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i-REXFO LIFE: an innovative business model to reduce food waste

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Abstract

Every year the food produced and wasted consumes a volume of water equal to 250 km^3, requires around 30% of the world agricultural land, and it is responsible for the emission of 3,3 billion tons of greenhouse gases. The direct economic consequences of food waste are ranging around 750 billion dollars per year (FAO source). i-REXFO designs an innovative business model with the objective of reducing significantly the amount of landfilled food waste. The actions are economically sustained by public incentives, tax reductions and private revenues from energy valorization of residual food waste. Uptaking the good practices from other EU countries (Denmark) the project will develop a tool to design the integrated model, optimize it from a technical, economic and environmental point of view and transfer it to other EU regions. i-REXFO will increase consumer awareness on food waste reduction in retail malls and HORECA while facilitating the sale and donation to charities and food banks of close to expiration and aesthetically not adequate food; it will also remove the barriers that hamper the use of food residues in biogas plants. The actions are economically sustained from energy valorization of food waste in biogas plant that use the digestate as fertilizer, closing the cycle. I-REXFO will achieve an overall reduction of 17000 tons/year of food waste landfilled during the project duration and in the after life phase. This will correspond to an overall reduction of 41000 tons of CO_2 equivalent emissions.

Keywords: European project, expired food, biogas

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1. Introduction

According to FAO each year 1/3 of the food produced is lost or wasted: the economic loss is estimated around 7.500 T$. The global volume of food wastage is estimated at 1.6 billion tonnes of "primary product equivalents." Total food wastage for the edible part of this amounts to 1.3 billion tones [1].

While 28% of available land (around 1.4 billion hectares of land) and 250 km^3 of water is used to grow crops that are wasted, waste food produced and landfilled emits the equivalent of 3.3 Gtons of CO_2 (if it were a country it would be the third emitting country in the world).

In terms of GHG emissions, according to estimates of BIOIS [2], the food wastage in EU is responsible for the release of at least 76 million tons of CO2-eq which is broadly equivalent to 1.9 tons of CO2-eq per ton of food waste. These calculations include all stages of the life cycle of a food product from cultivation through harvesting, processing, packaging, transportation, storage and sale. The food we consume has an embedded environmental impact due to the energy and natural resources used, and the associated emissions generated, throughout its life cycle. Therefore the later a product is lost along the chain, the higher is the environmental cost.

Using the model and data provided by [3], 1 ton of landfilled food waste is estimated to produce 12 kg of CH4, and 281 kg of CO2, while 16 kg of carbon are stored in the landfill site (assuming food waste contains 10.3% of carbon [4]. 75% of landfill gas is recovered [5], 0.1% of the CH4 produced is oxidised in the soil cap [3] and 84% of the carbon in food waste decomposes [6]. This gives overall GHG emissions of 606 kg CO_2e per ton of landfilled food waste (this total ignores embedded emissions and those that arise from transporting waste and the running and maintenance of landfill sites). Moreover, this value has to be increased considered the GHG emissions of the packaging. Therefore considering 1 ton of waste food landfilled has a carbon footprint of roughly 1.9 tCO2eq without considering transportation and packaging.

The overall amount of wasted food disposed of in landfill (40 Mton) in EU per year contributes to roughly 76 MtCO2eq/year emission without considering transportation and packaging [7].

Methane emissions from landfills represents one of the largest sources of GHG emissions from the waste sector. Home composting can potentially divert up to 150 kg of food waste per household per year from local collection authorities. Developing countries suffer more food losses during agricultural production, while in middle-and high-income regions, food waste at the retail and consumer level tends to be higher. Household Food and Drink Waste (FDW) has the largest share in food wastage in industrialized countries. About 95 kg per capita is wasted each year by consumers in Europe [8].

When the food becomes not suitable for human consumption, there are economic, logistic, legal and cultural barriers, which prevent its reuse as animal feed and energy source and as a results one third of the global food production is lost or landfilled. However diverting even just a portion of this waste to so-called Waste-To-Energy (WTE) systems could free up large amounts of landfill and generate renewable energy.

i-REXFO project fits in this context because it proposes an innovative integrated approach to optimize food waste prevention and preparation and final use of food waste as an energy vector in biogas plant.

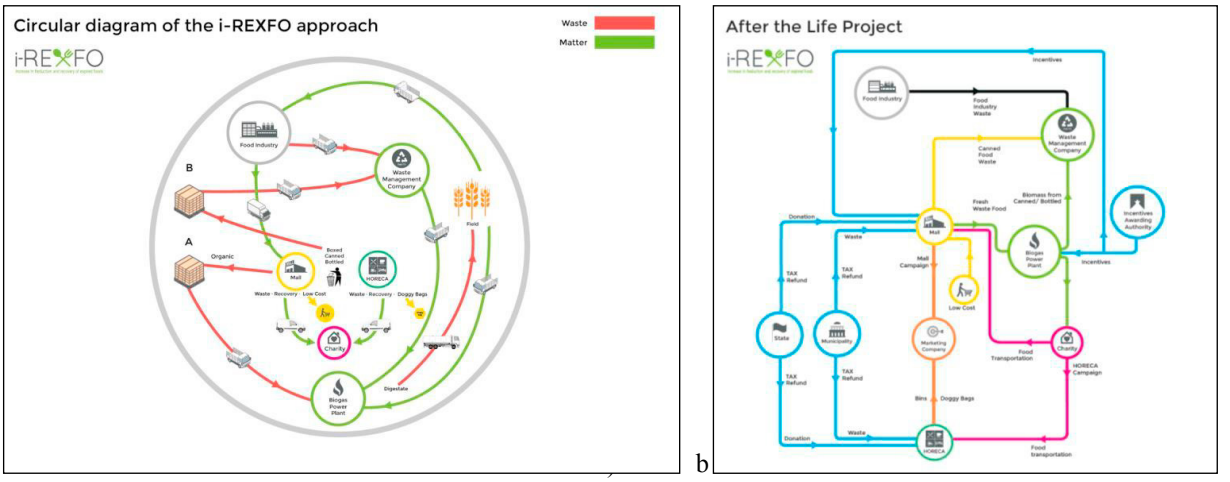
i-REXFO aims to demonstrate an innovative and sustainable business model to reduce food waste through an holistic approach, that optimizes the integration, interaction and communication between stakeholders of the food chain (production, distribution, use and end of life) in a circular economy scenario according to a new European Directive that is being drawn [9] on the matter of the food waste reduction at all steps of the supply chain.

2. Description of the project

i-REXFO is a demonstration project, financed by the EU in the framework of the LIFE program, with the objective of reducing significantly the amount of landfilled food waste, through an innovative approach that incentivizes actions to reduce food waste and energy valorization from the inevitable waste produced. By focusing on food waste produced by food industries, farms, HORECA and consumers, i-REXFO will demonstrate the feasibility, sustainability and replicability of an integrated business model that considers both REF (Reduction of Expired Food) chain and EFE (Expired Food to Energy) chain.

The i-REXFO approach integrates new actions and existing ones already put in place by the key actors, in a economically, environmentally and socially optimized scenario based on minimizing, recycling and reusing food

waste in the circular economy (Fig. 1a). i-REXFO will increase consumer awareness on food waste reduction in retail malls and HORECA while facilitating the sale and donation to charities and food banks of close to expiration and aesthetically not adequate food; it will also remove the barriers that hamper the use of food waste as biomass in biogas plants. i-REXFO will develop an open-source software to design the integrated scenario and optimize it from a technical, economic and environmental point of view. i-REXFO will uptake good practices from other EU countries (Denmark), will demonstrate the model in Umbria Region (Italy) and eventually transfer it to other Italian and EU countries (Hungary).



a b

Fig. 1. (a) Circular diagram of the i-REXFO approach; (b) i-REXFO financial flows.

Although these techniques may be already applied throughout EU their uptake is extremely varying throughout the different countries and regions due to a combination of administrative, cultural and economic reasons which hamper a full exploitation of their potentialities.

The innovation in i-REXFO lies in the teaming of stakeholders, actors, end users and legislators to demonstrate sound reduction and reuse of food waste and to produce usable tools for the replicability at EU level. i-REXFO is focused on food waste available at wholesale-retailer, HORECA, food processing and farming level and it is aimed to demonstrate the feasibility, economical, convenience, environmental soundness and replicability of both reduction and final use as energy vector in biogas plants.

These sectors will be engaged to separate efficiently food waste from surplus food, with particular focus on near expiration date foods, and to use available IT tools to communicate in real time available food to donate to the partnering food banks and charities. Near expiration products will be sold on special sales and consumers awareness on food waste and on expiration label significance will be raised. Waste food separated from surplus food will be processed by a partnering waste management company to separate valuable matter and prepare it to be digested for biogas production in a near partnering biogas plant. Partnering local administration will develop a dedicated legislative framework to allow the use of in farm biogas plant food waste as biomass. i-REXFO will produce a software tool for the optimization and design of open database, legislation and feasibility studies to facilitate the uptake of the approach at EU level.

i-REXFO innovative business model is economically sustained by public incentives, tax reductions and private revenues from energy production from residual food waste (Fig. 1b). The specific objectives are:

- to develop and test a practical tool for the design, application and transfer of the i-REXFO approach directly usable by stakeholders and investors for techno-economic evaluation at European scale. The tool helps the user to define the geographical area, the feasibility studies and business models, the guidelines for legislative framework and permit release, and the bio-methanation potential of waste food;
- to develop and demonstrate the technical, economical and environmental sustainability of the integrated i-REXFO business model in Umbria Region. The demonstrative actions are aimed at promoting the use of near to expiration food use, distribution to charity and consumers engagement based on label information and price

policy. These actions will be financed by the activation of a self-sustained, biogas energy chain that re-use waste food from HORECA, food industry and farms, reducing significantly the amount of waste food landfilled, according to EU directive 1999/31/CE [10], favouring renewable energy production according to EU directive 2009/28/CE [11];

- to transfer the i-REXFO approach to different national (northern and southern Italy) and international (eastern and western Hungary) geo-economical areas.

i-REXFO will activate different actions to meet the goals listed above.

Action n.1: Tools to design and demonstrate the feasibility of the i-REXFO approach.

Building from best practices, i-REXFO partners will develop a user friendly tool to design and optimize the Energy from Expired Food (EFE) and Reduction of Expired Food (REF) chains that constitute the i-REXFO integrated approach (Fig. 2). They will be tuned during the demonstrative actions in Umbria, to guarantee the economic and environmental sustainability during the whole life cycle. The tools will be available for download to users interested in replicating the i-REXFO approach in other scenarios, thus favouring replicability and transferability. These tools will support investors and stakeholders by removing technical and non-technical bottlenecks and consist of:

- a calculation software to support design and feasibility studies by linking waste food characteristics and energy properties, from a database built within, to their availability, cost and localization;
- guidelines to help public authorities to set up a proper framework of legislation, permits, tax benefits and incentives to facilitate the sustainable integration of excess food donation, food waste reduction measures and energy production.

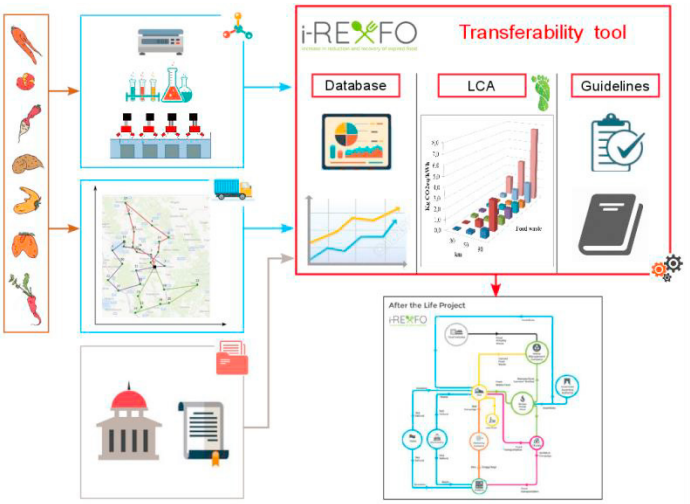


Fig. 2. Transferability tool for the design and optimization of the i-REXFO integrated approach.

The feasibility tool is a calculator system developed by UNIPG characterized by two sections to evaluate the feasibility and impact of the business model starting from food waste characterization, food availability, localization and typology (both expiring and expired). For both chains the tool will allow the optimization of the supply chain to minimize economical and environmental costs on a life cycle approach. The tool will help to design the i-REXFO approach by supporting key actors of both the EFE and REF chains. The tool will contain a database of expired food properties that will be classified in 16 food categories (Table 2) according to the FAO classification and used in EU project FUSION [12]. The database contains chemical properties of food waste obtained from literature data or laboratory tests. Biochemical Methane Potential (BMP test) is an essential information to determine sludge dilution or concentration at the real plant and the resulting biogas and energy produced.

Table 2. Food classification

Categories	Food classification	Categories	Food classification
1	Dairy product	9	Fish and Fish products
2	Fats, oils and grease (FOG)	10	Eggs and Egg products
3	Ice cream	11	Sweeteners and sweet good
4	Fruit and vegetable	12	Salt, sauces, spices, soups
5	Confectionary (canned good)	13	Food stuff
6	Cereals and cereals products	14	Beverages
7	Bakery wares	15	Ready to eat food or restaurant waste
8	Meat and Meat Products	16	Other

This will be measured at the laboratory of UNIPG in batch bottles for BMP test, which are used to measure the yield and the composition of biogas from different substrates at different conditions [13-14]. Literature data about the anaerobic digestion of expired foods are present however not coeherent and results are seldom directly applicable to real plants, given the varying operational conditions and mixtures [15-24]. Each bottle has a capacity of 1 L and it is equipped with probes for pressure, temperature and pH measurement and biogas sampling, in order to analyze its composition. The vessels are maintained at constant temperature in a thermostatic bath (Fig. 3). Biogas production pressure sensors are connected to a system for data acquisition. Biogas is sampled with air tight syringes and then it is analyzed by a gas-chromatograph. Best performing substrates will be then tested in significative mixtures with waste waters provided from the biogas plant in order to identify the best working conditions.

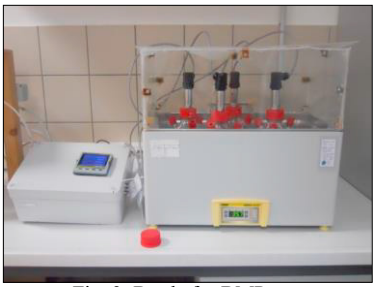
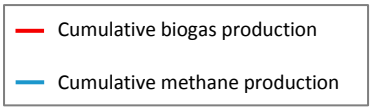


Fig. 3. Bottle for BMP test

Preliminary results for BMP tests, with substrate to inoculum ratio of 0,3, show that higher methane yields are achieved with substrate with a high content of sugars, as bread and onion. A right amount of organic matter has avoided the acidification of the substrate maintaining the pH between 6,5 and 7,5, without any correction. The methane yields of the tested substrate and cumulative biogas and methane production are shown in Figure 4.

Substrate	BMP ($Nm^3/kgSV$)
Apple	0,305
Onion	0,480
White bread	0,507
Lettuce	0,296



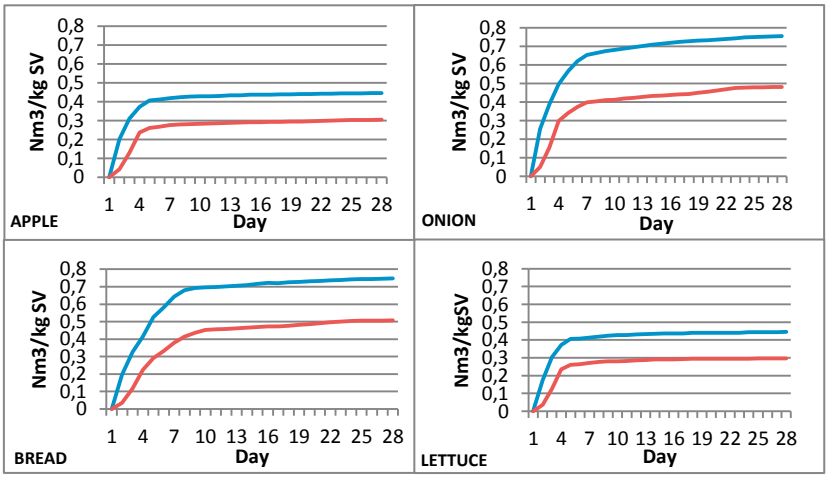


Fig. 4. Methane yields in BMP tests and cumulative biogas and methane production

The database will provide methane yield from different food mixtures that are the base for the techno-economic and environmental design of the EFE chain, which partially supports the REF chain through the incentives. The tool also calculates investment cost, transportation cost (€/ton), disposal cost saved (€/ton), energy production, environmental benefit, revenues, to allow the closing of the business plan.

The second part of the tool consists of operational and regulation guidelines. The Regulation framework guidelines will be developed to overcome the main barriers which jeopardize the full exploitation of the integrated REF and EFE chains providing clear indications to policy makers and stakeholders. The regulation will impact on the reduction of expiring food, identifying specific target with actions as: making it easier to donate food to charities at no extra cost, facilitate companies to donate food that has been mislabelled as long as it does not pose a safety risk, removing complex procedures surrounded donating food, around maintaining sanitation and traceability standards, encouraging greater use of "doggy bags" at HORECA, activation of fiscal instruments such as waste tax reduction and donation incentives.

For the waste food to energy chain the guidelines will provide information on the range of incentive required and on the requirements for use of digestate in agriculture. It will also discuss the procedures and arrangements to ensure that the phases of production and use of energy feedstock, including the stages leading to them, does not endanger human health and the environment (in strict collaboration with the local health service).

The tool and the guidelines are developed according to the European Commission Communication of December 2015 entitled Closing the loop – An EU action plan for the Circular Economy announced several objectives as the reduction of food loss and waste generation and the clarification of EU legislation on waste, food and feed in order to facilitate food donation and ensure the safe use of former foodstuffs and by-products in feed production and the exploration of options to improve the understanding and use of date marking by all actors, including consumers.

Action n.2: Demonstrative actions for the Reduction of Expired Food - REF

The EU Commission recommends as a first measure to reduce food waste, to avoid food becoming waste. Hence i-REXFO will demonstrate a sustainable strategy for the reduction of food waste produced by industries, farms, retails, HORECAs and consumers, by engaging over 100 businesses in Umbria Region in actions such as:

- promotion of sale and consumption of pre-expiration food in malls and HORECAs, through a dedicated price and communication policy;
- consumer awareness campaign on how to read food expiration label (e.g. difference between 'best before'and 'expires on') and what to do with leftovers and expired food;
- collection and distribution to charities of unsold food and groceries;
- distribution of design doggy bags in HORECAs.

The demonstration will significantly reduce food waste while also measuring the financial requirements for the economic sustainability that will be provided by a combination of public incentives, tax reductions and private contributions from the EFE chain.

Action n.3: Demonstrative actions for the production of Energy from Expired Food -EFE

Inevitably, some food will eventually become not suitable for human consumption; to avoid its landfilling it will be used as an energy vector in anaerobic digestion plants for the production of biogas. This action will demonstrate the sustainable feasibility of energy valorization of waste food through a demonstrative action in Umbria Region. Waste food will be recovered from the engaged food industries, farms, retails and HORECAs, treated and prepared (removal of packaging, grinding, mixing, etc.) to obtain an energy produce that will be eventually used in a biomass biogas plant for electricity production. All steps will be carefully designed and monitored to guarantee the economic feasibility, and to minimize the overall environmental impact on the life cycle. Revenues from energy production will contribute to the economic sustainability of the REF chain

Action n.4: Replicability and transferability of the i-REXFO

To increase the impact of i-REXFO, the sustainable model demonstrated in Umbria Region must be replicable in other EU scenarios. To this aim the i-REXFO approach will be transferred to other Regions and Countries (2 other Regions in Italy and 2 Regions in Hungary) where preliminary actions will be carried out to guarantee the start up after the end of the project. After having identified the 4 Regions, in each of them the main actors will be engaged and the REF and EFE chains will be designed and optimized. Business plans, specific legislative and permit measures will be drafted and the technical, economic and environmental feasibility will be assessed, using the tools developed in action 1 building from the demonstration in Umbria Region (actions 2 and 3).

3. Expected results

The long term objective of the project (including the after-LIFE phase) is a consistent reduction of food waste landfilling, including a significant increase in food donations to food banks in Italy, and in EU countries, from wholesale retailers and HORECA. This will happen, thanks to the integrated approach of increasing the availability of food surplus at warehouse level, by providing doggy bags to HORECA and increasing the efficiency of distribution. The i-REXFO food waste reduction chain will provide benefits for both the mass retailers, which will reduce the disposal costs and increase the revenues selling near to expiration date products at discount rates, and consumers who can buy optimal products at a lower cost, modifying their shopping and consuming habits, and by increasing the house shelf life of products, by learning what labels mean. Finally waste food produced will be used as an energy vector.

The environmental benefits achievable through i-REXFO are summarized in the following, considering also the after LIFE:

- to reduce of 17.340 ton/year of food waste landfilled from wholesale/retail, HORECA, food processing and farming sectors through demonstrative and self sustained actions in warehouses, supermarkets, etc.;
- to decrease of 41.000 tCO_2eq/year of GHG deriving from food waste landfilling (according to EU directive 1999/31/CE);
- to decrease the water consumption due to avoided waste food of 2.150.000 m^3 per year;
- to decrease the land use consumption due to avoided waste food of 1.080 ha per year;
- 10.650 MWh/year of energy saving due to avoided food production;
- to produce 14.250 MWh/year of renewable energy (according to EU directive 2009/28/CE) .

Other significant results include:

- to involve 641.400 consumers in awareness raising actions on the significance of food expiration labelling and on proper storage and consumption through a demonstrative action in the target area and in EU in the after-LIFE phase;
- to develop a EU database on methane production capacity of different waste food categories;
- to develop tailored guidelines to improve the legislative framework aimed at the food waste prevention and the re-use of waste food for energy purposes eliminating the possible waste/biomass conflict and to facilitate the possibility of donating exceeding food;
- to produce a software tool to assess the techno-economic and environmental feasibility of a self-sustained, biogas, i-REXFO Business model.

4. Summary

i-REXFO is an innovative business model that aims at reducing food waste that ends up in landfills through a holistic approach, optimising communication and involving all players (stakeholders) in the food cycle (production, distribution, use, end-of-life). This is possible by financing measures to reduce food waste through waste-to-energy valorization. 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. The actions of the project consist in the development of a feasibility tool to optimize and evaluate the economic and environmental performance of the

business model when applied to different scenarios. Umbria Region will be the stage of the first demonstrative application of the innovative business model. By operating in synergy the Reduction of Expired Food (REF) chain and the Expired food to Energy (EFE) chain the model will be fined tuned to reach economic and environmental sustainability within the project end. Finally the business model will be replicated in Hungary in order to test its transferability. Main results consists of reducing 17.340 ton of food waste landfilled during the project duration and in the after LIFE. This determines also an overall reduction of 41.000 tons/year of CO_2 equivalent emissions.

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