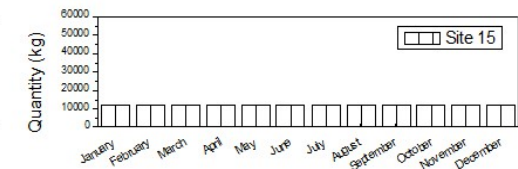
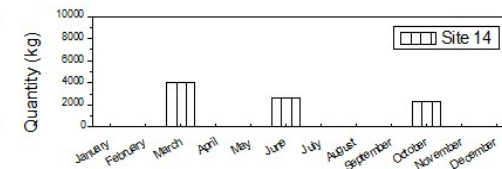
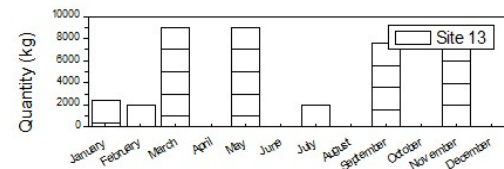
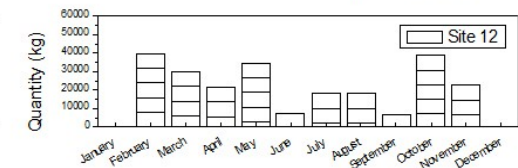
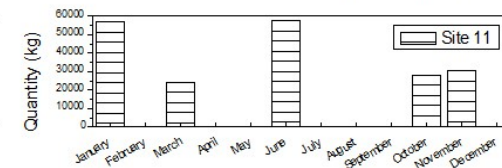
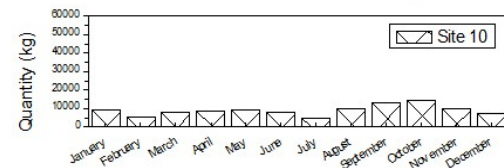
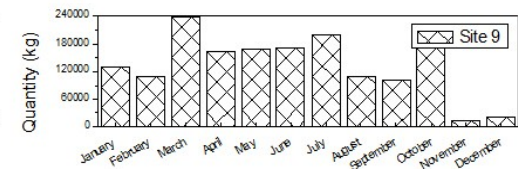
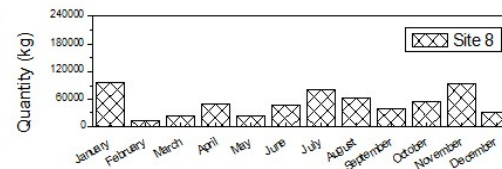
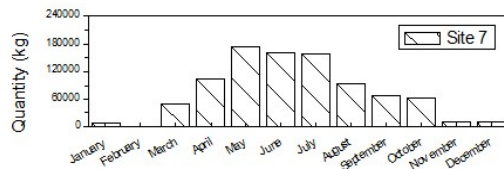
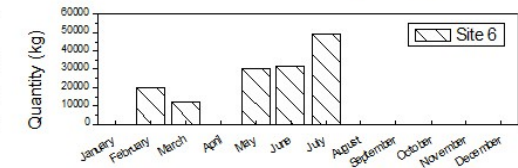
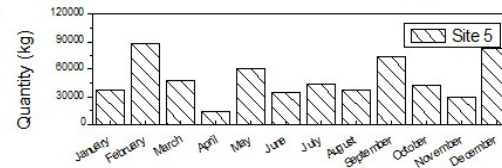
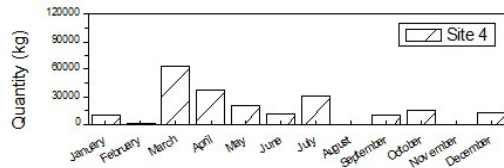
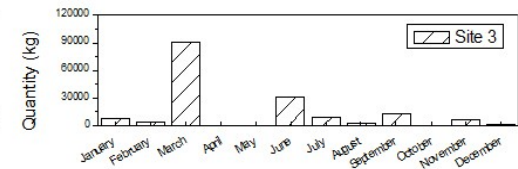
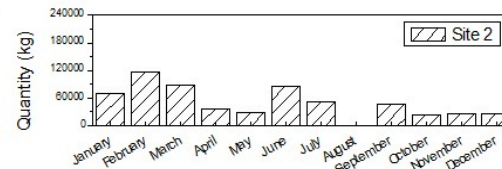
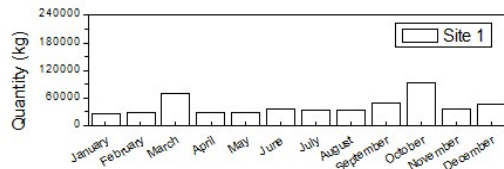


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Results: Food industry waste production





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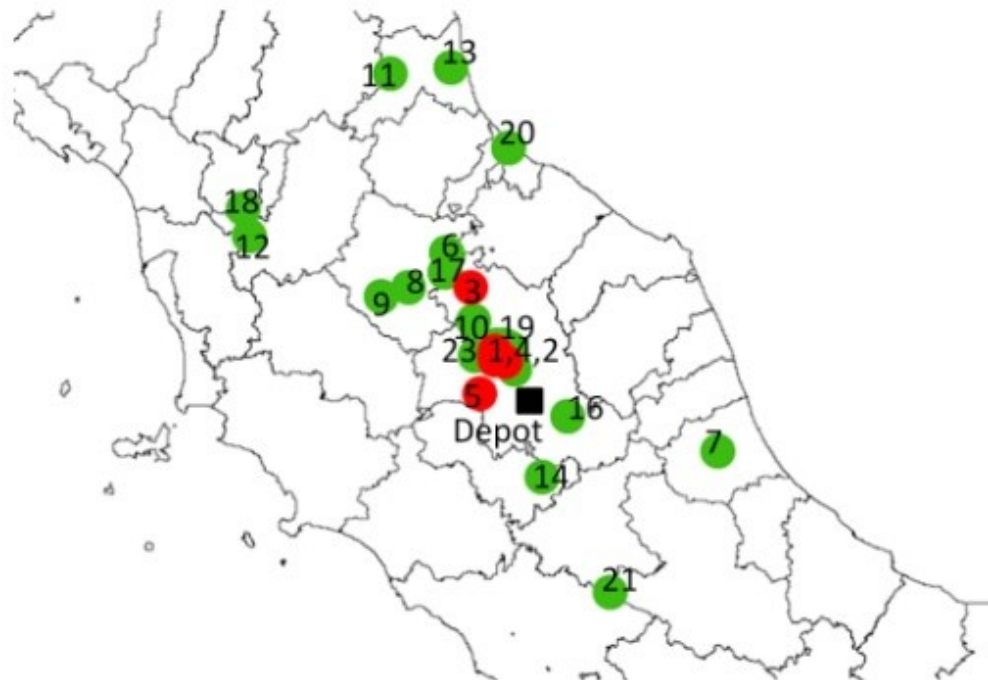
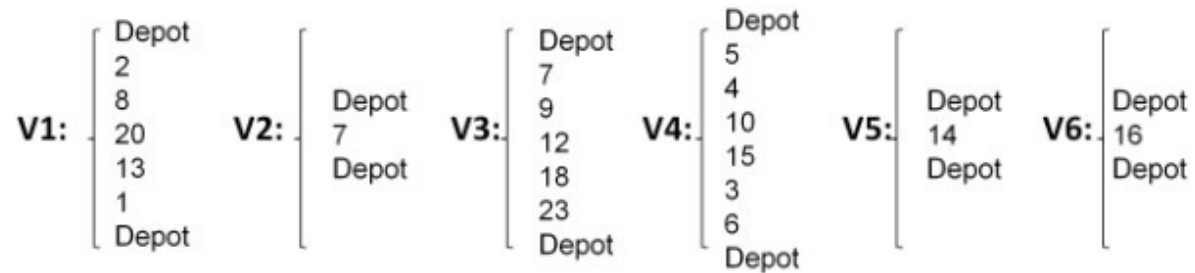


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Results: Route optimization process – 1st scenario





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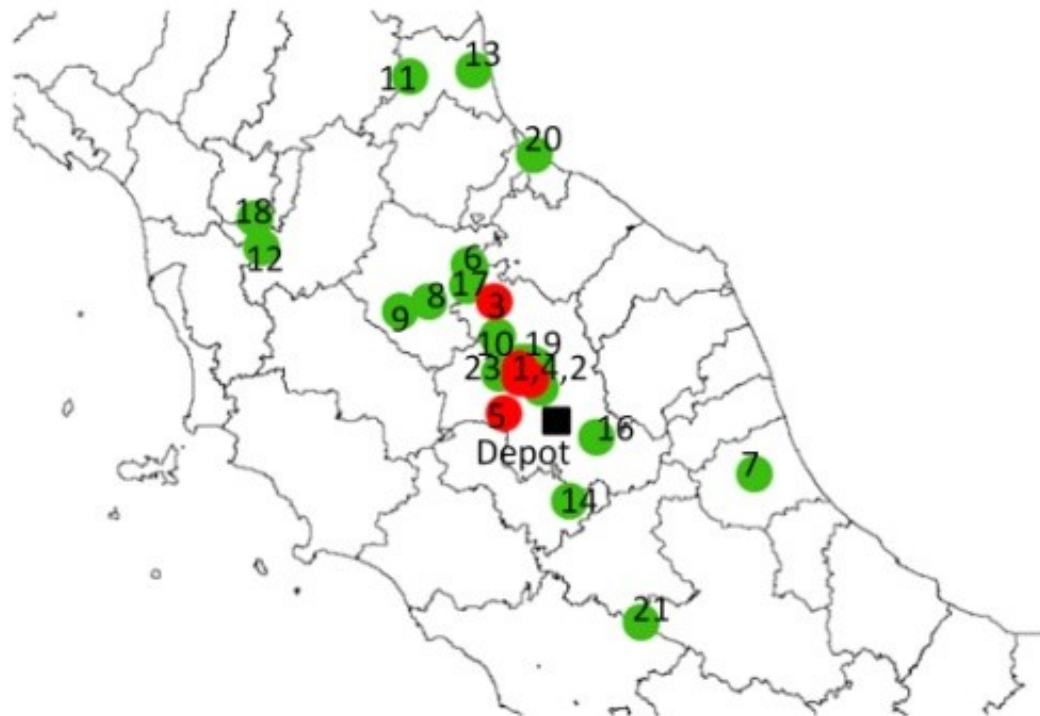
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Results: Route optimization process – 2nd scenario

V1:	Depot 14 Depot	V2:	Depot 7 Depot	V3:	Depot 8 20 13 Depot	V4:	Depot 10 12 18 Depot	V5:	Depot 23 15 9 6 16 Depot
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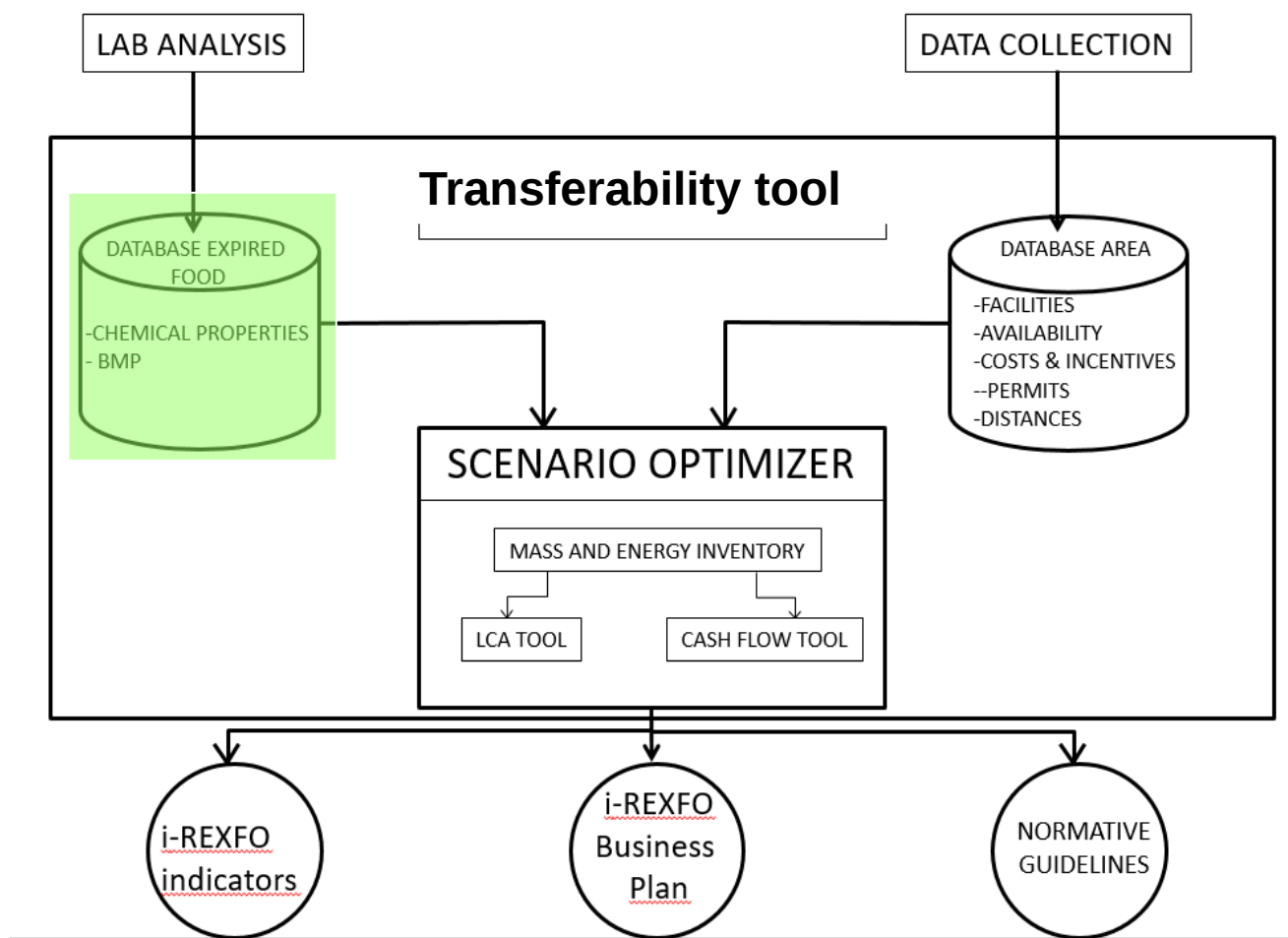


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FOOD WASTE CHARACTERISTICS

DATABASE - CHEMICAL AND PHYSICAL CHARACTERIZATION

Substrate: CHOCOLATE-PUDDING.....Chemical-and-physical-characterization¶



Ultimate-analysis¶

C (%wb)¶	43.50¶
H (%wb)¶	8.89¶
N (%wb)¶	1.14¶
C/N¶	38.18¶

Proximate-analysis¶

Moisture (%wb)¶	15.68¶
Total-solids (%wb)¶	84.32¶
Volatile-solid (%wb)¶	69.63¶
Asb (%wb)¶	1.19¶
Fixed-Carbon (%wb)¶	13.51¶

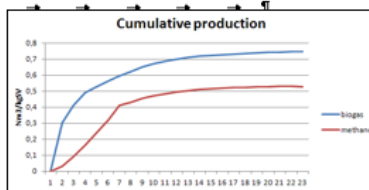
TOC (%wb)¶	-¶
TKN (%wb)¶	-¶
Fat (%db)¶	-¶
Protein (%db)¶	-¶
Carbohydrate (%db)¶	-¶
TP (%db)¶	-¶
TK (%db)¶	-¶
pH¶	5.13¶

BIOMETHANE-POTENTIAL-TEST¶

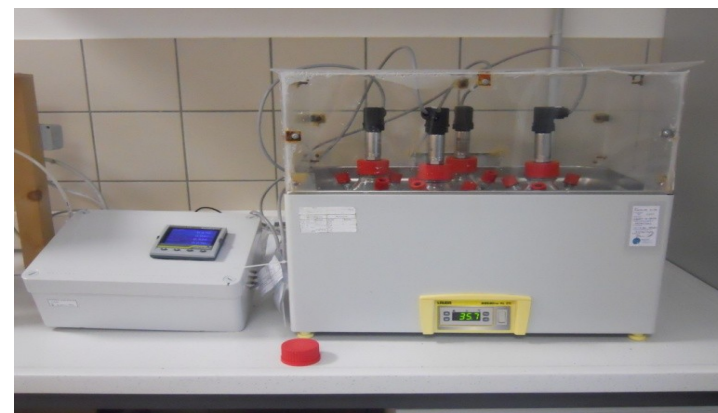
Experimental-design¶

Substrate/inoculum-ratio (VS-basis)¶	0.303¶
Temperature (°C)¶	40¶
Starting-pH¶	7.75¶
Total-Solids-mixture (%wb)¶	12.15¶
Volatile-Solids-mixture (%wb)¶	9.06¶
C/N-mixture¶	18.13¶

Results¶



Biogas-yield¶	0.747-Nm³/kg-SV¶
Methane-yield (BMP)¶	0.527-Nm³/kg-SV¶





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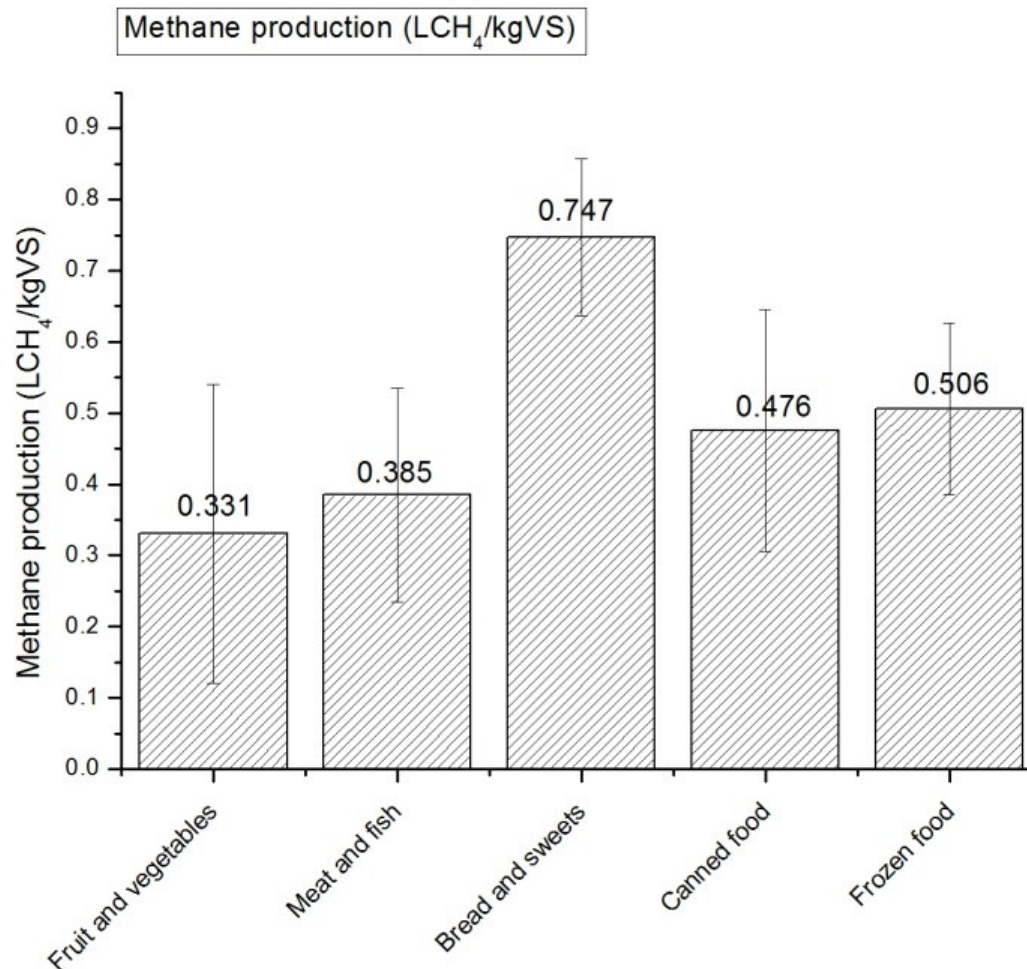


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Results of biogas yields laboratory analysis





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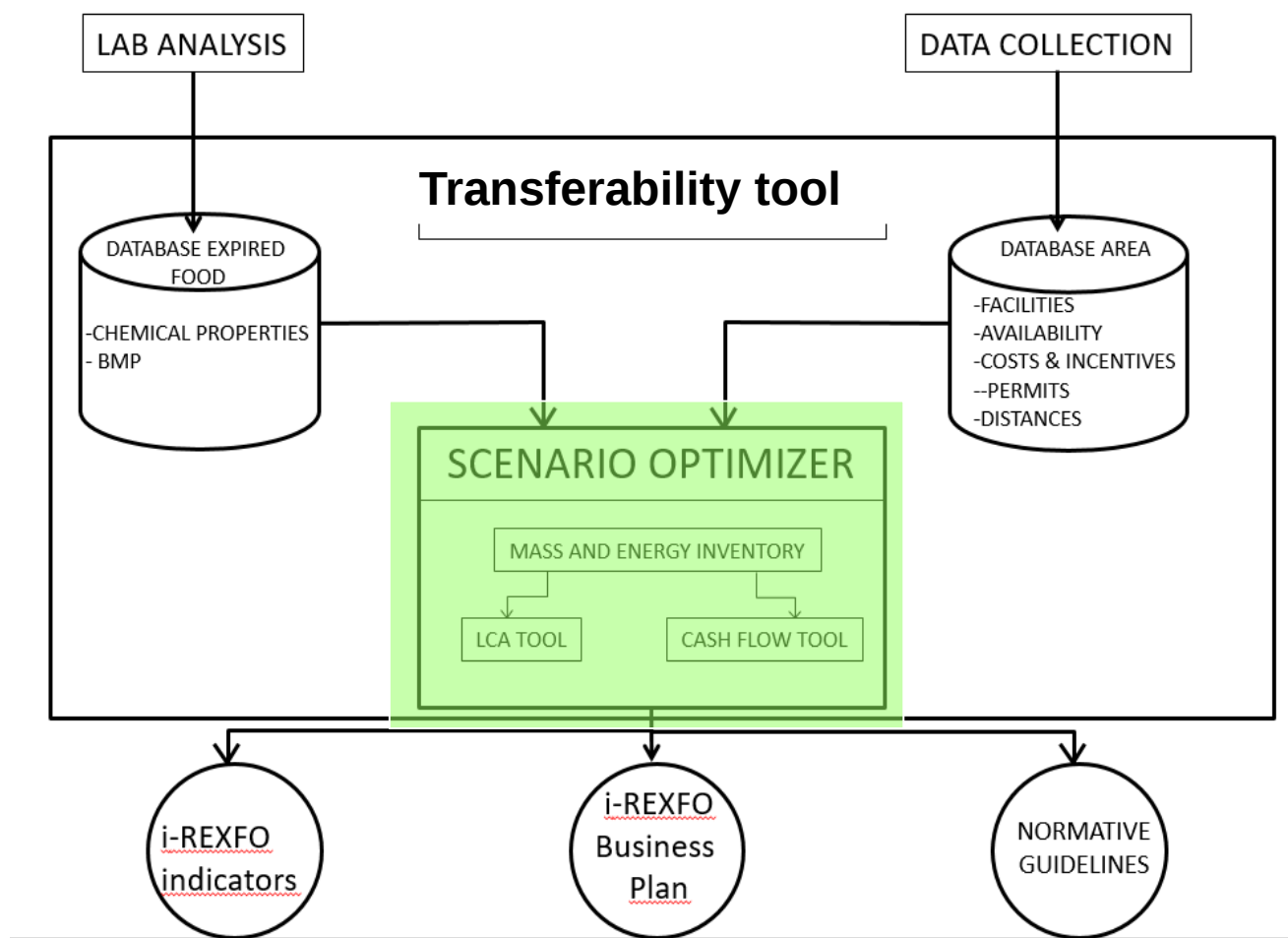


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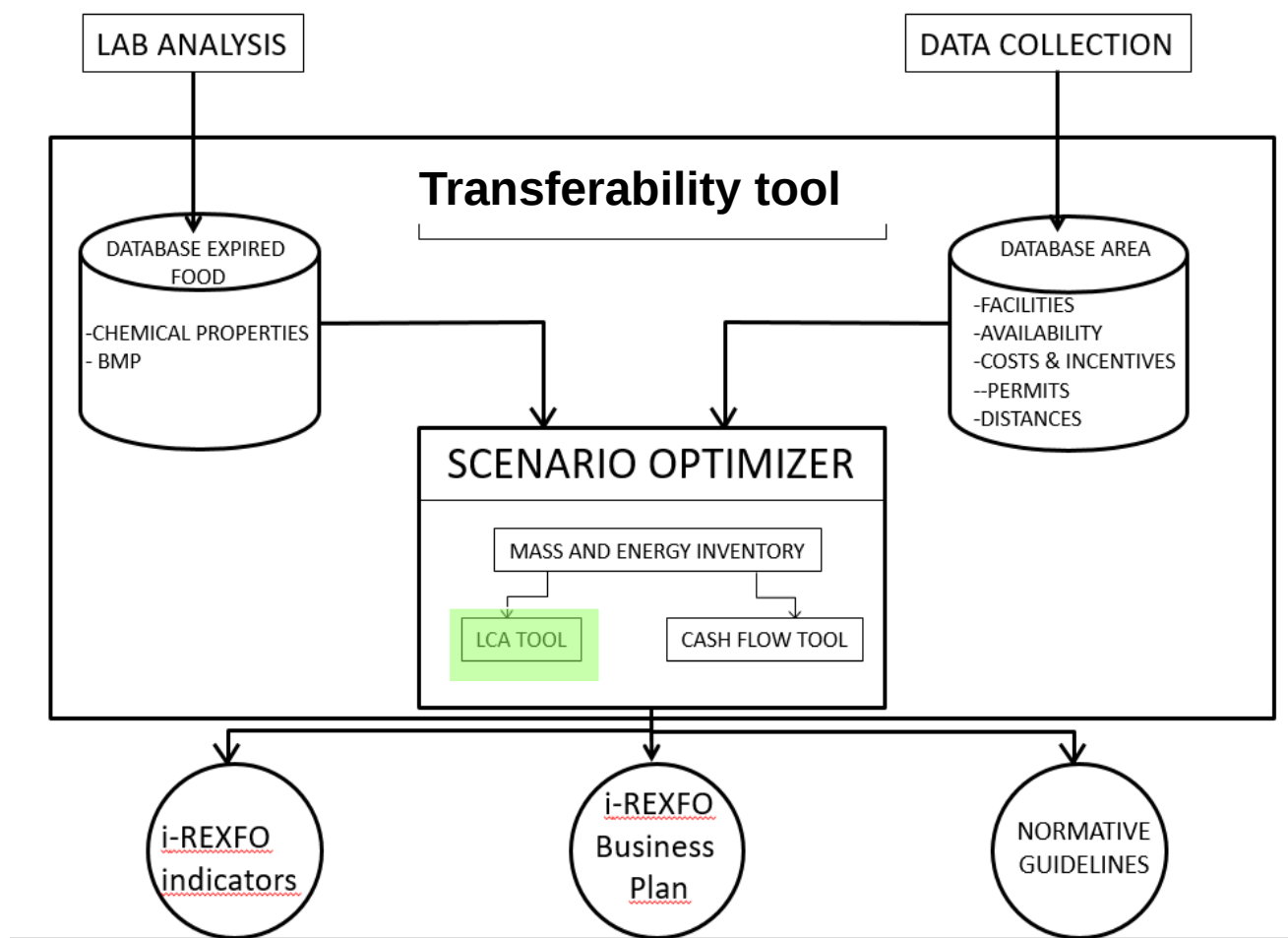


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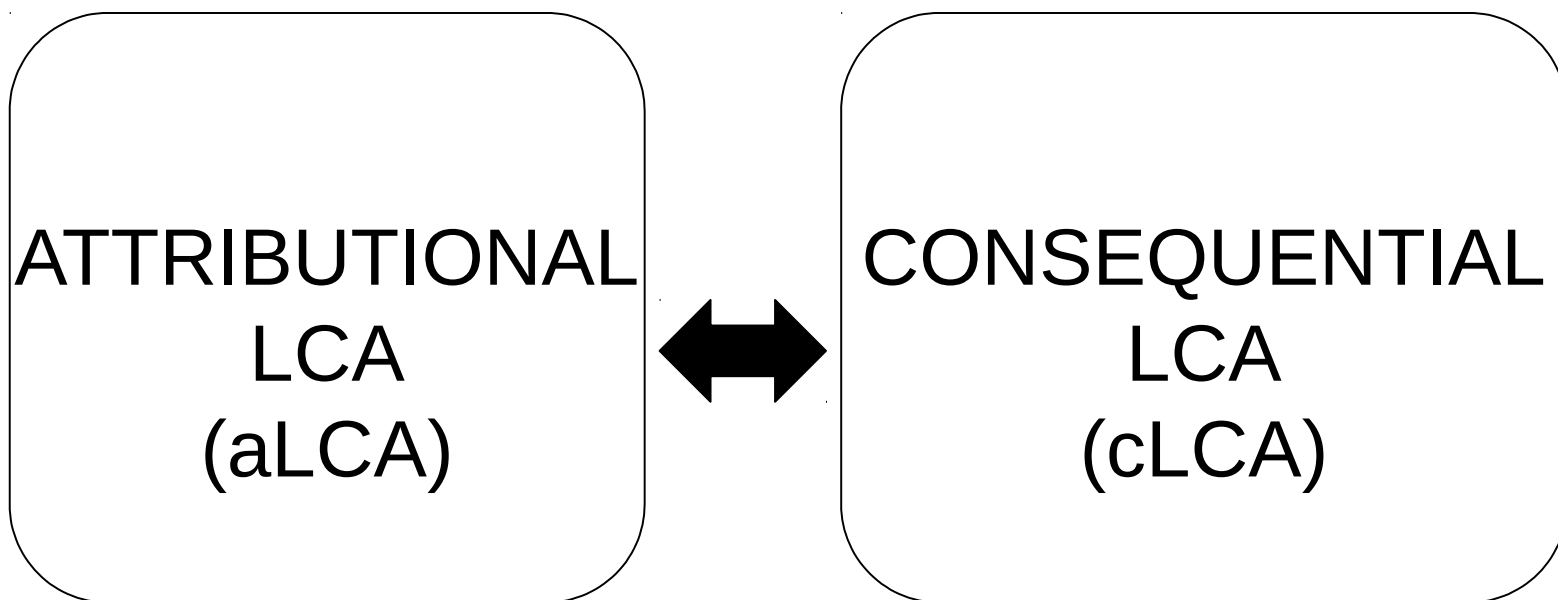


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Environmental Evaluation





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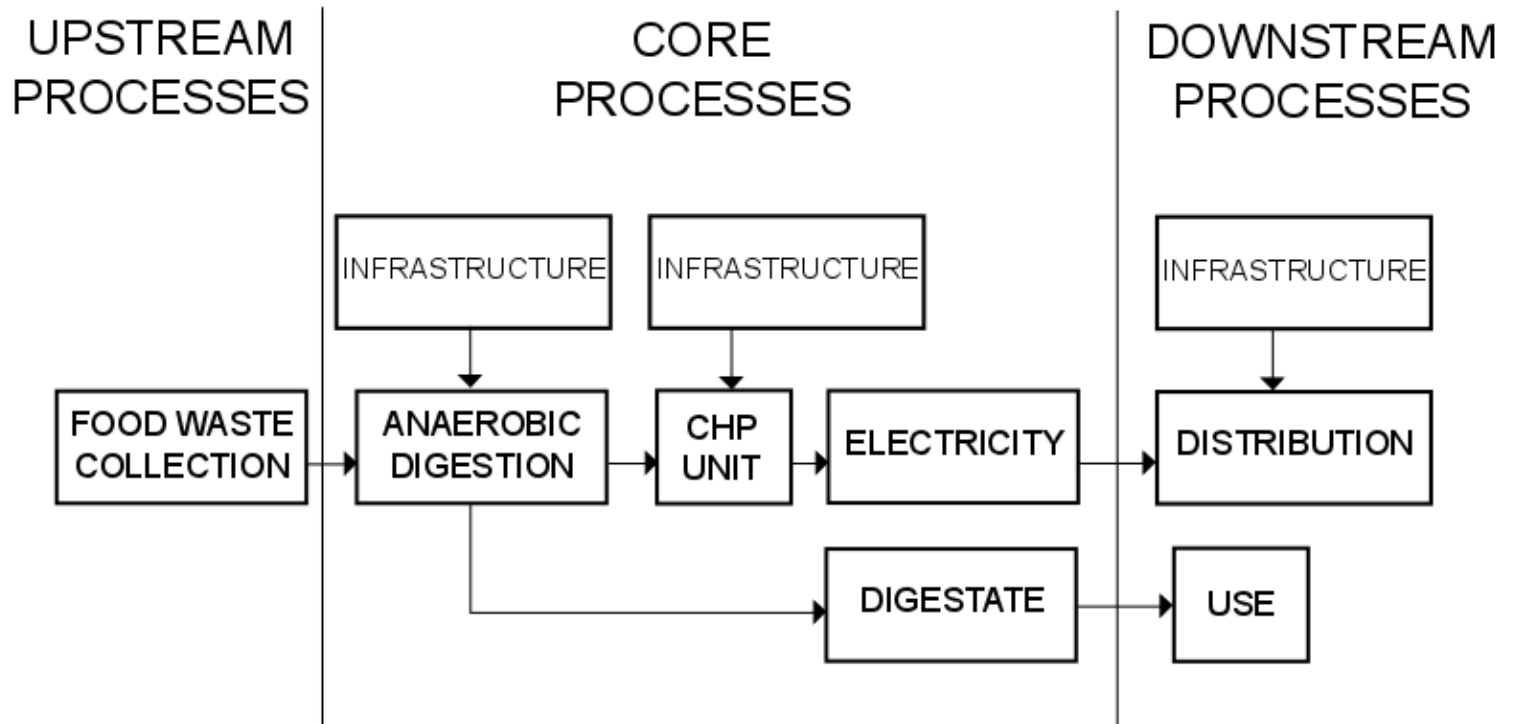


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Attributional LCA (aLCA)





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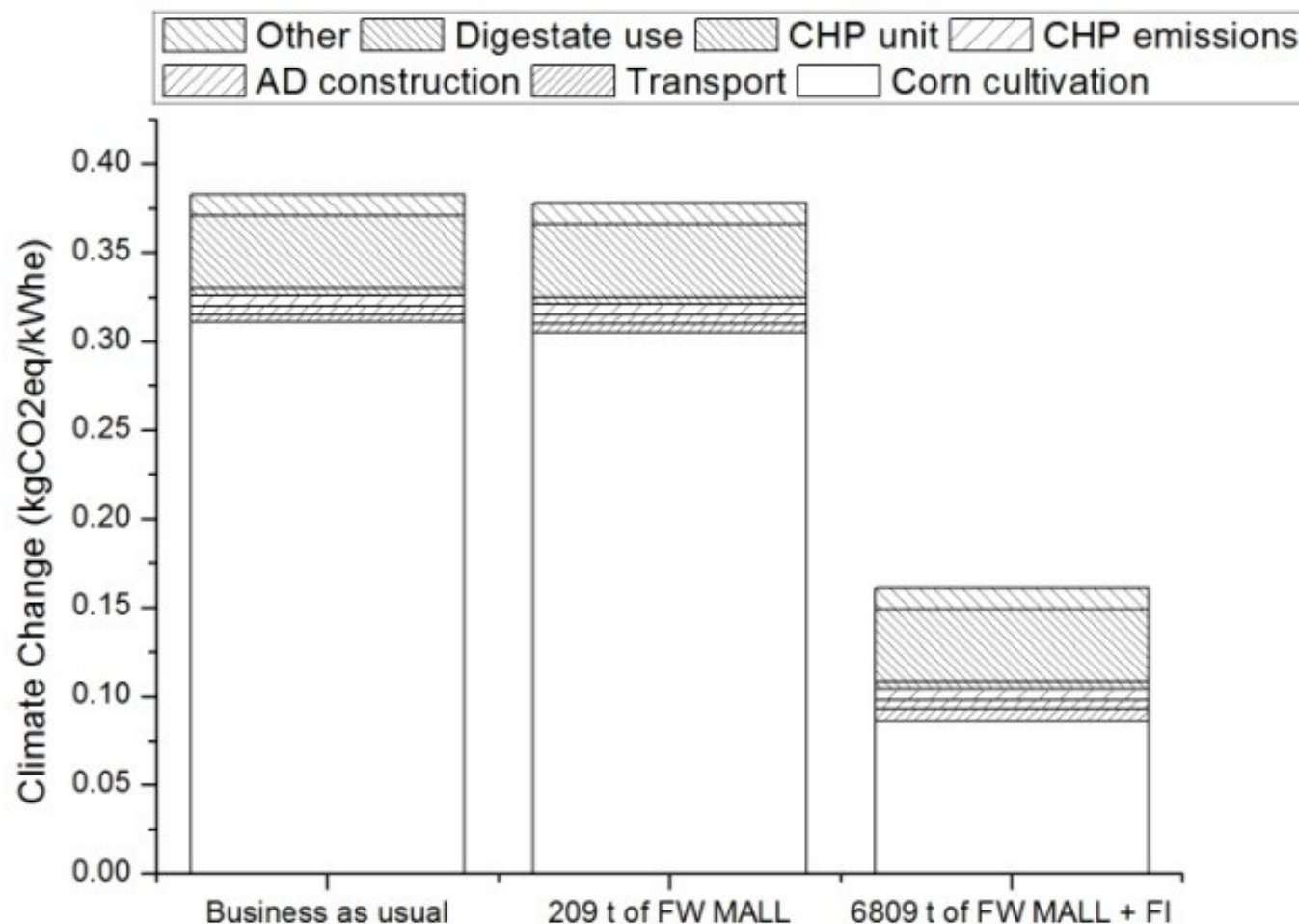


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Results of the aLCA - 1st scenario



FUNCTIONAL UNIT – 1 kWh electric

UN-CPC 171 and 173 (Product Category Rules for preparing an Environmental Product Declaration for Electricity, Steam, and Hot and Cold Water Generation and Distribution), Version 3.0



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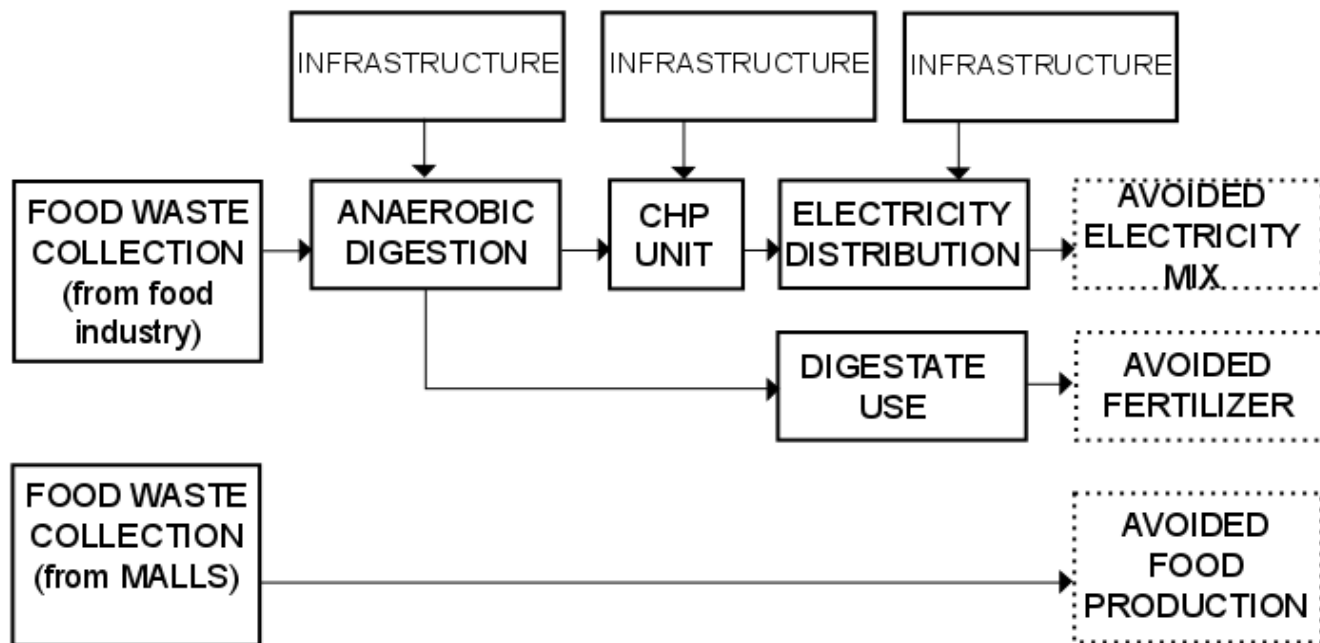
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Consequential LCA (cLCA)

2nd Scenario





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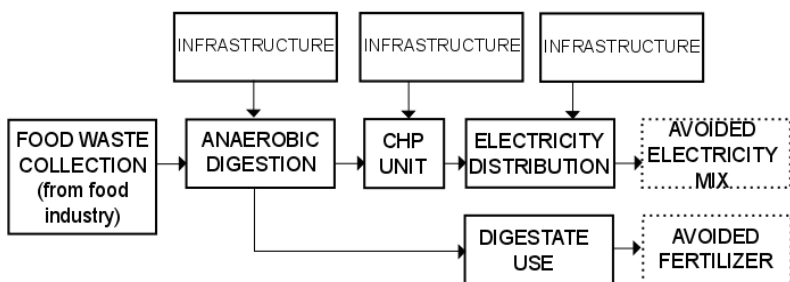
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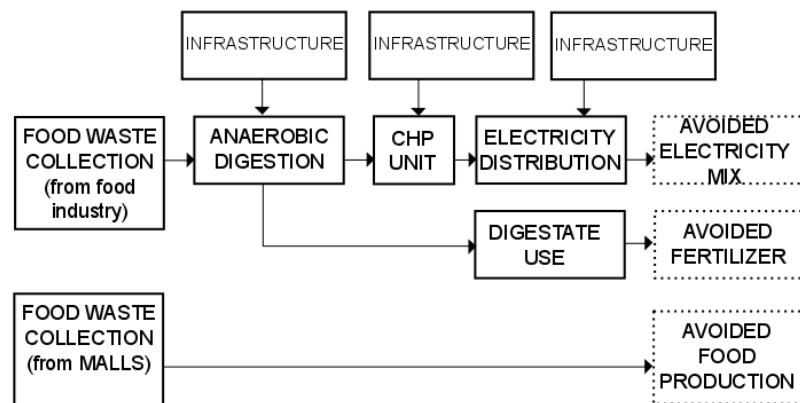
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ENVIRONMENTAL INDEX

1st Scenario



2nd Scenario



$$Env_i = GHG_t + GHG_{AD} + GHG_{CHP} + GHG_{TR} + GHG_{SOIL}^* - GHG_{UREA} - GHG_{EMIX} - GHG_{AFW}$$



ENV_i

*PCR on Arable Crops - Environdec



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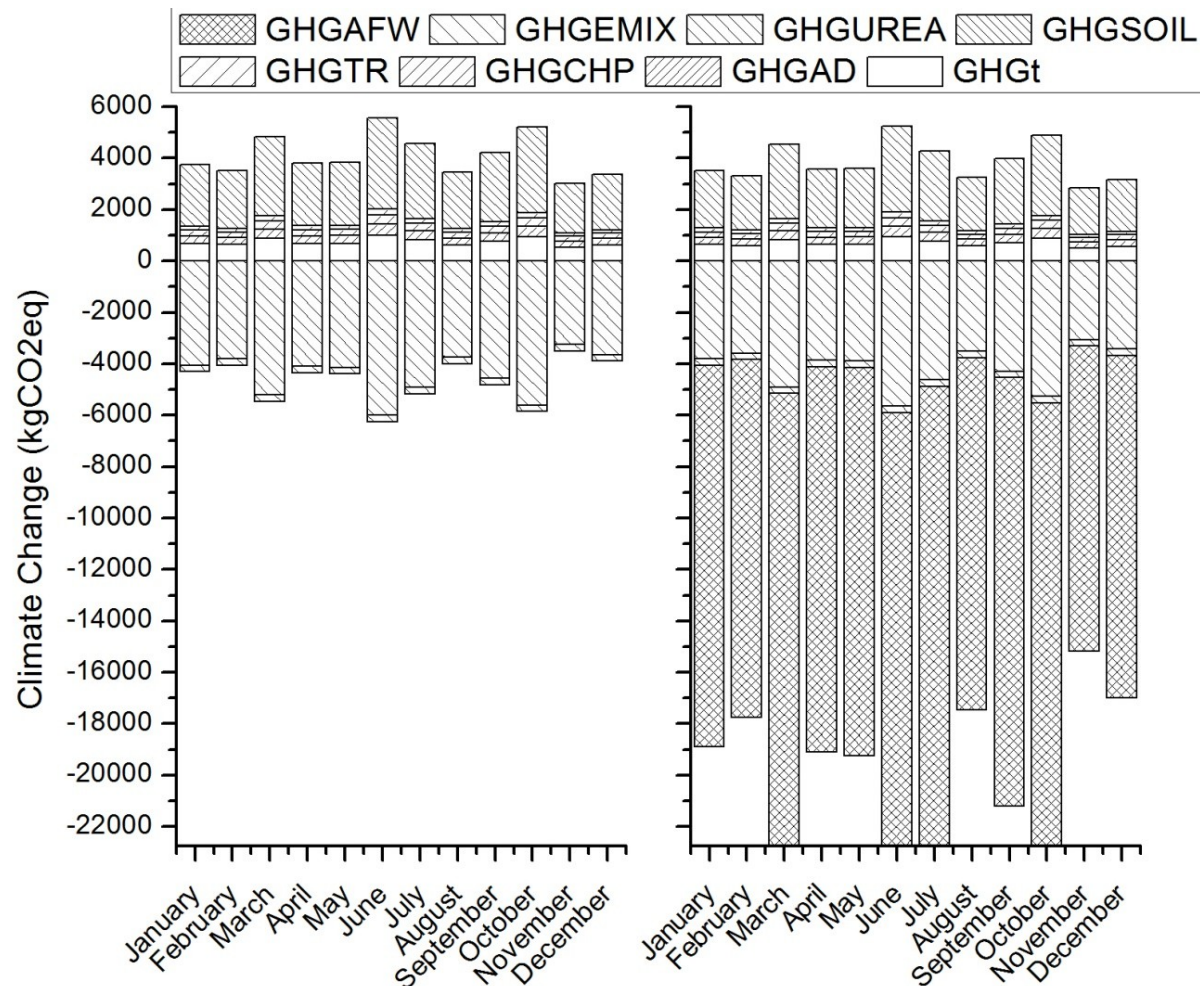


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Results of the cLCA



1° scenario

2° scenario

FUNCTIONAL UNIT – 1 kWh electric



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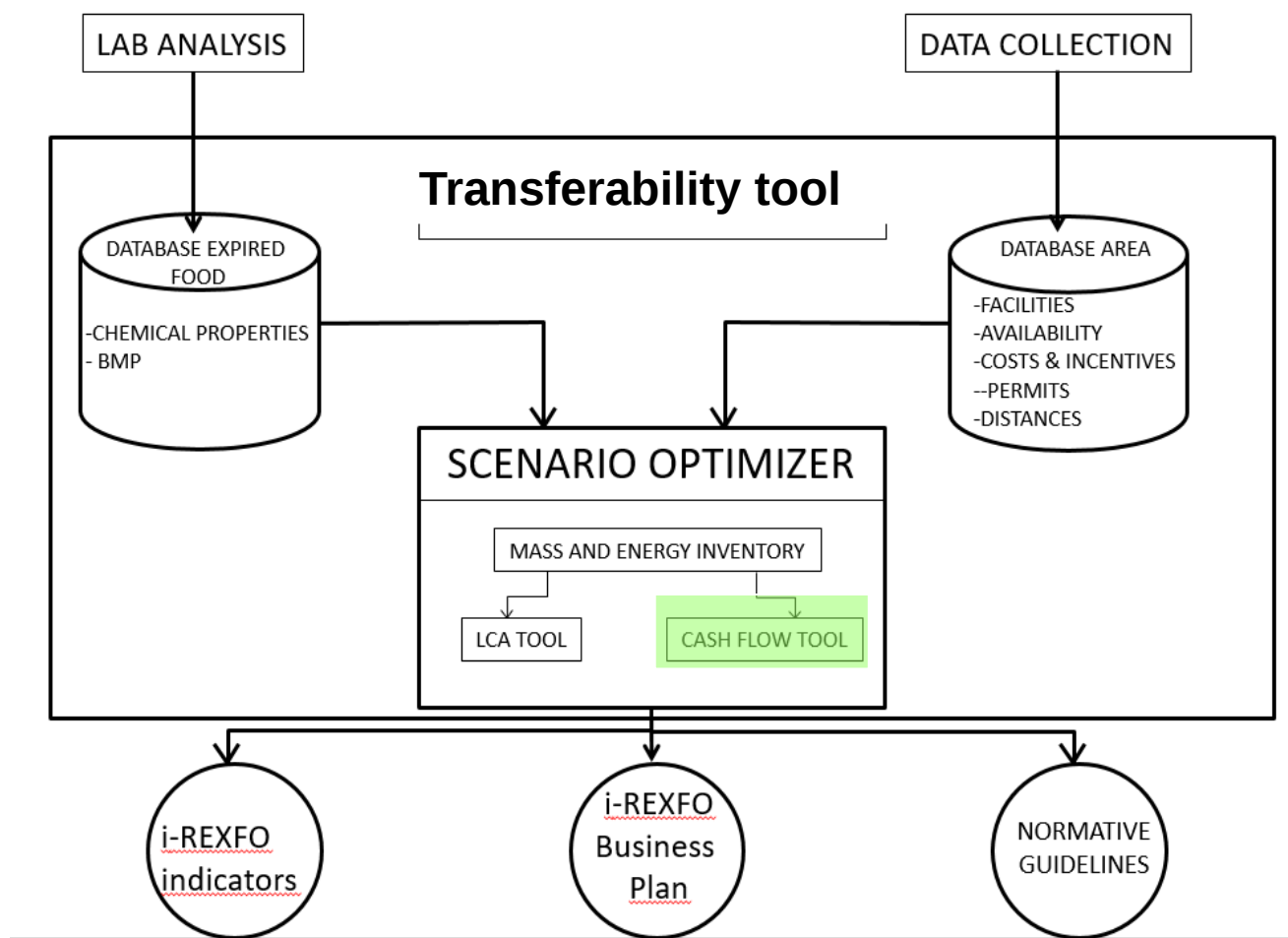


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Economic Index (E_i)

Laboratory BMP Tests Scale up of the results



$$\sum_{i=1}^{52} (Income_i - Costs_i)$$

Biogas Yield * Biogas HHV * Plant Efficiency * Electricity Price

Transport costs
Calculated using
the VRP solver



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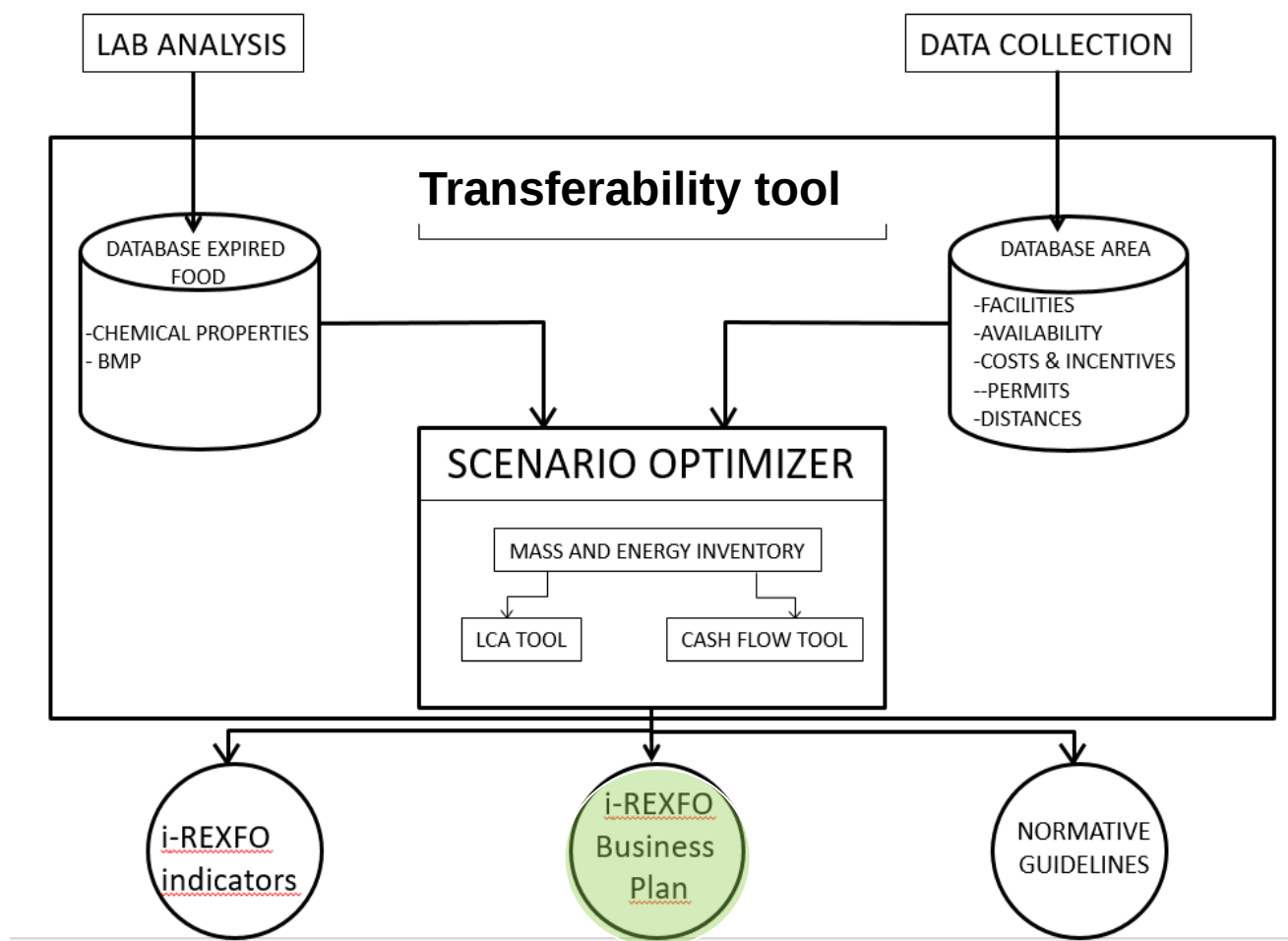


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Economic index calculation first week - year 2020

1st scenario		2nd scenario	
Hours	38.72 h	Hours	36.85 h
Distance	1622.29 km	Distance	1577.79 km
Total collection costs	1626 €	Total collection costs	1565 €
Total Collected Mass	123.5 t	Total Collected Mass	115.8 t
Biogas Yields	29370 m ³	Biogas Yields	28985 m ³
Income	19857 €	Income	19597 €
Income-costs	18231 €	Income-costs	18031 €



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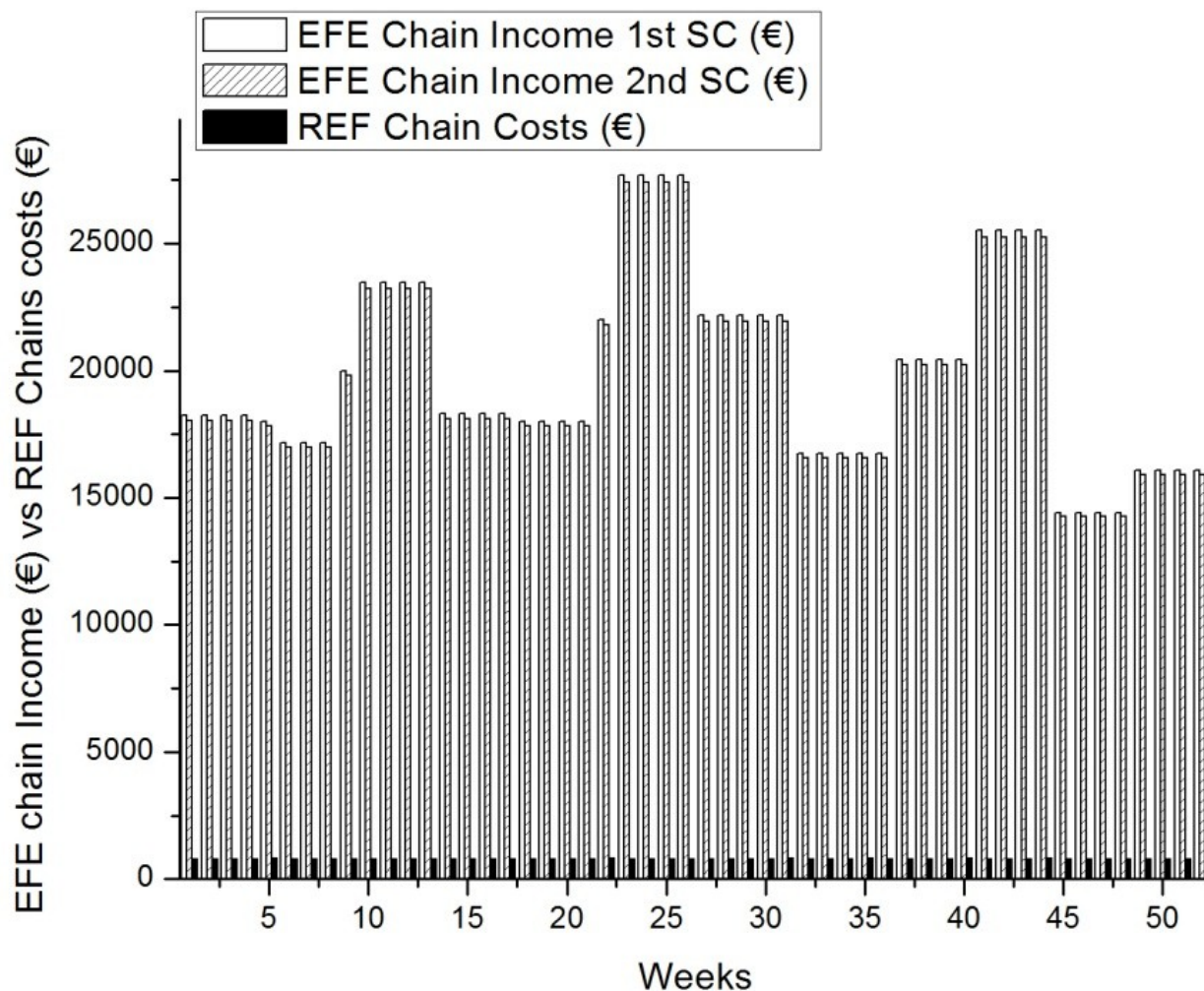


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EFE Income vs REF costs





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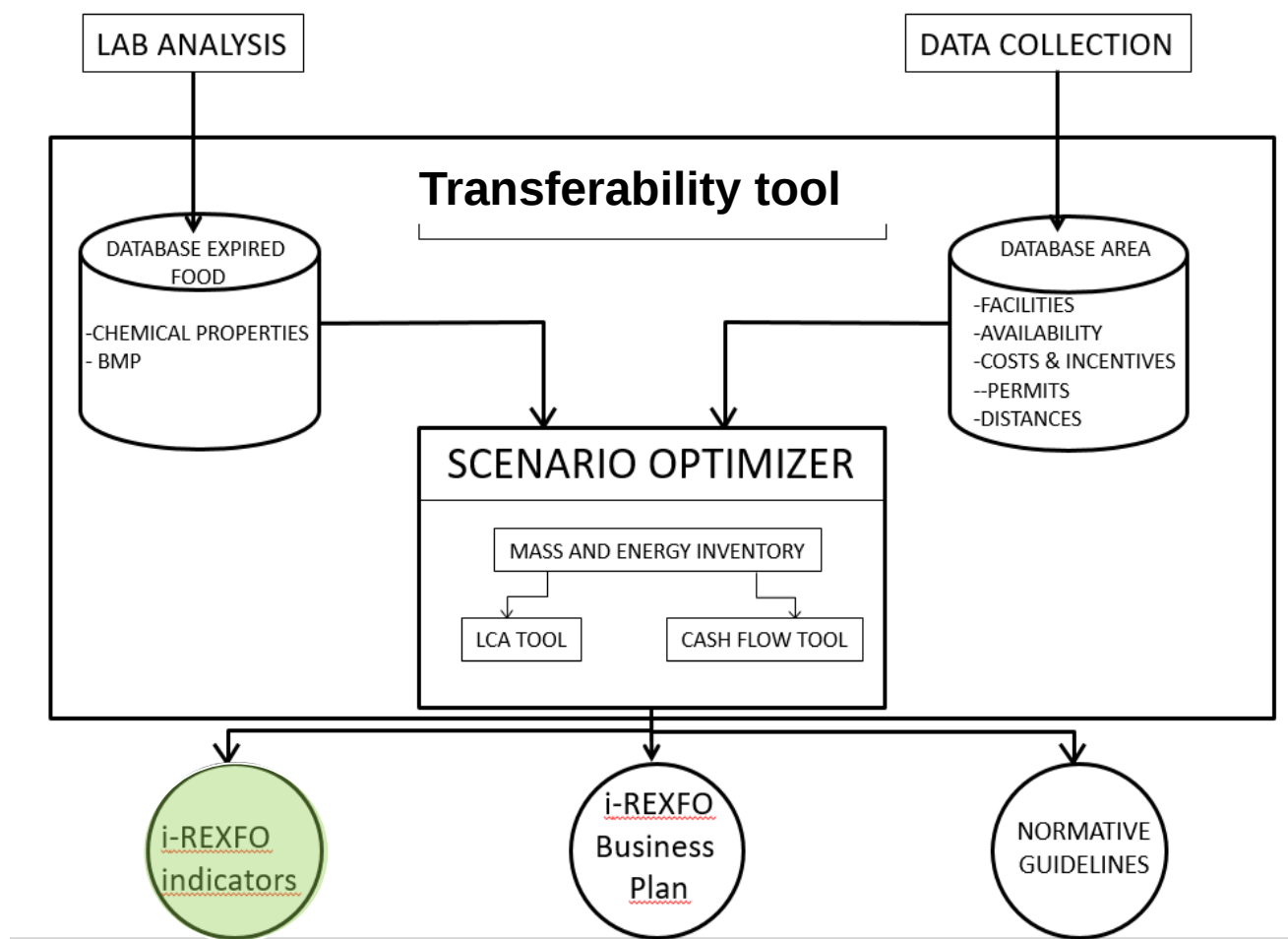


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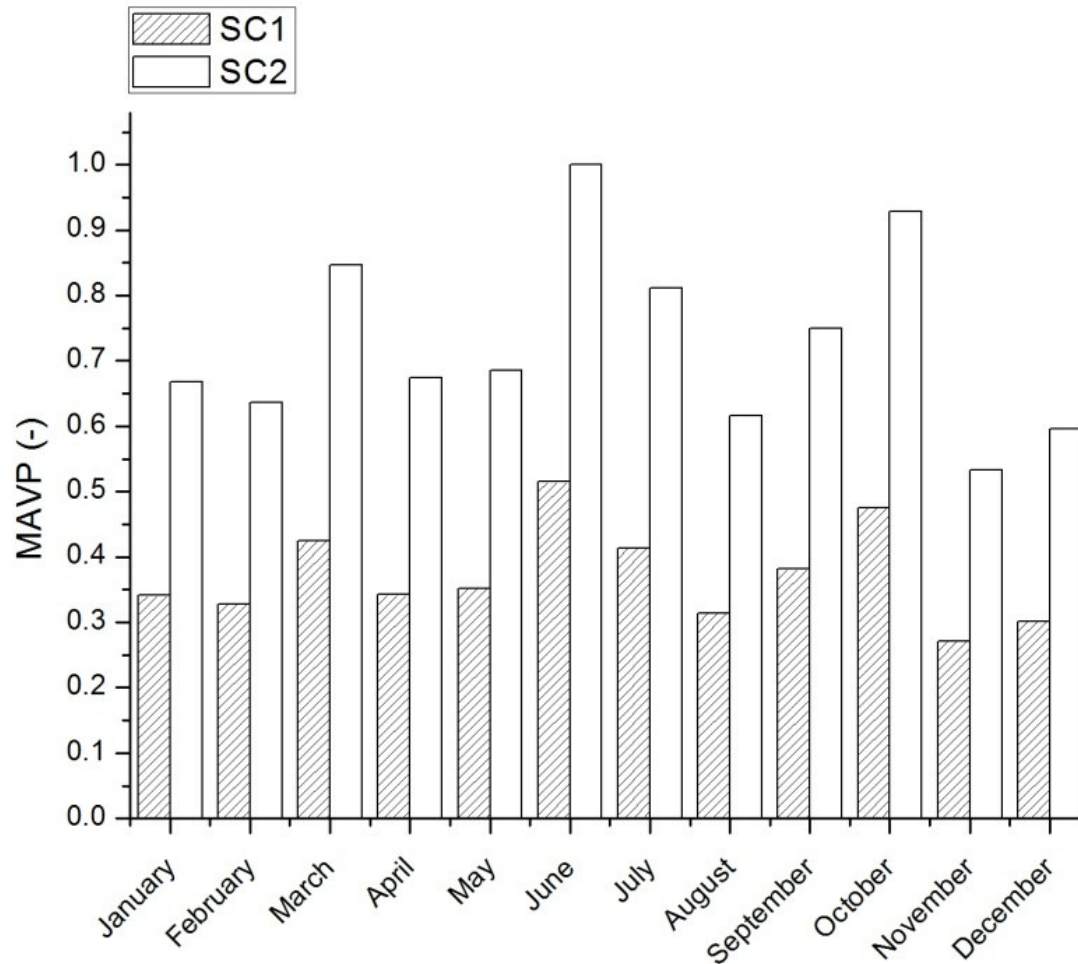
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Multiple Attribute Value Parameter

$$MAVP = EI * 0.5 - Envi * 0.5$$



The higher is the MAVP the higher is the convenience

Envi is usually negative index taking into account GHG emissions reduction



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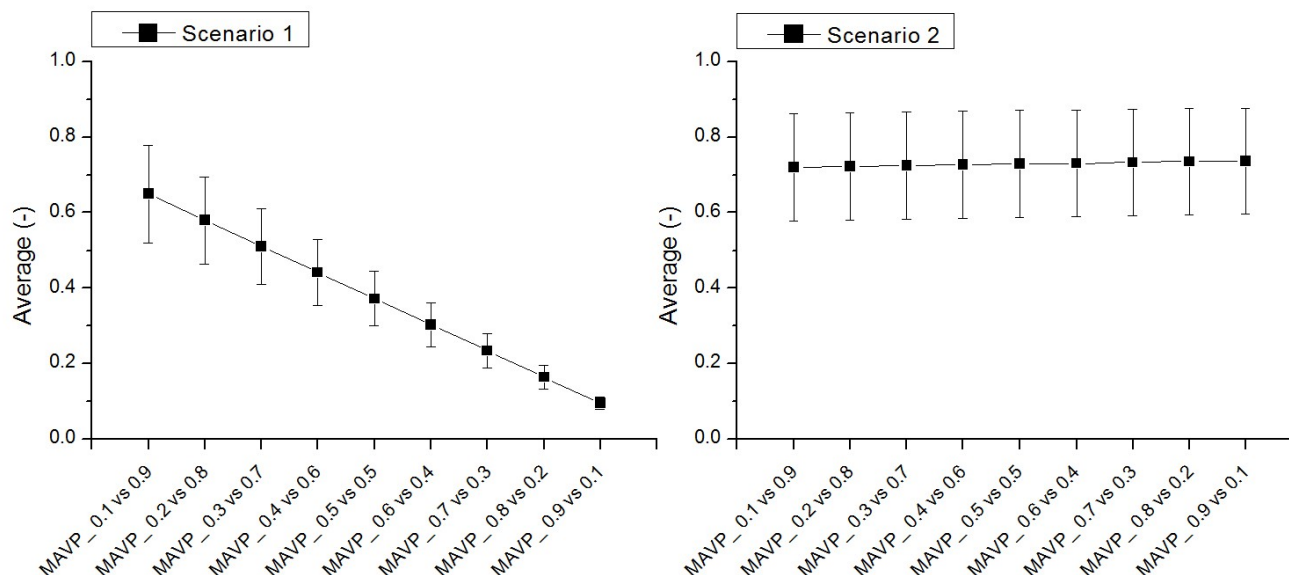


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Sensitivity analysis on the Weights of the MAVP index



- scenario 1 the environmental index is low (about 0.03 in average) while the economic index is high (about 0.71)
- scenario 2 the environmental index is high (0.73) and the economic index is also high (0.72), so changing the weights does not change the final result



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www.irexfo.eu



budget:

2,324,915 Euro

Duration

September, 2017 - February, 2021



LIFE 16 ENV/IT/000547



Partner of

