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European Union in the Context of the Current Model of Production and Consumption: Food Self-Sufficiency from a Photosynthetic Energy Perspective

Joan-Carles Gil-Martin[1, 3], Yvonne Colomer-Xena[1, 3], Eusebi Jarauta-Bragulat[2, 3, *], Ramon Clotet-Ballus[3]

[1]Department of Management, Technical University of Catalonia, Barcelona, Spain

[2]Technical University of Catalonia, Barcelona, Spain

[3]UNESCO Triptolemos Chair, National University Distance Education, Madrid, Spain

Email address:

joan.carles.gil@upc.edu (Joan-Carles Gil-Martin), ycolomer@triptolemos.org (Yvonne Colomer-Xena), eusebi.jarauta@upc.edu (Eusebi Jarauta-Bragulat), rclotet@triptolemos.org (Ramon Clotet-Ballús)

[*]Corresponding author

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Abstract: For their effective management, food systems need to have an understanding of their capacity for self-sufficiency in a sustainable environment, not only to achieve goal 2 (zero hunger) of the 17 United Nations (UN) Sustainable Development Goals (SDGs), but also considering all the interrelationships between them. The European Union (EU) can be considered a complex food system due to the territorial identity of regulations that define it from production to consumption, so it makes sense to study the balance of food energy produced and consumed in its different forms. The complexity of this system requires to have detailed data for its study; The available official data often lacks these details, so it has been necessary to carry out an extensive additional search for complementary data. In this work, the EU is considered as a closed system both in population and in exchanges of valid products for its food and refers exclusively to food energy, its production and consumption, without taking into account the consumption of energy corresponding to the operation of all the agri-food chain. Food consumption, intake plus waste, has been calculated considering as intake not only basic energy consumption, but also extra consumption due to cultural, social or behavioral causes. The availability of real food energy has been evaluated from the initial value obtained from all sources and from there the photosynthetic energy dedicated to intensive livestock and equivalents and that destined to other non-food uses has been deduced. Apart from the partial data (see comments and conclusions), the global results of this study show a dietary energy deficit of the order of 17%, due to an excess of consumption, waste and the allocation to collateral uses of a part of the available energy. The information and knowledge provided by the results obtained have to be valid in order to contribute to the analysis of food strategies in the EU and provide solutions.

Keywords: Food Self-Sufficiency, Photosynthetic Production, European Union, Food Consumption, Sustainable Production, Food Systems, Nutrition

1. Introduction

The human being obtains all the energy necessary for life through products of plant origin, either directly (consumption of vegetables, cereals, fruits, etc.) or indirectly (consumption of meat, fish, milk, honey, eggs and others). This last source of energy can have two origins: that which is generated from animals fed by products obtained by photosynthesis and not suitable for human consumption (grass, plankton, etc.) and that which comes from animals fed with products susceptible to enter the human food chain. Both cases are evaluated, for what they represent, in the energy balance.

From this perspective, it seems reasonable to analyze two

fundamental concepts to manage the strategy related to food availability:

1) the sources of available plant photosynthetic resources and their use;
2) proximity (distance between the area of production and the area of consumption).

In the European Union (EU), both concepts are aligned with the "Farm to Fork" strategy included in the "European Green Deal" [1, 2] with its two basic axes:

1) food security for the population (accessible and healthy food);
2) sustainability, in which proximity or self-sufficiency are important factors, as the expression from "Farm to Fork" symbolically indicates.

It should be taken into account that not all photosynthetic production capable of being used as human food is used for this purpose; Indeed, Clotet and others [3] conceptually describes production technologies and their uses, as well as both material and energy flows.

The first piece of information needed is to know what the capacity of the European Union is to autonomously and sustainably feed its entire population (calculation made from the current 27 Member States). This debate becomes even more relevant after the publication of some reports, both from the European Union itself [4] and from government agencies of other countries [5], among others, warning of the foreseeable reduction of said capacity as a consequence of the application of the measures provided for in the Green Deal strategy [6].

In the current complex context of production and consumption in the socio-political sphere of the EU, in order to determine whether or not its self-sufficiency is at risk, it is particularly important to have a reliable estimate of the capacity for autonomous production of food energy and the real demand for energy by its population. This is important not only to study food self-sufficiency, but also for said study to serve as a basis and support for strategic decision-making.

The lack of adequate data for a study of this nature has made it necessary to seek complementary paths from sources from different institutions; therefore, an Annex has been prepared with the sources and procedures for obtaining data. This has made it possible to have a vision that is as complete and approximate as possible of the food energy balance in the European Union. Consequently, the main objective of this work is to carry out a food energy balance considering the European Union (EU) as a closed system both from the point of view of population, and commercial exchange of products intended for human consumption. This approach has been the basis of the present approximation taking the years 2017, 2018 and 2019 as the data source of the variables (before the Covid-19 Pandemic).

2. Methodology

The study of food self-sufficiency in the EU is a subject that, to date, has been little investigated with the necessary rigor. It is intended to give an answer to this issue from an energy perspective and with the greatest possible precision. Given the variety of products and processes involved in production, global uses and individual consumption, the energy balance is presented as the only way to study food self-sufficiency. For this, the factors discussed below in relation to consumption and availability are considered in accordance with the definitions given below and with the corresponding energy scheme in Figure 1. The elements of the energy associated with human nutrition are described below, with the definition and notation adopted in this work.

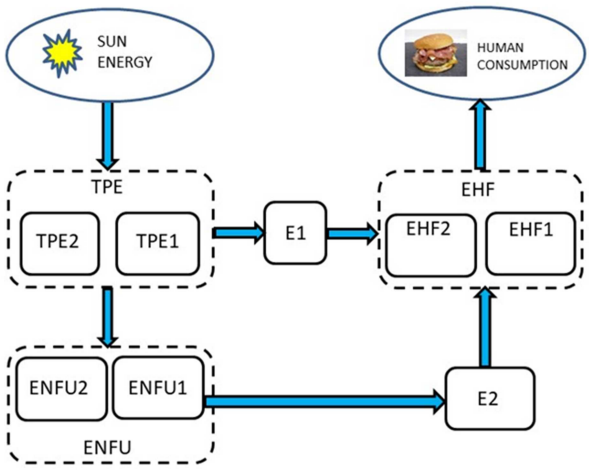

Figure 1. *Energy flow associated with the products from photosynthesis.*

With potential destination for human consumption. TPE = Total Photosynthetic Energy; ENFU = Energy for Non-Food Uses; EHF = Energy Human Food

Total Photosynthetic Energy (TPE). Energy that corresponds to the use of solar energy through photosynthesis and has two components:

1) corresponding energy of plant production valid for direct food consumption (TPE1);
2) energy corresponding to the consumption of non-vegetable products, those derived from grazing livestock, deep-sea fishing, honey, mushrooms and others, for whose production photosynthetic resources not directly food have been used (TPE2).

Of these two parts, only a part of the energy for human consumption (E1) is linked; energy flow is reflected in Equation (1).

Photosynthetic energy for not direct food uses (ENFU). Energy for animal production and non-food crops. This energy is divided also into two components:

1) energy used for animal production such as intensive livestock farming, aquaculture, heliciculture, insect breeding, obtaining protein matter in bioreactors and others (ENFU1). A part of this energy partially returns to human food (E2);
2) energy dedicated to plant production of both strictly non-food products such as coffee, tea and alcoholic beverages, as well as biofuels, pet food, textiles, tobacco, opiates, gardening, pharmacy, perfumery and others (ENFU2).

Energy for Human Food (EHF). Energy dedicated to human food that comes in part from the global photosynthetic energy (E1), adding the energy coming from return through animal production (E2). This energy is divided also into two components:

1) net dietary energy (EHF1), which is the energy that is incorporated into the human physiological system;
2) wasted food energy (EHF2), energy lost due to food waste.

With this, the equations that define the food energy balances suitable for human consumption are obtained:

$$TPE = TPE1 + TPE2;\ E1 = \alpha(TPE),\ 0 < \alpha < 1. \quad (1)$$

$$ENFU = ENFU1 + ENFU2;\ E2 = \beta(ENFU1),\ 0 < \beta < 1. \quad (2)$$

$$EHF = E1 + E2 = EHF1 + EHF2;\ EHF1 = \gamma(EHF),\ 0 < \gamma < 1. \quad (3)$$

The energy study is divided into an analysis of three elements: those related to food availability, food consumption and population, according to the considerations detailed below.

Availability:

1) Consider that the basic energy necessary to feed the population comes from photosynthetic production. That is to say, the use of solar energy through the food consumption of vegetable production, as well as the consumption of non-vegetable products, such as those derived from grazing livestock, deep-sea fishing, honey, mushrooms and others, for whose production photosynthetic resources not directly for food (TPE) have been used;
2) Deduct the additional photosynthetic energy necessary to obtain the calories from foods that do not come entirely from photosynthetic feeding, such as meat from intensive livestock breeding, fish from aquaculture, dairy products, eggs, heliciculture, insects, etc., and components obtained through biotechnology, since this implies an additional energy cost of transformation due to loss of direct energy yield (ENFU1 – E2);
3) Subtract from the total supply of photosynthetic energy produced that would be suitable for potential food consumption, the non-food uses for which it is intended (biofuels, alcoholic beverages, textile applications, biodegradable packaging, etc.), (ENFU).

Consumption (EHF):

1) Consider not only the basic average energy consumption (kcal) that the human being needs to survive, but also add the extra energy consumption due to cultural, social or behavioral factors;
2) Include the percentage of final food waste (domestic, catering, etc.) generated (EHF2).

Population:

The data with which we have worked come from EUROSTAT and correspond to the average value of the years 2017, 2018 and 2019 (before the Covid-19 Pandemic) for the set of countries that make up the so-called EU (without the United Kingdom), since these three years constitute the first series with all the data available at the time of the study, they are the first without data from those countries. The three-year average has been used to statistically neutralize punctual anomalies. The expected trend in the EU for the general population is a certain stabilization with the beginning of depopulation in the middle of the 21st century (EUROSTAT, 2022), regardless the floating population coming from outside the EU itself.

3. Calculations and Results

3.1. Energy Demand for Basic Food: Habits and Consumption (EHF)

The total energy expenditure in human nutrition is a value that depends on the food consumption of the population, one necessary (basic food energy) and other circumstantial (extra food energy consumed for cultural, behavioral reasons...). Although from a strict thermodynamic vision energy should be expressed in kilojoules (kJ, international system), the authors have preferred to use kilocalories in this work (1 kcal = 4186 kJ; 1kJ = 0.0239 kcal), given that this is the unit commonly used in the context of the food system and this facilitates the interpretation of the numerical data.

Based on an average of European data [7], the average energy requirement to cover the basic needs of the European population is estimated at 2200 kcal per day and person, considering their different energy needs depending on the age range and lifestyle (childhood, adolescence, maturity, old age, sedentary lifestyle, physical activity, etc.). The data on overweight and obesity of the population in the EU are high (56% and 26% respectively). It is estimated that in the most highly developed countries of the EU a consumption of 3470 kcal/day can be reached [8]. For this reason, the authors have set a consumption value of 2640 kcal/day for this study, considering the extra energy demand of 20% based on the basic energy requirement of 2200 kcal per person and day (E1+ E2, where the value includes the distribution among all the usual sources of energy in the European population, considered omnivorous).

Domestic food waste (EHF2) is part of the citizen's consumption and represents an additional cost of 25% of food energy, which could have been used. This data is a prudent consideration taking into account some estimates [9, 10] which set food waste at around 30%, the first for developed countries and the second specifically for the USA. The European Union estimates this waste at 42% [11], but since the European Commission itself highlights the deficiencies of the study, this value has not been considered. All this is displayed in Table 1 (EHF).

Table 1. *Population and daily caloric intake (EHF) in the European Union in the period 2017-2019 (Source: own elaboration).*

Description	Energy
Basic theoretical caloric needs per person and day	2200 calories
Increased caloric intake for social and cultural reasons (20% of the previous value)	440 calories
Real caloric needs (kcal) per person and day (E1 + E2)	2640 calories
Household food waste (EHF2) (25% on 2640 kcal)	660 calories
Real caloric consumption per person and day	3300 calories
EU average population (2017-2019)	446 $\cdot 10^6$ inhabitants
Real daily caloric consumption EU (2017-2019)	1.4718 $\cdot 10^6$ Mkcal

The final value in Table 1 (1472$\cdot 10^6$ Mkcal) shows the daily energy needed to feed the EU population according to their current consumption habits (intake plus waste) and with a uniform omnivorous diet for the entire population.

3.2. Food Energy Availability

3.2.1. Full Availability (TPE)

In calculating the food energy supply, all products generated in the EU by direct photosynthesis (agricultural crops) or indirect photosynthesis (grazing livestock, deep-sea fishing, honey, wild mushrooms, algae, etc.) that can be used in human feeding are considered.

It must be considered that throughout the production and transformation process up to domestic consumption, a series of losses are generated. To apply the yield in all stages of the food chain prior to consumption (primary production, processing or transformation, distribution) the percentages indicated by Food and Agriculture Organization of the United Nations, FAO [9, 12] for each product group have been taken into account. In the cases in which this estimate has not been available, the value of 20% has been applied and the energy values have been calculated from the data of the tables of the BEDCA Network of the Ministry of Science and Innovation of the Spanish Government (Table 2) (BEDCA: Spanish Food Composition Database published by the BEDCA Network of the Ministry of Science and Innovation and under the coordination and financing of the Spanish Agency for Food Safety and Nutrition of the Ministry of Health, Social Services and Equality. The food composition values collected in this database have been obtained from different sources including laboratories, the food industry and scientific publications. https://www.bedca.net/).

Table 2. *Total food photosynthetic daily production suitable for human food use (TPE).*

Agricultural product or crop	GDP	EFF	NDP	MEEF	DEP
Cereals for grain production (including seeds)	785.93	92.0%	723.06	3371.0	$2.4374 \cdot 10^6$
'Green' cereal crops (corn and others)	690.90	92.0%	635.63	3371.0	$2.1427 \cdot 10^6$
Dried legumes and for grain production	12.17	82.0%	9.98	2906.0	$2.9000 \cdot 10^4$
Tubers (potato, beetroot and others)	471.52	50.0%	235.76	546.0	$1.2872 \cdot 10^5$
Oilseeds	87.60	82.0%	71.83	3482.0	$2.5012 \cdot 10^5$
Fresh vegetables (including melons) and strawberries	170.40	62.0%	105.65	222.0	$2.3454 \cdot 10^4$
Other permanent crops for human consumption	165.17	80.0%	132.14	510.0	$6.7389 \cdot 10^4$
Nuts	2.94	60.0%	1.76	5827.0	$1.0279 \cdot 10^4$
Olives	32.32	80.0%	25.86	3482.0	$9.0031 \cdot 10^4$
Fish caught in own or international waters or by agreements	12.30	75.0%	9.23	918.0	$8.4686 \cdot 10^3$
Grazing livestock (extensive)	4.59	60.0%	2.75	1407.0	$3.8749 \cdot 10^3$
Honey	0.69	85.0%	0.59	3092.0	$1.8135 \cdot 10^3$
Wild mushrooms	0.59	85.0%	0.50	259.0	$1.2989 \cdot 10^3$
Algae	0.82	85.0%	0.70	222.0	$1.5473 \cdot 10^2$
Sum	2437.94		1955.42		5.1936 · 106

Variables: GDP = Gross Daily Production (Mkg/day), EFF = Efficiency (percentage),
NPD = Net Daily Production (Mkg/day), MEEF = Mass Energy Equivalence Factor (kcal/kg),
DEP = Daily Energy Produced (Mkcal/day). Source: own elaboration.

3.2.2. Photosynthetic Energy for Non-Food Use (ENFU2)

The net availability of energy does not reach the entire food system since significant amounts of photosynthetic energy in the form of cereals, grapes or apples are used to obtain alcoholic beverages. The authors, following the indications of the World Health Organization [13] have not considered them food, since their consumption is related to the recreational and cultural aspects of society. Likewise, a quantifiable amount of cereal production is dedicated to obtaining biofuels and pet food (including equines). All the data referring to this energy, valid for human consumption but intended for other uses, are detailed in Table 3.

Table 3. *Photosynthetic daily per day used for human non-food use (ENFU2).*

Agricultural product or crop	NDP	MEEF	DEP
Cereals for pet food	23.58	3371	$7.9488 \cdot 10^4$
Cereals for alcoholic beverages	15.72	3371	$5.2992 \cdot 10^4$
Cereals for biofuels	23.58	3371	$7.9488 \cdot 10^4$

Agricultural product or crop	NDP	MEEF	DEP
'Green' cereal crops (corn and others) for energy	207.27	3371	$6.9871 \cdot 10^5$
Grape for wine production	63.07	510	$3.2166 \cdot 10^4$
Apples for cider production	4.8	510	$2.4480 \cdot 10^3$
Sum	338.02		9.4929 · 105

Variables: DP = Daily Production (Mkg/day), MEEF = Mass Energy Equivalence Factor (kcal/kg), DEP = Daily Energy Produced (Mkcal/day). Source: own elaboration.

3.2.3. Food Energy Used for Food Production (ENFU1)

This is the photosynthetic energy used by living beings or by biotechnological processes for the production of food whose consumption will be used to satisfy part of the demand (contribution E2 for EHF). From the data of the internal consumption of this type of product in the EU, the energy (kcal) provided for human consumption has been calculated, evaluated from the official data of food composition of the BDCA Network and the European Network Euro FIR AISBL. From this value, the photosynthetic energy that has been necessary to obtain them is deduced using the conversion efficiency data in animal feed developed by Spedding *et al.* [14] and validated as a reference by FAO [15]. For efficiency in aquaculture, an estimate has been made based on the data provided by FAO [16] and Jover [16]. Table 4 shows the results of these calculations. To interpret the data properly, it should be clarified that the term "Energy produced (EP)" means the energy contained in the consumable product and that "Feed Energy (ENFU1)" means the energy that the animal needs to ingest to produce the consumable product.

Table 4. *Energy balance in the process of obtaining calories from foods not entirely derived from photosynthetic feeding (E2).*

Product consumed	DC	MEEF	EP (E2)	ER	FE (ENFU1)	ED (ENFU1 – E2)
Beef and veal	17.96	1260	$2.2630 \cdot 10^4$	0.032	$7.0718 \cdot 10^5$	$6.8455 \cdot 10^5$
Mutton and lamb	0.40	2150	$8.6000 \cdot 10^2$	0.033	$2.6061 \cdot 10^4$	$2.5201 \cdot 10^4$
Pork	57.16	2190	$1.2518 \cdot 10^5$	0.250	$5.0072 \cdot 10^5$	$3.7554 \cdot 10^5$
Poultry	31.57	1115	$3.5201 \cdot 10^4$	0.146	$2.4110 \cdot 10^5$	$2.0590 \cdot 10^5$
Aquaculture fish	3.09	1390	$4.2951 \cdot 10^3$	0.290	$1.4811 \cdot 10^4$	$1.0516 \cdot 10^4$
Butter	6.02	7533	$4.5349 \cdot 10^4$	0.140	$3.2392 \cdot 10^5$	$2.7857 \cdot 10^5$
Cheese	25.64	3274	$8.3945 \cdot 10^4$	0.140	$5.9961 \cdot 10^5$	$5.1566 \cdot 10^5$
Powered whole milk	1.11	4975	$5.5223 \cdot 10^3$	0.140	$3.9445 \cdot 10^4$	$3.3922 \cdot 10^4$
Liquid milk	433.48	55	$2.3841 \cdot 10^4$	0.140	$1.7030 \cdot 10^5$	$1.4645 \cdot 10^5$
Nonfat powdered milk	2.82	3627	$1.0228 \cdot 10^4$	0.140	$7.3058 \cdot 10^4$	$6.2830 \cdot 10^4$
Yogurts and others	21.29	540	$1.1497 \cdot 10^4$	0.140	$8.2119 \cdot 10^4$	$7.0622 \cdot 10^4$
Eggs	17.72	1500	$2.6580 \cdot 10^4$	0.105	$2.5314 \cdot 10^5$	$2.2656 \cdot 10^5$
Sum	618.26		3.9513·105		3.0315·106	2.6363·106

Variables: DC = Daily Consumption (Mkg/day), MEFF = Mass Energy Equivalence Factor (kcal/kg), EP = DC · MEEF = Energy Produced (Mkcal/day), ER = Energy Ratio, FE = Food Energy = EP / ER (Mkcal/day), ED = Energy Difference (Mkcal/day) = ENFU1 – E2.
Source: own elaboration.

The difference between the photosynthetic energy (kcal) that the animal needs to ingest to produce the consumable product and the energy contained in the product itself, provides us with the extra energy that has been necessary in each case and which in total amounts to $2.6363 \cdot 10^6$ daily Mkcal for the EU in the analyzed period.

Taken together, it can be seen that the real demand for daily photosynthetic energy necessary to feed the entire EU population for 1 day in the period considered (2017, 2018 and 2019, before the Covid-19 Pandemic) amounts to $1.472 \cdot 10^6$ Mkcal, as indicated in Table 1.

On the other hand, the real daily supply of food photosynthetic energy available to EU citizens and which is generated exclusively in their geographical environment, amounts to a total of $1.2168 \cdot 10^6$ Mkcal. Table 5 details how to obtain this value from the data in Tables 2, 3 and 4.

Table 5. *Balance between daily available food energy and consumed food energy in the EU (period 2017, 2018, 2019).*

Energy Component	Energy Value (Mkcal/day)	Table
Energy for Human Food (EHF)	$1.4718 \cdot 10^6$	1
Energy for Non-Food Products (ENFU1)	$3.0315 \cdot 10^6$	4
Energy for Animal Production (ENFU2)	$0.9453 \cdot 10^6$	3
TPE	$5.1936 \cdot 10^6$	2

Consumption (EHF + ENFU1 + ENFU2) (Mkcal/day)	Availability (TPE) (Mkcal/day)	Balance (Availability – Consumption) (Mkcal/day)
$5.4485 \cdot 10^6$	$5.1936 \cdot 10^6$	$-0.25498 \cdot 10^6$

Source: own elaboration.

The consumption and waste forecasts have been set with a weighted interpretation based on various expert opinions and the rest of the data has been obtained from various public and referable databases. With this, the results obtained show, with a reliability linked to that of the data sources used, that the European Union is deficient in the order of 17%, in an approach of food self-sufficiency in the current production and consumption conditions and in the period from 2017 to 2019. The distribution of the results is visualized in Figure 2, which graphically and semi-quantitatively describes the numerical results expressed in Table 5.

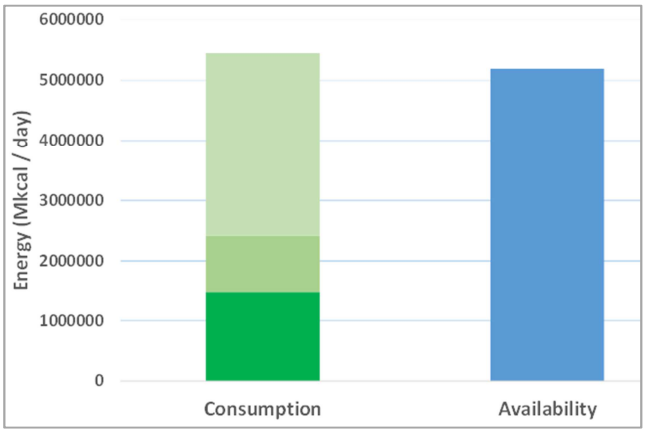

Figure 2. *Illustration of the energy balance values in Mkcal/day according to Table 5.*

(Consumption: Human Food $1.4718 \cdot 10^6$+ Animal Production $0.9453 \cdot 10^6$ + Non-food Products, $3.0315 \cdot 10^6$. Availability: Photosynthetic Energy $5.1936 \cdot 10^6$). Source: own elaboration.

4. Conclusions

This work is the result of a hypothesis aligned with sustainable production and consumption approaches and simulating the EU as a closed food system, both in terms of food availability and population. This has made it possible to know its complexity in a quantified way and to have information that allows evaluating future actions not only for the EU (Green Deal Strategy) but also as an improvement in global coordination.

The conclusions to which the results obtained in this study lead, in the period of time considered from 2017 to 2019 (before the Covid-19 Pandemic), can be specified in the following points:

1) Without commenting on the form of use, the European citizen uses a greater amount of food energy than the photosynthetic genesis structure in the EU can provide. Globally, the EU considered as a closed system appears to be deficient with a value of the order of 17% to feed its citizens under the current conditions of consumption and production.
2) The implementation of the Green Deal strategy may lead to a decrease in agricultural and cattle raising production, which would dangerously increase the deficit that could, in addition to increasing prices, increase the need to import ready-made food from third countries that may or may not be guided by the same principles and requirements that the EU determines in its Green Deal, that is, that the new sustainable policies carry the risk of unsustainable imports.
3) Nutritional studies in the EU indicate an excess consumption with a large contribution of energy already converted into non-vegetable food. The study is consistent with this nutritional opinion, because approximately 60% of the initially available photosynthetic energy is used for its intermediate conversion into human food.
4) It is necessary to prioritize that photosynthetic production has a more frequent destination for human food (consumption of plant products, meat from pastures and deep-sea fishing), if the balance between sustainability, the right to healthy eating and responsible economic activity is to be strengthened.
5) The wide global presence of European food products is due to its processing power. Given the negative result of the balance (deficit), the need for strong imports of raw materials (cereals and legumes) is evident, not only to offset the deficit but also to support the EU's export capacity.
6) This work responds to a description of reality from an energy approach and shows the multiplicity of factors involved in food systems: technologies, economies, training, habits, cultures and governance systems. For its optimal functioning, all of this requires adequate training, information and governance at all levels [17].

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Appendix

Sources and procedures of data collection

1. Gross food photosynthetic production per day suitable for human food use.

On occasions Eurostat data is not always complete for all countries, because it is not significant, it is not available or it is confidential. In this case, estimates have been made based on the years available and the general trends observed.

1) Cereals for grain production (including seeds): Eurostat, Crop production in national humidity, Cereals for the production of grain (including seed), Code C000, Harvested production (1000 t), Data extracted on 03/03/2021 15:45:20 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_637935/default/table).
2) 'Green' cereal crops (maize and others): This variable is

the result of the sum of Green maize (Code G3000) and Other cereals harvested green (excluding green maize) (Code G9100).

3) Green maize: Eurostat, Crop production in national humidity, Green maize, Code G3000, Harvested production (1000 t), Data extracted on 14/07/2021 20:19:16 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_1147383/default/table).
4) Other cereals harvested green (excluding green maize): Eurostat, Crop production in national humidity. Other cereals harvested green (excluding green maize), Code G9100, Harvested production (1000 t), Data extracted on 07/14/2021 20:21: 56 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_1147393/default/table).
5) Legume crops and for grain production: Eurostat, Crop production in national humidity, Dry pulses and protein crops for the production of grain (including seed and mixtures of cereals and pulses), Code P000, Harvested production (1000 t), Data extracted on 03/03/2021 15:40:10 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_637935/default/table).
6) Tubers (potato, beetroot and others): Eurostat, Crop production in national humidity, Root crops, Code R0000, Harvested production (1000 t), Data extracted on 03/28/2021 23:26:15 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_747687/default/table).
7) Seeds oilseeds: Eurostat, Crop production in national humidity, Oil seeds, Code I1100, Harvested production (1000 t), Data extracted on 28/03/2021 23:45:28 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_747729/default/table).
8) Fresh vegetables (including melons) and strawberries: Eurostat, Crop production in national humidity, Fresh vegetables (including melons) and strawberries, Code V0000_S0000, Harvested production (1000 t), Data extracted on 03/03/2021 15:47:26 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_637935/default/table).
9) Other permanent crops for human consumption: This variable includes all types of fruit, after subtracting nuts and olives. Therefore, it is calculated by subtracting from the Permanent variable crops for human consumption (Code H000) the variables Nuts (Code F4000) and Olives (Code O1000).
10) Permanent crops for human consumption: Eurostat, Crop production in national humidity, Permanent crops for human consumption, Code H0000, Harvested production (1000 t), Data extracted on 03/03/2021 15:53:05 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_637935/default/table).
11) Dry fruits: Eurostat, Crop production in national humidity, Nuts, Code F4000, Harvested production (1000 t), Data extracted on 03/28/2021 23:53:47 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_747745/default/table).
12) Olives: Eurostat, Crop production in national humidity, Olives, Code O1000, Harvested production (1000 t), Data extracted on 03/28/2021 23:59:42 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_747752/default/table).
13) Grazing livestock (extensive): this variable had to be estimated due to the lack of useful data, both in official sources and in those of sectoral organizations. To this end, it has been calculated that the production of meat from extensive livestock farming represents 20% of the total production in the case of cattle and 50% in the case of sheep.
14) Total bovine production is the sum of that which has been slaughtered in slaughterhouses (Bovine meat - Slaughtering in slaughterhouses) plus that which has not (Calve and young Cattley, Adult cattle - Slaughtering, other than in slaughterhouses).
15) Beef - Slaughtering in slaughterhouses: Eurostat, Slaughtering in slaughterhouses, Bovine meat - Slaughtering in slaughterhouses, Code B1000, Thousand tons, Data extracted on 06/04/2021 13:19:58 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_PANN__custom_778581/default/table).
16) Calves and young cattle, Adult cattle - Slaughtering, other than in slaughterhouses: Eurostat, Calves and young cattle, Adult cattle - Slaughtering, other than in slaughterhouses, Code B1100_B1200, Thousand tons, Data extracted on 04/06/2021 14:54: 11 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_SLOTH$DEFAULTVIEW/default/table).
17) Total sheep production is the sum of that which has been slaughtered in slaughterhouses (Meat of sheep and goats - Slaughtering in slaughterhouses) plus that which has not (Lamb - Slaughtering, other than in slaughterhouses).
18) Meat from sheep and goats - Slaughtering in slaughterhouses: Eurostat, Meat of sheep and goats - Slaughtering in slaughterhouses, Code B4000, Thousand tons, Data extracted on 06/04/2021 13:54:48 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_PANN__custom_778749/default/table).
19) Lamb - Slaughtering, other than in slaughterhouses: Eurostat, Lamb- Slaughtering, other than in slaughterhouses, Code B4000, Thousand tons, Data extracted on 06/04/2021 15:04:53 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_SLOTH__custom_779328/default/table).
20) Honey: The data have been obtained from the publication of the European Commission. Honey market Presentation, Autumn 2020'. This publication

offered the production corresponding to the years 2017 and 2018, but not those of 2019, which were estimated as the average of both years. (https://ec.europa.eu/info/sites/default/files/food-farming-isheries/animals_and_animal_products/documents/market-presentation-honey_autumn2020_en.pdf).

21) Wild mushrooms: Eurostat statistics only provide data on the production of cultivated mushrooms. There are no reliable statistics from other sources, therefore, based on expert opinion, it has been estimated that the collection of wild mushrooms for human consumption represents around 20% of the weight of cultivated mushrooms.
22) Cultivated mushrooms: Eurostat, Crop production in national humidity, Cultivated mushrooms, Code U1000, Harvested production (1000 t), Data extracted on 22/03/2021 12:14:20 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_719213/default/table).
23) Algae: There is no statistical information on algae production in the EU. Euronews.com, in collaboration with the European Commission, published in June 2020 the article ' Algae farming: an economical and sustainable opportunity for Europe ', where it is stated that the EU contributes to 1% of world algae production, which amounts to 30 million tons per year. Consequently, the figure of 300 million kg has been taken as representative of the annual production of algae in the EU-27 during the period considered. (https://www.euronews.com/green/2020/06/09/seaweed-farming-an-economic-and-sustainable-opportunity-for-europe).

2. Photosynthetic production per day for human non-food use

1) Cereals for feeding domestic animals: No reliable data has been found on the production of cereals derived for the consumption of pets. It has been estimated that this variable represents 3% of the production of cereals for the production of grain (including seeds).
2) Cereals for alcoholic beverages: No reliable data has been found regarding the value of this variable, which is why it has been estimated that it represents 2% of the production of cereals for the production of grain (including seeds).
3) Cereals for biofuels: The European Commission estimates the percentage of European cereal production that goes to the production of biofuels at 3%: European Commission, ' Cereals, oilseeds, protein crops and rice', ' Overview ', ' Cereals ', Accessed on 07/13/2021, (https://ec.europa.eu/info/food-farming-fisheries/plants-and-plant-products/plant-products/cereals_en).
4) 'Green' cereal crops (corn and others) for energy: Eurostat considers 'green' crops those whose main destination is animal feed and energy production (biomass) from the farm itself. Eurostat does not differentiate this production based on its destination, so the production of 'green' cereal crops (corn and others) to produce energy (biomass) is estimated at 30% of the total 'green' crops resulting from the sum of the variables Green maize (G3000) and other cereals harvested when green (excluding green corn) (G9100).
5) Green maize: Eurostat, Crop production in national humidity, Green maize, Code G3000, Harvested production (1000 t), Data extracted on 14/07/2021 20:19:16 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_1147383/default/table).
6) Other cereals harvested when green (excluding green maize): Eurostat, Crop production in national humidity, Green maize, Code G9100, Harvested production (1000 t), Data extracted on 14/07/2021 20:21:56 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_1147393/default/table).
7) Grapes for wine production: Eurostat, Crop production in national humidity, Grapes for wines, Code W1100, Harvested production (1000 t), Data extracted on 08/06/2021 16:24:48 from [ESTAT], Data extracted on 06/08/2021 16:24:48 from [ESTAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_1041654/default/table).
8) Apples for cider production: Eurostat separates apple production into two categories, Apples for fresh consumption and apples for processing, but within this category apples processed for food use are not distinguished from those processed to obtain cider. To estimate the production of the latter, it has been necessary to resort to the European report Cider Trends 2019 of the European Cider and Fruit Wine Association (AICV) that has allowed calculation of the average consumption of the period 2013-2018 of the EU-27 in 000 Hl. A conversion factor 1.5 kg = 1 liter has been applied to this value to obtain the equivalence in weight. (https://aicv.org/files/attachments/.74/AICV_Cider_Trends_2019.pdf).

3. Additional photosynthetic calories needed to obtain calories from foods not coming from 100% photosynthetic food

Since Eurostat does not provide consumption data but production data, in most cases alternative sources have had to be consulted.

1) Beef and veal: This variable is obtained by subtracting from the total consumption of beef and veal consulted on Indexmundi.com, the one that comes from extensive livestock, since the latter has fed exclusively on pastures.
2) Beef and Veal Meat: Indexmundi.com, European Union (EU-27) Beef and Veal Meat Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 07/14/2021 11:31, (https://www.indexmundi.com/)
3) Beef and veal from grazing livestock (extensive): The procedure for obtaining this variable is explained in the corresponding point of Table 4 of this annex.

4) Sheep meat: This variable is obtained by subtracting from the total consumption of sheep meat, the one that comes from extensive livestock, since the latter has fed exclusively on pastures. EU sheep meat consumption has been obtained from Statista.com sources. As these are data referring to the EU-28, the consumption of the EU-27 has been estimated based on per capita consumption data in the United Kingdom provided by the British consultancy Savills. Since these data correspond to the year 2019, the percentage of British consumption of this year has been considered as representative for the calculation of the other two years.
5) Mutton and lamb: Statista.com, Forecast volume of mutton and lamb consumed in the European Union (EU 28) from 2015 to 2030, Unit of measure 1000 t, Data extracted on 14/07/2021 11:52, (https://www.statista.com/statistics/545582/mutton and lamb-consumption-volume-european-union-28/).
6) UK consumption per capita: Savills Research, UK meet consumption, Red Meat Outlook, Accessed on 15/07/2021. (https://www.savills.co.uk/research_articles/229130/298951-0.)
7) Pork: Indexmundi.com, European Union (EU-27) Swine Meat Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 07/14/2021 11:59, (https://www.indexmundi.com/).
8) Chicken (poultry): Indexmundi.com, European Union (EU-27) Chicken Meat Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 07/14/2021 11:39, (https://www.indexmundi.com/).
9) Aquaculture fish: For this variable, in the absence of consumption data, the production figures offered by Eurostat have been considered as representative of consumption: Eurostat, Production from aquaculture excluding hatcheries and nurseries, Code F00, Tonnes live weight, Data extracted on 07/14/2021 18:27:00 from [STAT], (https://ec.europa.eu/eurostat/databrowser/view/FISH_AQ2A$DEFAULTVIEW/default/table).
10) Dairy - Butter: Indexmundi.com, European Union (EU-27) European Union (EU-27) Dairy, Butter Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 14/07/2021 11:01, (https://www.index-undi.com/).
11) Dairy - Cheese: Indexmundi.com, European Union (EU-27) Dairy, Cheese Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 14/07/2021 11:07, (https://www.indexmundi.com/).
12) Dairy - Whole powder Milk: Indexmundi.com, European Union (EU-27) Dairy, Dry Whole Milk Powder Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 14/07/2021 11:11, (https://www.indexmundi.com/).
13) Dairy - Liquid milk: Indexmundi.com, European Union (EU-27) Dairy, Milk, Fluid Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 14/07/2021 11:14, (https://www.indexmundi.com/).
14) Dairy - Skimmed powder milk: Indexmundi.com, European Union (EU-27) Dairy, Milk, Nonfat Dry Domestic Consumption by Year, Unit of measure 1000 t, Data extracted on 14/07/2021 11:19, (https://www.indexmundi.com/).
15) Dairy - Yogurts and others: The consumption of yogurts and other similar dairy products has been obtained from the Italian consultant specialized in the dairy sector CLAL (Modena - Italy): Clal.it, European acidified milk (yogurts and other) production data, Unit of measure Tons, Accessed on 07/27/2021, (https://www.clal.it/en/?section=consegne_eu&p=D4100__THS_T).
16) Eggs: The consumption of eggs in the EU has been obtained from the Spanish association "*Organización Interprofesional del Huevo y sus productos* (Inprovo)". As these data refer to the EU-28, the consumption of the EU-27 has been estimated from laying hen populations provided by Eurostat.
17) Egg consumption in the EU-28: Inprovo, Egg production in the European Union, EU eggs market balance, 1000 t, Accessed on 07/19/2021, (https://www.inprovo.com/produccion-de-huevos-en-la-union-europea/)
18) Laying hens (producing eggs for consumption): Production of eggs for consumption and number of laying hens, Laying hens (producing eggs for consumption), Code A5110OH, Unit of measure Thousand, Data extracted on 07/19/2021 16:15:09 from [STAT], (https://ec.europa.eu/eurostat/databrowser/view/APRO_EC_EGGHEN$DEFAULTVIEW/default/table).

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