Waste food reduction as a way to reduce resources and energy consumption in the Italian industrial sector: an IO-LCA analysis

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Abstract. Food production involves both agricultural and industrial activities which consume several resources among which: water, energy, land, minerals and chemicals. The efficiency in the use of the resources depends on the type of food which is produced and the adopted processes. In any case if food is discarded or lost at any step of the supply chain this represents a waste of energy and resources. For this reason, the LIFE project irexfo, coordinated by the University of Perugia has proposed a way to promote a business model aiming at both: the reduction of food losses and also the reuse of the not comestible food waste in biogas plants. The model has been tested in Umbria as a pilot region and in this study the results obtained are scaled up to a national level and applied to the Italian IO database reported in the EXIOBASE, to evaluate which could be the benefits of the application of the irexfo business model to the whole Italian agroindustry sector and also the interrelations between this sector and the Italian energy sector. The analysis is performed using SimaPro software 9.0, results are compared with those of similar studies which have been performed at European level. This is the first study of this kind focused on Italy.

1 Introduction

Few studies are available on the detailed analysis of the use of energy in the agri-food industry in Italy. An interesting example is provided by Latini et al. [1], in which it is shown how the Italian production of food commodities is composed and also some more specific data on the consumption of energy obtained for the fruit and vegetable sector. Other useful information is reported in the website of the Italian National Institute of Statistics (ISTAT) in the part dedicated to energy [2].

Another approach can be based on the use of the EXIOBASE database. As reported in [3] the EXIOBASE v3.3 is a multiregional input-output (MRIO) model developed by [4]. There are currently two EXIOBASE v3.3 available: one is monetary the other is hybrid. In this analysis the hybrid will be used because it relates the impacts to the unit of mass of the produced good, while the monetary relates the impact to the currency unit, or the unit of economic value.

In [3] the reduction of environmental impact due to the reduction of production of waste food is calculated, in particular the following impacts are considered at European level:

- GHG emissions;
- Land use
- Domestic Extraction of materials;
- Blue Water consumption.

So in [3] the consumption of energy is not considered while it can be of interest to analyse the interaction between the food sector and the energy sector, especially focusing on waste food reduction. In fact waste food reduction can be also considered as a type of energy efficiency measure. By reducing waste food we reduce the waste of energy which is needed in its production and also in the production of the chemical inputs, which are used in the agro-industry (one example is the fertilizer used).

In particular the University of Perugia is coordinating a LIFE16 project named iREXFO [4-6], which aim is to avoid that about 2500 t/year of food waste is conferred to the landfill and to valorised it producing biogas; to employ the revenues obtained from food waste AD to promote communication campaigns and redistribution actions able to reduce at least another 2500 t/year of food waste production.

To develop the food waste reduction chains in the iREXFO project a tool has been used programmed in VBA code. The objective of this work is to assess: what is the benefit on energy consumption reduction which

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can be achieved with the reduction of food waste production that can be achieved by applying the iREXFO business model to the 21 Italian region and to to the whole Italian territory.

The novelty of the work is represented by two basica aspects:

- very few data on the energy consumption of the Italian agroindustrial sector are available;
- the effect of food waste reduction on the combined agroindustrial sector and energy sector has not been analysed till now in detail.

2 Materials and Methods

To analyse the energy consumption of the agroindustrial sector the activities shown in figure 1 are taken into consideration. The final treatment of the food waste is presented in figure 2, where we see the percentage for the different treatments on the total food production in Italy.

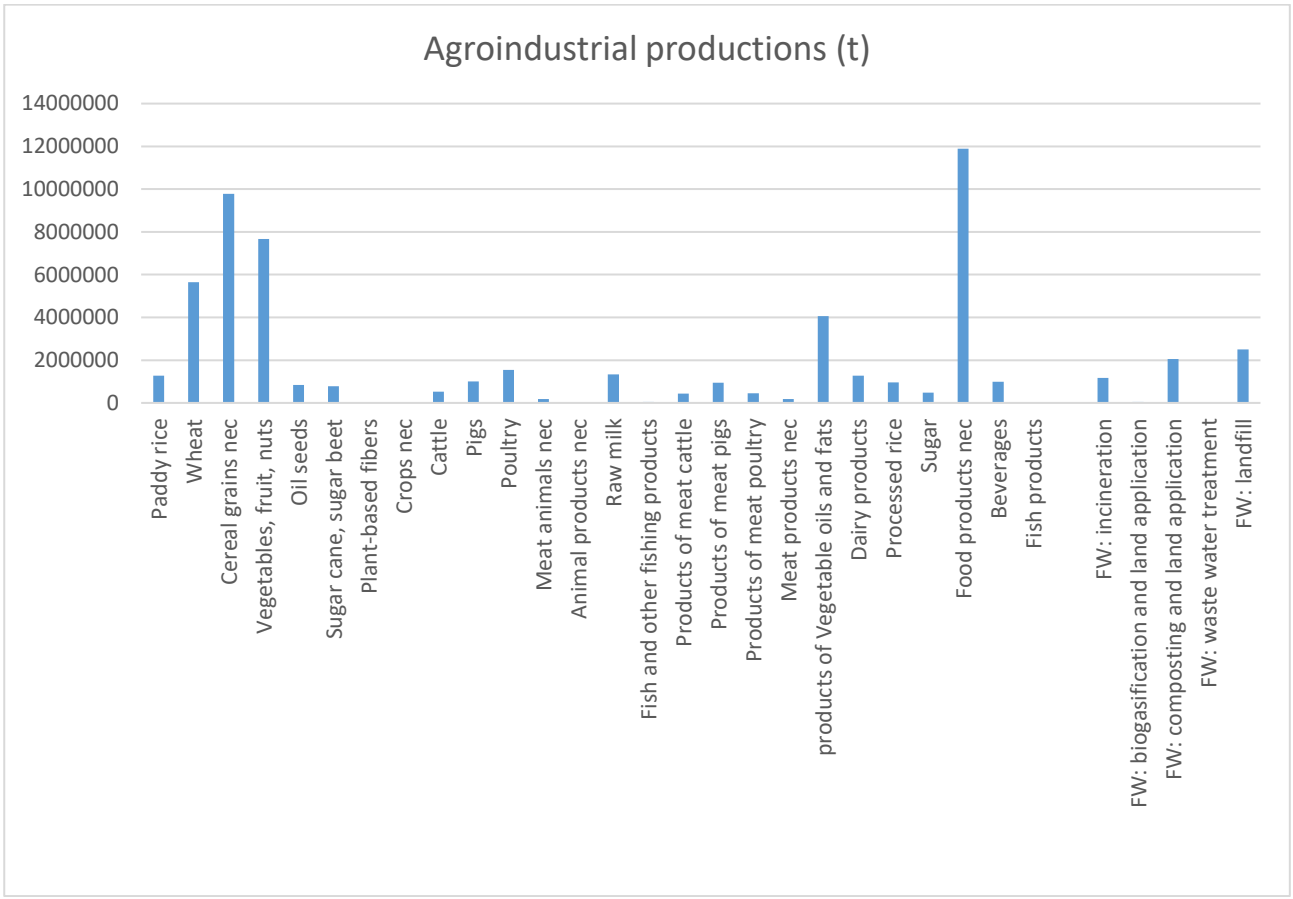

Fig. 1. Italian agroindustrial productions.

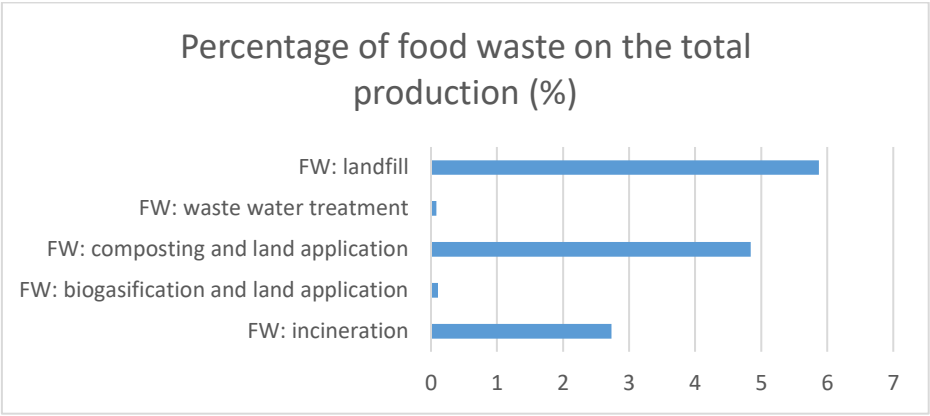

Fig. 2. Food waste treatment scenarios

The total food treated in Italy, according to the EXIOBASE v3.3 is about 5.8 Mt; this value which is in agreement to that presented in [7].
Dealing with the energy input consumed during food production in Italy, this is shown in figure 3. The diagram is a chord diagram obtained through [8]. The analysis is limited only to the internally produced energy, which we assume it is the great part. As it is shown in figure 3, mor than 50% of the required energy is provided by natural gas in the form of electricity. Much electricity is needed for example for milk production, while quite few is needed for wheat production. Poultry, pigs and cattle at breeding stage require a reduced amount of electricity. The fruit and vegetable sector demand for electricity is probably due to cooling needs, which is probably the cause of electricity demand also in the milk sector.

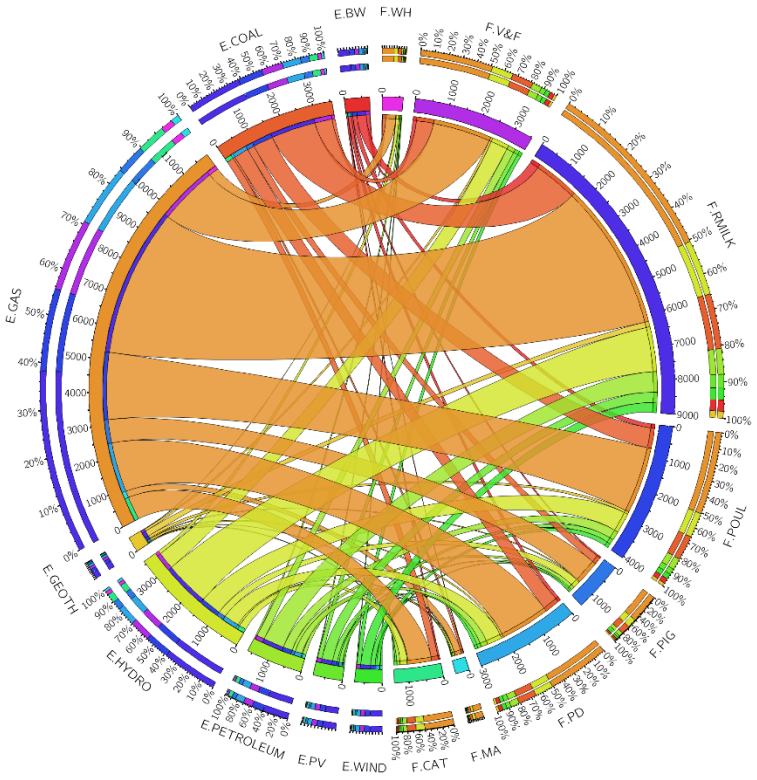

Fig. 3. Energy consumption (expressed in TJ) for the agricultural sector, where F.CAT = cattle farming; F.MA = meat animals; F.PD = paddy rice; F.PIG = pig breeding; F.POUL = poultry breeding; F:RMILK = raw milk production; F.V&F = fruit and vegetables production. E.BW = Energy from Biomass and Waste

In figure3 the cereals grain and the cultivation of oil seeds are neglected. Besides electricity consumption, also the fuel consumption has to be taken into account, see figure 4. From figure 4 it can be seen that the highest consumption of refined petroleum products is represented by: the fruit and vegetables sector, the cultivation of cereals grains and the cultivation of wheat; while the raw milk the rice and all the meat productions have a reduced consumption of energy. Concerning the use of natural gas, which is probably due to the heating process, this is mostly concentrated in the seeds production.

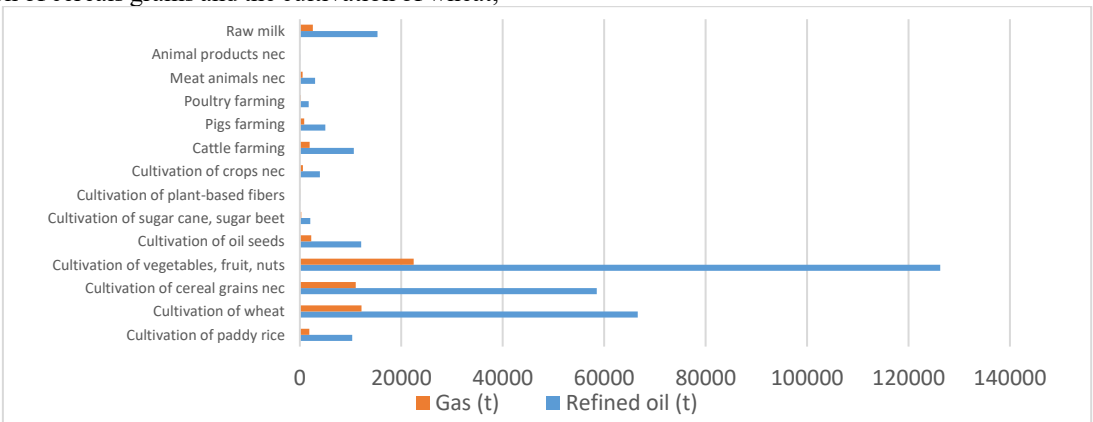

Fig. 4. Refined petroleum and natural gas consumption (expressed in t) for the agricultural phase

The energy consumption of the industrial sector is presented in figure 5. Two sectors are neglected because they have a reduced consumption of energy: processing of dairy products and processing of fish products. From figure 5 we can see that the consumption of electricity of the beverage sector is very high and it is produced in great part from natural gas, but also from coal, depending on the site in which the plants are situated.

Dealing with the consumption of refined oil and natural gas, the consumption of diesel fuel in the industrial sector is quite reduced, while natural gas is important for the following sectors: beverage sector, manufacturing of other food; sugar refining.

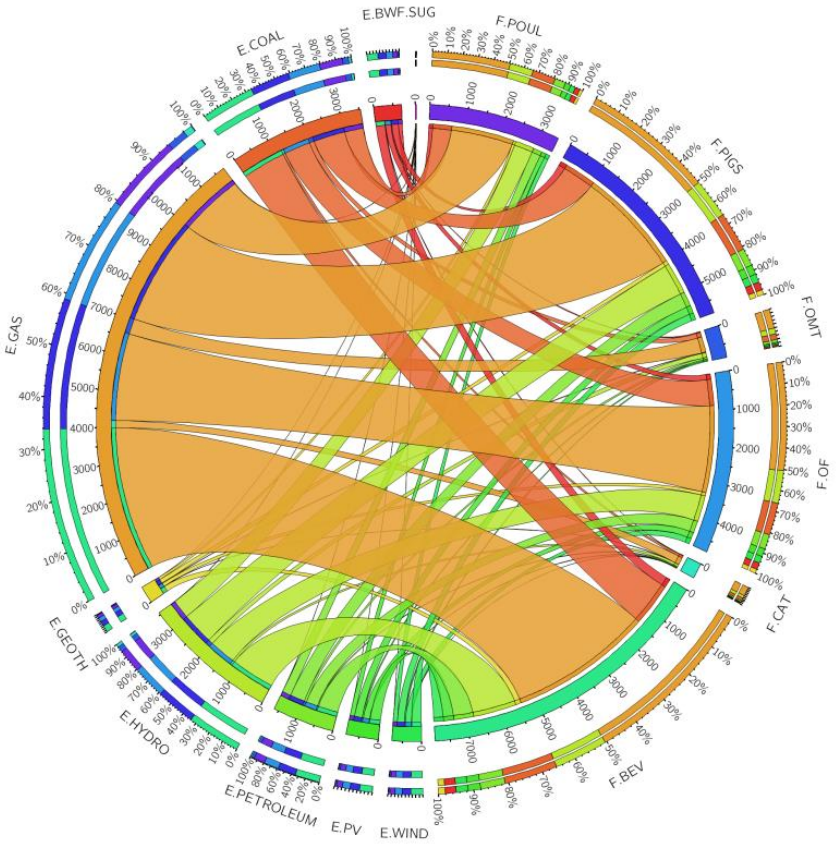

Fig. 5. Electricity consumption per agroindustrial sector, where F.BEV = beverage industry; F.CAT = cattle meat production; F.OF = other food production; F.OMT = other meat production; F.PIGS = pig meat production; F.POUL = poultry meat production; F.SUG = sugar refining. E.BW = Energy from biomass and waste.

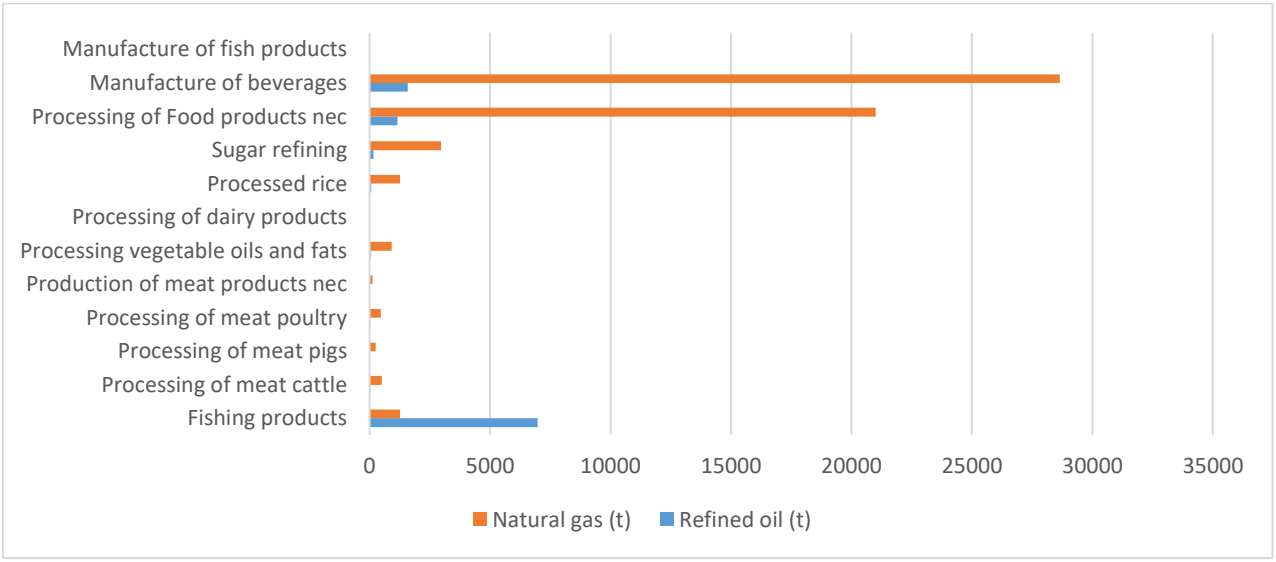

Fig. 6. Refined petroleum and natural gas consumption (expressed in t) for the industrial phase

3 Results

Once the energy consumption has been traced at national level for the most important goods belonging to the agricultural and agro-industrial sector; it can be interesting to understand what could be the benefit of adopting the business model developed in the LIFE16 project iREXFO to the whole Italian country.

If we assume to scale up the targets of the iREXFO project referred to the Umbria region and extend them to all the 21 Italian regions, based on their population (see table 1). We obtain that the total food which is not disposed of in landfill is about 342,188 t/year which is close to the 6% of the total food waste produced in Italy. So this can be an interesting result.

Table 1. Reduction of Food Waste generation by adopting the iREXFO model throughout Italy [9]

Region	Population	Food Waste to EFE	Food Waste to REF
Lombardia	10103969	28695	28695
Lazio	5865544	16658	16658
Campania	5785861	16432	16432
Sicilia	4968410	14110	14110
Veneto	4907704	13938	13938
Emilia-Romagna	4467118	12687	12687
Piemonte	4341375	12329	12329
Puglia	4008296	11384	11384
Toscana	3722729	10573	10573
Calabria	1924701	5466	5466
Sardegna	1630474	4631	4631
Liguria	1543127	4382	4382
Marche	1518400	4312	4312
Abruzzo	1305770	3708	3708
Friuli Venezia Giulia	1211357	3440	3440
Trentino-Alto Adige	1074819	3052	3052
Umbria	880285	2500	2500
Basilicata	556934	1582	1582
Molise	302265	858	858
Valle d'Aosta	125501	356	356

If we use the data shown in the materials and methods section about the production of food, by dividing the energy consumption for the total production of the good we can calculate the total energy consumption for each good, both in terms of electricity and of fuels (natural gas and refined oil). The we can calculate the amount of biogas which can be produced from the treated food waste. In this way two indicators can be calculated: the bioenergy produced from food waste and the energy spared reducing food waste production. We can relate these two kinds of energy efficiency measures with the total consumption of energy of the agroindustrial sector in Italy and then estimate how much energy is spared respect to the total consumption.

The final indicators are proposed in table 2. In the first part of the table we have reported the input data which are used for the final calculations. It can be seen that the average electricity demand of the Agricultural sector is lower (773 MJ/t) respect to that of the food industry (1076 TJ/t). This is reasonable.

Table 2. Impact of food waste reduction on the total consumption of energy in the Italian food industry

Indicator	Unit	Agricultural Production	Food Industry
Electricity by coal	MJ/t	117	163
Electricity by gas	MJ/t	392	543
Electricity by hydro	MJ/t	118	164
Electricity by wind	MJ/t	26	36
Electricity by petroleum and other oil derivatives	MJ/t	54	75
Electricity by biomass and waste	MJ/t	24	34
Electricity by solar PV	MJ/t	28	39
Electricity by Geothermal	MJ/t	15	21
Total Electricity consumption	MJ/t	773	1076
Refined petroleum	MJ/t	470	21
Natural gas	MJ/t	97	138
Total FUEL consumption	MJ/t	567	159
Total Energy consumption	MJ/t	1340	1235
Total Electricity consumed by Landfill treatment of Food waste	MJ/t	0.07	
Total FUEL consumed by Landfill treatment of Food Waste	MJ/t	1.54	
Total Electricity spared through REF	TJ	316	
Total FUEL Spared through REF	TJ	124	
Total Electricity produced through EFE	TJ	308	
Total Energy spared avoiding landfill	TJ	0.55	
Total FINALE Energy spared	TJ	748.55	
Total energy consumption of the agro-industrial sector	TJ	67805	
Total reduction of energy consumption of the agro-industrial energy sector	%	1.10	

The average fuel consumption of the agricultural production is higher (567 MJ/t) than the average fuel consumption of the food industry (159 MJ/t). If we sum the average electricity consumption and the average fuel

consumption of the agricultural and the industrial sector we obtain a total energy consumption, which is quite similar for the agricultural sector and the food industry. From the analysis presented in the table we see that the average energy consumption for food, resulting by the sum of the consumption during the agricultural phase and the consumption during the industrial phase, results to be about 2.6 MJ/kg. This is a low value if we consider the data reported by the JRC report "Energy use in the EU food sector: State of play and opportunities for improvement" [10], can reach even 50 MJ/kg. Nevertheless we have to take into consideration that in this study the energy consumption due to the production of fertilizers and other chemicals is not considered and it is also neglected the energy consumption during the whole life cycle (so the energy consumed for the extraction of the fossil sources, for example). The consumption of energy in this case is given only by the measurable inputs of electricity, heat and other fuels.

The electricity and fuel consumption reduction due to the Expired Food Reduction chains is calculated by dividing the total electricity and fuel consumption for the total production (expressed in tonnes) for each sector. The production of electricity obtained from the conversion of the food waste in biogas, through the Expired Food to Energy (EFE) chains, is calculated assuming an average moisture content of the food waste of 50% and a yield of biogas which is about 300 Nm^3/tTS. The energy spared for the avoided treatment of the food waste in the landfill is almost negligible.

Finally the table shows that in the end the whole project if scaled up to the entire national level can reduce about 1% of the total consumption of energy of the entire agricultural and food sectors, which contributes to the 11% of the total Italian GDP. It has to be considered that the development business type which has been launched by the project corresponds to a moderate total investment cost, compared to the final benefits, which are even higher in terms of GHG reduction, which were not taken into account in this study.

4 Conclusions

The study ha firstly provided a clear analysis of the agricultural sector and of the food industry sector, identifying which are the main productions and what is the corresponding energy consumption in terms of electricity, heat and fuel. Based on these statistics which were retrieved by the EXIOBASE v3.3 database, the calculations about the impact of the iREXFO project, developed by the University of Perugia, on the Italian agroindustrial sector has been calculated. It can be seen from the results that through the two main interventions of the project, that is: Reduction of Expired Food (REF) chains and Expired Food to Energy (EFE) chains, the reduction food waste reduced can be about the 6% of the total food waste treated in Italy (which amounts to circa 6 Mt). The reduction of food waste and its use to produce biogas can bring also to a reduction in energy consumption and a production of green energy (through biogas) which are equal to 1.1% of the total energy consumption of the agricultural sector plus the food industry sector. This reduction in the energy consumption is the lowest that can be achieved because it does not consider the reduction in the use of fertilizers and the reduction in the use of other chemical and also the energy consumed during the life cycle of the fossil fuels production and renewable energy plants production.

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