Article

Life Cycle Assessment Model of a Catering Product: Comparing Environmental Impacts for Different End-of-Life Scenarios

Judit Lovasné Avató [1] and **Viktoria Mannheim** [2,*]

1   Department of Methodology for Business Analysis, Institute of Quantitative Methodology,
     Budapest Business School, Alkotmány str 9–11, 1054 Budapest, Hungary; lovasneavato.judit@uni-bge.hu
2   Institute of Energy Engineering and Chemical Machinery, University of Miskolc, 3515 Miskolc, Hungary
*   Correspondence: viktoria.mannheim@uni-miskolc.hu

Abstract: This paper assesses the primary energy and environmental impacts of a restaurant main course product's lifecycle, especially focusing on end-of-life (EoL) stage. In the first step, a cradle-to-grave complex life cycle assessment (LCA) model of the product has been set up from the extraction of the required raw materials through the preparation, cooking and use phase to the end-of-life. In the second step, three scenarios (landfilling, incineration, and composting) were compared for the generated food waste in the end-of-life stage given that one of the biggest challenges in waste management is the optimal management of food waste. We calculated eleven environmental impact categories for the examined food product with the help of GaBi 9.0 software. During our research work, the primary energy was examined in each phase. In the third step, a comparison between the traditional and "sous vide" cooking technologies has been created to optimise of the cooking/frying life cycle phase. This paper basically answers three main questions: (1) How can the main environmental impacts and primary energy throughout the whole life cycle of the examined product be characterised? (2) What methods can optimise the different life cycle stages while reducing and recycling energy and material streams? and (3) what is the most optimal waste management scenario at the end-of-life stage? Based on the analysis, the highest environmental impact comes from the preparation phase and the end-of-life scenario for the traditional incineration caused almost twice the environmental load as the landfilling of the food waste. Composting has the lowest environmental impact, and the value of the primary energy for composting is very low. The sous vide cooking technique is advantageous, and the continuously controlled conditions result in a more reliable process. These research results can be used to design sustainable cooking and catering with lower environmental impacts and energy resources in catering units.

Keywords: food product; life cycle assessment; end-of-life scenarios; environmental impact; primary energy; food waste; circular economy

1. Introduction

1.1. Research History and Hypothesis

Today, the contradiction between the need for economic growth and the scarcity of natural resources is growing. The role of tourism is continuously growing, and the Sustainable Development Goals (SDGs) require a more holistic approach to supply and sales processes. The hospitality sector, which is closely related to tourism, has a significant environmental impact, where the complexity of the supply and sales chain is the main determinant of the impact on climate change. From a life cycle assessment perspective, a restaurant main dish is also a product containing waste just as a used PET bottle or a building, as residual material is generated during its preparation [1,2]. Therefore, we cannot forget the other economic player in this sector, the guests as product consumers and waste producers. The behaviour of the consumers (inappropriate consumer choices, irresponsible behaviour, and consumption residues) also has a significant impact on the

hospitality sector's environmental burdens. The thinking way of the population is still focused on increasing consumption. That is, the principle of waste prevention has not become an integral attitude regarding consumption. Nowadays, one of the significant challenges of waste management is the ever-increasing volume of created municipal solid waste (MSW) [3,4]. The amount of MSW is 2.01 billion tons, but it is expected to increase to 3.4 billion tons by 2050 [5]. We assume that in the context of sustainability for reducing MSW volume, it is also important to know the life cycle of food products. We think that one possible solution to the described above problems is the development of a complex life cycle model in the context of the circular economy (CE). The circular economy aims to keep a product and its components in the economy for as long as possible and in as high a quality as possible, and consequently to reduce the material and energy resources. Several research studies argue that the circular economy helps to minimise resources and reduce waste [6]. In recent years, CE better practices are becoming known, such as application of renewable energy sources, new solid waste management, and second generation biorefinery in the touristic sector [7,8]. With the application of a circular economy, avoidable or less food waste is generated at lifecycle stages of food products [9]. Nowadays, sustainable technological strategies should combine and integrate different LCA environmental data with the technological, social, energetic, and economic parameters [10]. Basically, in the catering industry, the economic participants have a financial interest in the avoiding of food waste based on the integration of the life cycle assessment and the circular economy.

1.2. The Literature Review

As early as 1955, Kuznets [11] pointed out that the relationship between economic growth and pollution describes an inverted U-shaped curve. As income increases, the rate of environmental impacts increases and decreases after reaching a peak point [12,13]. The framework for the Sustainable Development Goals and the targets of the Agenda 2030 [14] look at a growing number of methods and indicators are helping to quantify environmental impacts.

One of the widely used holistic approaches is the life cycle thinking, which includes the assessment of product and technological procedure lifecycles and allows the possibility of changing effects on the environment. Life cycle assessment represents a method to quantify and evaluate environmental impacts of value chains. The idea of life cycle assessment was conceived in the 1960s when limited access to resources started to become a concern [15]. The first practical implementation of life cycle analysis took place supported by the Coca-Cola company in 1969, where the impacts for different beverage containers from manufacturing processes were examined [16]. In 1988, life cycle assessment was developed as a relevant tool for examining environmental impacts [17]. In recent years, the growing importance of environmental management has enlarged interest in the LCA method [18–20]. This method is used to assess the environmental impacts of food products too. Longo et al. [21] applied this methodology to investigate the supply chain of organic and conventional apples. Based on the results of Tsangas et al. [22], recommendations are made for grape products and fruit products, and they indicated changes in cultivation and production to optimize the environmental footprint. Iannone et al. [23] have used the LCA to reduce CO_2 emissions from wine production. In Japan, by the joint application of LCA with data envelope analysis, the eco-efficiency of rice production was assessed [24]. Focusing on the safety of the circular economy can take this method to a new level. According to the European Food Safety Authority (EFSA) [25], the recycling of food waste is generally beneficial from an environmental point of view. In recent years, the integration between LCA and different accounting methods, such as exergy analysis and emergy accounting, has also come to the fore [26–29]. Considering the planetary boundaries structure, life cycle assessment creates an affiliation between the SDGs and the European Green Deal (EGD) [30]. Regarding the used environmental indicators today, it can be said that the carbon footprint is still the most used indicator [30]. In the calculation of the carbon footprint, the LCA methodology is used in accordance with the recommendations of ISO 14040 and

14044 standards [31,32], where the exact term for carbon footprint is the global warming potential (GWP). This is estimated at 100 years, but time horizons from a few decades to several centuries can be found [33–35]. The carbon footprint in the hospitality sector is one of the easiest indicators to quantify. The carbon footprint detects the greenhouse gas emission during food production and consumption, regardless of supply chains. This indicator is beneficial for the unit management because it helps to select the optimal cost-effective recipe and preparation method in the hospitality sector. More recent studies [36–41] have added technological development, the extent of urbanisation, the structure of industry, the development of the financial system and the structure of energy use to the range of factors influencing carbon dioxide emissions. Huppes and Ishikawa [42] basically propose four environmental indicators for evaluating technologies: environmental productivity, environmental intensity, environmental development costs, and environmental cost-effectiveness. Kruszelnicka et al. [43] proposes an environmental efficiency index, an energy efficiency index, and a sustainable emission index for the environmental assessment of technologies. The most important aspect is that the used environmental indicators simultaneously provide environmental, economic, and energetic information to decision-makers.

Researchers [44–46] generally agree that changing consumer behaviour by raising environmental awareness and by the reducing of food waste is a very important factor in improving the sustainability of the food chain. According to integrated waste management, the reduction principle targets the minimisation of waste production and many research studies [6,47] described that the circular economy promotes the minimisation of waste production. According to the European Union (EU) food waste legislations [48,49], all EU member states are required to run awareness-raising campaigns to prevent food waste. According to the research results of the National Food Chain Safety Office (NÉBIH) [50], the share of solid food waste in total household waste was 51% in 2017. Nearly 63% of food waste is disposed in waste collection containers. The proportion of avoidable food waste is around 49% (around 33 kg per person per year) and the proportion of potentially avoidable waste is 4% [51]. Several studies [52–54] have been published that approach consumer-level food waste production in terms of attitudes and behavioural elements. Kasza et al. [55] explored the behaviour patterns behind household food waste using partial least squares structural equation modelling. There are several studies [56–58] which look at sustainability solutions that can be used in both catering establishments and households, and where possible, these also link this to healthy eating principles. Some studies [3,59,60] investigated and demonstrated that "pro-climate friendly behaviour" is positively related to awareness of the environmental impact of human activity and their risks. The concept of "green marketing" appeared as early as the late 1980s and an increasing number of studies [56,57] are examining the impact of eco-labelled foods on consumer behaviour. The ISO 22000 standard requires businesses to organise tasks to ensure the production of a safe consumer product and to demonstrate compliance with food safety requirements [61].

Although a part of produced food waste is unavoidable in food preparation and cooking/frying processes, the appropriate waste treatment method can be selected at the end-of-life. According to integrated waste management, landfilling and conventional incineration are the most widespread methods for MSW management [62,63]. However, recently, composting technologies have also come to the fore. As an example, Kiss et al. [64] have been conducting environmental impact assessments for Hosoya composting technology with LCA analysis for years. Therefore, we considered it important not only to examine and compare landfilling and conventional incineration, but also to examine of the composting at the end-of-life stage. In recent years, anaerobic digestion has also come to the fore as a treatment option. Norouzi and Dutta [65] compared a range of anaerobic digestion facilities in Canada in terms of digestion type, digester volume, feedstocks, and electricity capacity. Composting and anaerobic digestion may have a great future in the case of treatment of the food waste.

1.3. Research Aims

The main research aim of this scientific work was to determine and compare environmental impacts and energy sources of the whole life cycle of a restaurant main dish product (Viennese Steak/Wiener Schnitzel) by using the LCA method. The selected dish is well known in international cuisine, and an alternative and modern preparation method is also available for this dish. We compared eight environmental impact categories and the primary energy demand from renewable and non-renewable resources in the production (preparation + cooking/frying) and EoL stages of the examined product of one portion. Another purpose was to compare and assess three end-of-life stage scenarios and to find a more sustainable alternative for food waste. The third goal of this research was to compare the traditional and "sous vide" cooking technologies to create a more optimal and sustainable cooking/frying life cycle phase.

In the first step, we determined the product life cycle model from the extraction of the necessary raw materials through the preparation, cooking/frying, and use phases to the end-of-life. Given that food is consumed on site, we assumed in the use stage that no environmental impact occurred and food residue of 5% was generated on the plate after consumption. This food residue was introduced as food waste into the EoL stage along with food wastes from other lifecycle stages. In the second step, three scenarios were compared at the end-of-life stage. The end-of-life scenarios determine the primary energy, and the main impact categories when food waste is landfilled, incinerated, or composted. The reason for the third research step is that today's health-conscious consumers are increasingly demanding minimally processed, convenient, and affordable foods that retain their natural organoleptic properties while maintaining their nutritional value. The essence of the sous vide process is that the food is placed in a vacuum bag and cooked at a strictly controlled temperature and time [66,67]. It is generally proven that with application of this cooking technology it is sufficient to use a low temperature of 50–80 °C and four cooking time–temperature combinations [68,69].

This study focuses on the part of the cross-cutting research that presents environmental impact calculations for individual lifecycle phases on restaurant dishes.

2. Materials and Methods

2.1. Data Collection

Given that the research goal was to set up a life cycle model for a typical Hungarian restaurant dish, it was obvious to collect the needed data for the inventory analysis from a domestic restaurant. For data collection, we organised personal meetings with the chef of a Hungarian restaurant (Restaurant "Saint Anna", in Berkenye, Hungary) who provided us with accurate input–output data from all material and energy flows for each life cycle stage. These input–output resources provided the basis for our inventory analysis, which lasted for several months. For the preparation and cooking/frying life cycle phases, we obtained accurate material flows measured in mass, including the material losses and wastes. Regarding the used energy flows, for each energy source (electrical energy for meat storage with cooling, water for cooking of potatoes and washing dishes, and gas for frying of meat), we obtained the exact value of the previously measured energy consumption. Considering the portion capacity of the kitchen machines, they are statistically considered as average values per portion. The available data can be summarised as follows: the recipes are traditional, the in- and output flows are based on the information provided by the chef and the manufacturer's parameters for the kitchen appliances. In the use/consumption stage, food waste of 5% was assumed based on the chef's practical experience. Although the calculations presented here are based on only 1 sample, due to the very high information requirements, the specificities of the catering industry (constant recipes and kitchen equipment) ensure the representativeness of the sample. When taking into account the transport, we took into account the actual transport parameters (transport distance and vehicle type).

2.2. Life Cycle Assessment Methodology

This research sets up a whole life cycle model of the product from the extraction of the required raw materials through the production stage (preparation and cooking phases together) and use stage to the end-of-life. This approach enables the life cycle assessment of the environmental impacts and resources of the examined product associated with the different lifecycle stages. This work includes the life cycle inventory (LCI) analysis, the life cycle impact assessment (LCIA) method, and the interpretation of the research results. This research study analyses three scenarios regarding the environmental impacts that define the end-of-life of the food waste.

2.3. System Boundaries, Functional Unit and Allocation

In determining the environmental impacts, the raw and auxiliary materials were considered according to the classical formulation, with cradle-to-grave system boundaries. In the end-of-life stage, the wastes are treated as food waste and the energy is recovered. Equipment, machinery, and trucks were placed beyond the limits of the system. Auxiliary systems included transporting basic materials (meat and orange for decoration at serving) for preparation and cooking/frying, obtaining electric power from a European Union (EU-28) energy mix in all lifecycle stages, and diesel oil for transportation of the auxiliary materials. In addition to the main product, this process produces food waste (from the removal of the potato peel, the skinning of the meat and the breading process in the preparation and cooking/frying phases, and the leftover food in the use stage), and used cooking oil from frying phase. It includes wastewater mass flows from washing of the raw materials in the preparation phase, from the cooking of potatoes in the cooking phase, and washing dishes in the production stage, and the used cooking oil from frying. Figure 1 shows the LCA process with inputs, outputs, and interactions.
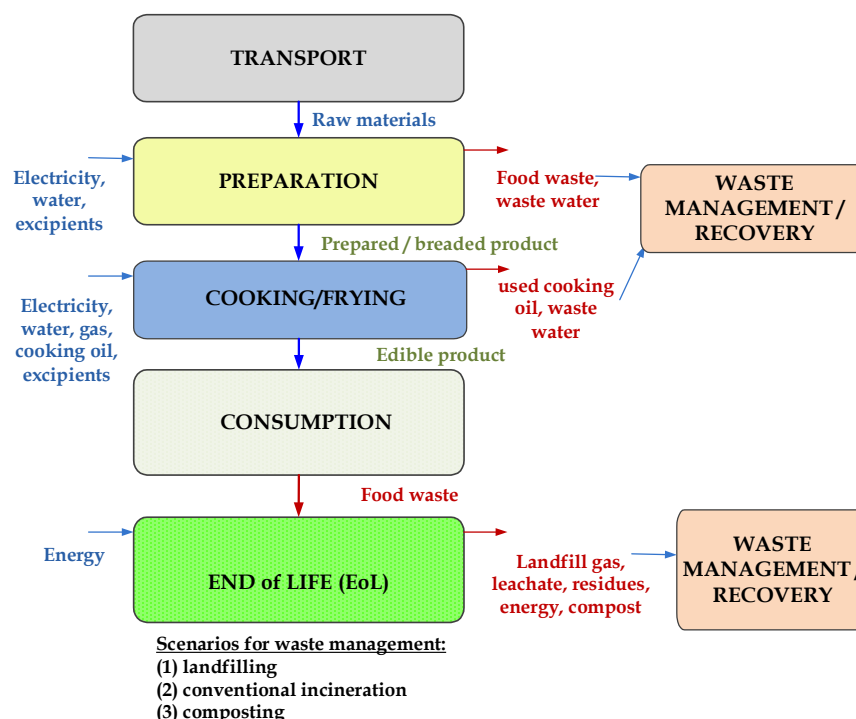

Figure 1. LCA phases of the product (self-edited illustration).

The life cycle phases were assigned as a function of the mass of the served main course. In the lifecycle stages all materials and energy that were used as well as all emissions that were produced are related to the examined food product. The functional unit (FU) was the standard 1 portion main dish for environmental impacts. Considering the effects of the life cycle of product in the preparation phase, the functional unit was defined as product

output of 0.427 kg. In the cooking/frying phase, the functional unit is defined as product output of 0.471 kg (due to oil absorption). The functional unit was described as 1 portion of product input–output for the life stages.

In the life cycle of the food waste, all process resources and emissions are associated with the product and the generated waste from different lifecycle stages. This method allocates environmental loads to the product and waste with mass allocation. Energy requirements were assigned as a function of the energetic content. The allocation by energetic content was applied for the combined heat and power production at the EoL stage.

2.4. LCA Software

The life cycle assessment of the examined system was carried out using GaBi 9.0 software (Sphera Solutions Ltd., Stuttgart, Germany) at the Budapest Business School. The applied software provided valuable resources for consistent life cycle modelling [70]. The results of the LCA software highlight the estimated environmental loads according to different aspects. Our main aim was to determine and quantify the main environmental impacts and the primary energy values for the whole life cycle of the selected food product with the available under the purchased license professional and food extension dataset.

2.5. Life Cycle Inventory

The related life cycle inventory methods include input–output material flows and energy supplies for all operation processes. The applied methodology is reliable with the LCI methodology explained in the ISO 14040:2006 standards [31]. The LCI dataset represents the state-of-the-art in view of the referenced functional unit. Datasets were linked with preparation and cooking/frying processes data to create life cycle inventories for the examined food product. The applied dataset is modelled according to the European Standard EN 15804 and an annual average of 2021. The energy balance and the composition of the municipal solid waste reflect the situation in EU-28. The following components of each system were not included in this life cycle inventory report: capital apparatus, various materials, and additives. The amount of energy used to heat, cool, and light was not included in the system boundaries of this life cycle inventory. In the completeness product models all relevant flows are quantified. Quantitative reference was 1.0 kg of unspecified product. Dataset information is the International Reference Life Cycle Data System (ILCD) dataset format. Collection, transport, and pre-treatment are not included.

At the end-of-life stage the dataset can be used to characterise the treatment of the defined waste product.

In the first EoL scenario, the product output as food waste was landfilled in a municipal landfill. The examined landfill process includes the landfill gas utilisation (system-dependent), the leachate and the sewage sludge treatments. Leachate treatment includes active carbon and flocculation/precipitation. This dataset includes the disposal technological module and lists the elementary flows, and the generated energy from gas utilisation (see Figure 2).

In the case of incineration, LCI data is valid for the thermal treatment of the average MSW. The dataset represents an end of-life inventory for the thermal treatment (10 MJ/kg net calorific value) of the food waste in an average waste-to-energy (WtE) plant with dry flue gas cleaning. The dataset covers all relevant process steps for the thermal treatment and corresponding processes, such as disposal of air pollution control residues or metal recycling. The inventory is mainly based on industry data. Produced electricity and process steam are unconnected.
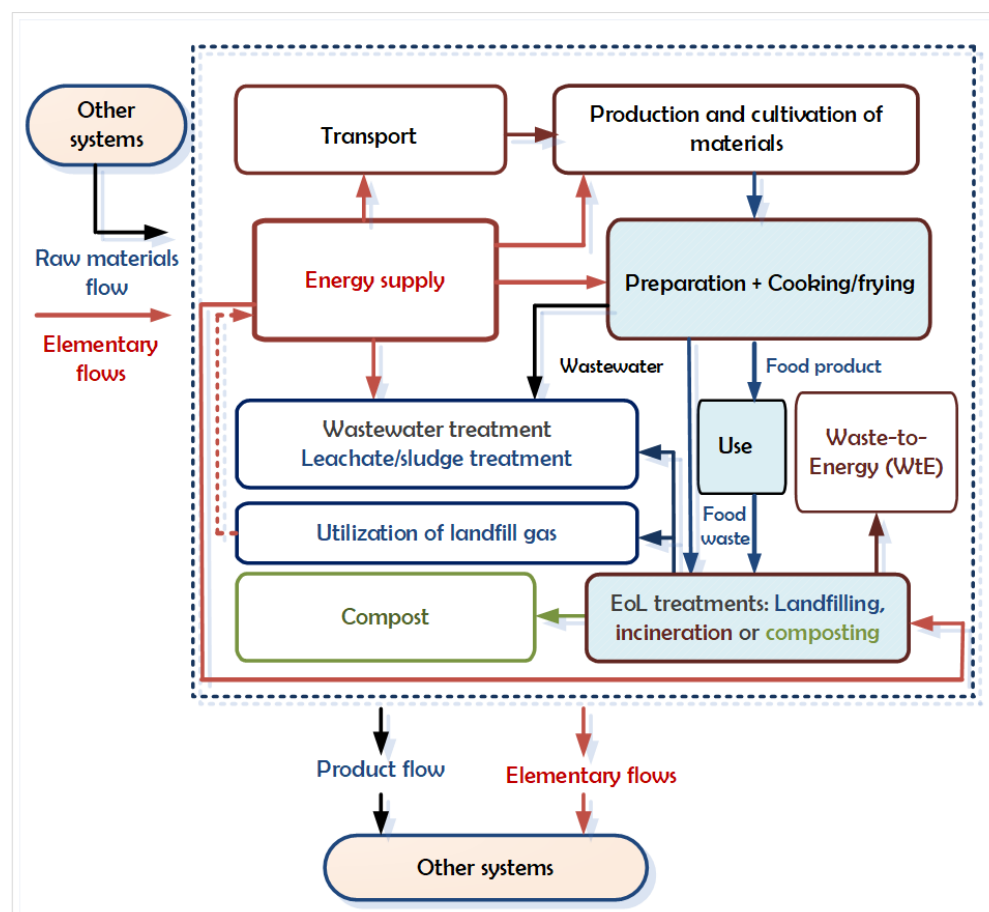
Figure 2. System boundaries for life cycle inventory (self-edited illustration).

The modelled open windrow composting plant is defined based on the treatment of average biodegradable waste consisting of biodegradable garden and park waste, food, and kitchen waste. The used model and the used settings allow us to attribute the environmental burden (emissions and resource consumption of auxiliaries and energy) as well as the credits for compost utilisation, according to a specific input composition (defined via dry matter, C:N ratio (26:8) and material composition). Therefore, the LCI data is valid for the open windrow composting of average biodegradable waste. The dataset covers all relevant process steps for the composting and corresponding processes, such as pre-treatment, post-treatment, sieving, compost utilisation and crediting of substituted humus (it is assumed that the application of compost is done to sustain the C and N reservoir of the soil) as well as NPK fertilisers. Inputs for the rotting process is rotting feedstock from pre-treatment as well as energy and fuels: electricity and fuel (for wheel loader) is needed through the entire composting process (pre-treatment, rotting and post-treatment). Output fractions are compost, sieving rest and impurities. Mass substances are divided between compost and sieving rest. Compost utilisation means the application of compost on agricultural land. The inventory is mainly based on the extended literature data as well as laboratory analysis and industry data.

2.6. Life Cycle Impact Assessment Method

The life cycle impact assessment method aims to investigate the achievable environmental impacts in the investigated systems. With the help of this applied method, we determined the resources, environmental emissions, and impact categories for the examined process in terms of a functional unit of product and waste input–output. In this research work, we used the CML 2016 (Centrum voor Milieukunde Leiden) method, where the environmental impact categories were developed by the Centre for Environmental Science

at Leiden University [71–73]. In the analysis, the reference system consisted of all inputs and outputs. For a comparable estimation of the impact categories, we used normalisation and weighting methods, which were the same for all life cycle stages. These methods were LCIA Survey 2012 with CML 2016 (excluding biogenic carbon) in the European Union. The eight calculated impacts include photochemical ozone creation, marine ecotoxicity, human toxicity, global warming, eutrophication, acidification, and abiotic depletions. The global warming potential value is valid for 100 years. In addition, we compared the environmental impacts of the average landfilling, incineration, and composting in the EU. Table 1 describes the examined environmental impacts in this analysis.

Table 1. The examined environmental impact categories in different equivalents [32,71].

Name of Impact Category	Interpretation of Impact Category
Abiotic Depletion for elements, *kg Sb Equivalent*	Use of elements and minerals (deals with the extraction of rare earth metals and their ores).
Abiotic Depletion for fossil, *MJ*	Use of fossil energy carriers (coal, petroleum, natural gas) as raw materials.
Acidification Potential, *kg SO$_2$ Equivalent*	Acidification of lakes, while in terrestrial ecosystems it indicates the acidification of forests.
Eutrophication Potential, *kg Phosphate Equivalent*	Damage to marine and freshwater ecosystems.
Global Warming Pot., *kg CO$_2$ Equivalent*	Effect of greenhouse gases on the atmosphere.
Human Toxicity Potential, *kg DCB Equivalent*	Potentially harmful effect of emitted substances (e.g., arsenic, hydrogen fluoride, sodium dichromate) on human health.
Marine A. Ecotox. Pot., *kg DCB Equivalent*	Impact of the release of toxic substances (e.g., heavy metals) on the marine ecosystem.
Photochem. Ozone Creat. Pot., *kg Ethylene Equiv.*	Ethylene equivalent emissions due to high NOx concentrations from photochemical oxidation.

3. Results

3.1. Life Cycle Assessment Set Up

The whole life cycle of the examined product can be divided into three stages (production, use, and end-of-life), and numerous factors and environmental loads must be considered. Within the total life cycle, the end-of-life stage plays an important role. Carbon storage and delayed emissions were not considered in the calculation of the global warming potential impacts. Emissions off-setting did not include fossil and biogenic carbon emissions and removals. All greenhouse gas emissions from fossil fuels were modelled consistently with the International Reference Life Cycle Data System list of elementary flows. Soil carbon accumulation (uptake) was excluded from the life cycle assessment model. First, we determined the input–output mass and energy values for each life cycle stage of the product and the typical electricity mix. For 2021, there is no literature on the use of electricity in different countries; therefore, we considered it important to create and illustrate 2021 professional databases from GaBi 9.0 software. Figure 3 illustrates the composition of the European Union's electricity mix in 2021 using a pie chart.

This pie chart shows an average specific electricity supply in the EU-28. This technology mix of electricity provided by non-combustible renewable energy sources also considered national or regional situations, such as the proportion of solar radiation (photovoltaic), annual full load hours (wind energy) and hydropower. Figure 4 clearly presents the percentage distribution of municipal solid waste (including food waste) in the European Union. Overall, the percentage distribution of organic waste occupied the highest rank at 40% among the seven given waste types. This pie chart shows that the percentage of other municipal waste ranked second with 19%, followed by paper waste (18%) and plastics (11%), respectively.
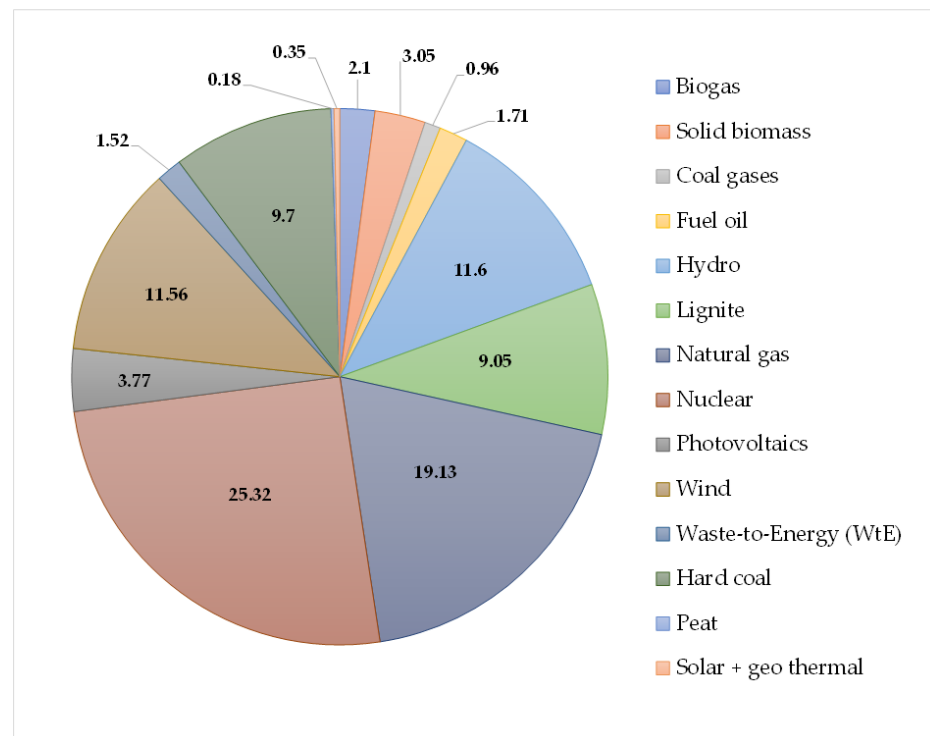
Figure 3. Electricity mix for European Union (year: 2021) (self-edited illustration).
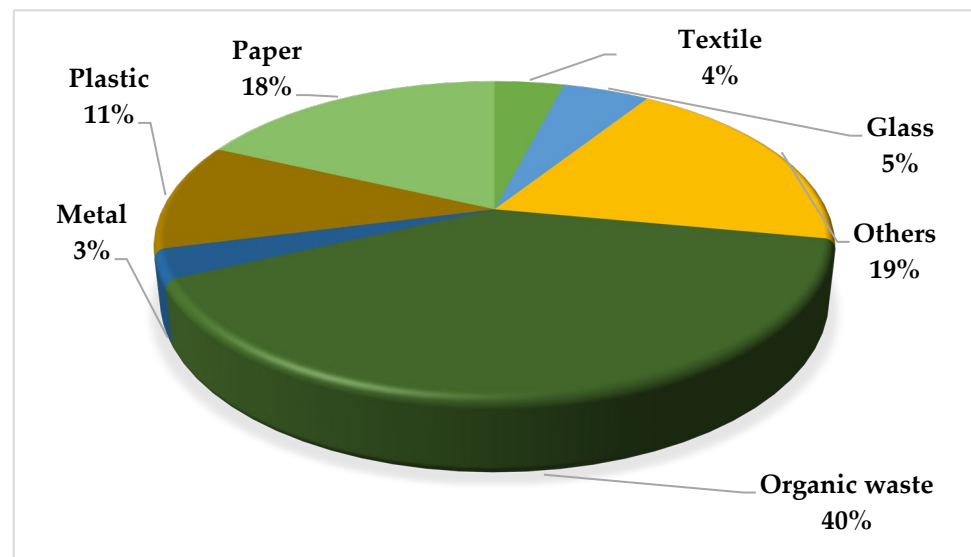

Figure 4. Percentage distribution of municipal solid waste in the European Union (year: 2021) (self-edited illustration).

3.2. Environmental Impact Results for the Production Stage

Throughout the LCA analysis, we assumed that the production stage is made up of the preparation and cooking/frying phases. Figures 5 and 6 present the eight examined impact categories for the preparation and cooking/frying life cycle phases of the food product of one portion in nanograms. These plotted values are normalised and weighted values. Table 2 presents the examined environmental loads for the production stage of the examined food product in nanograms. Table 3 shows the primary energy values for the preparation and cooking/frying phases of one portion product in MJ.
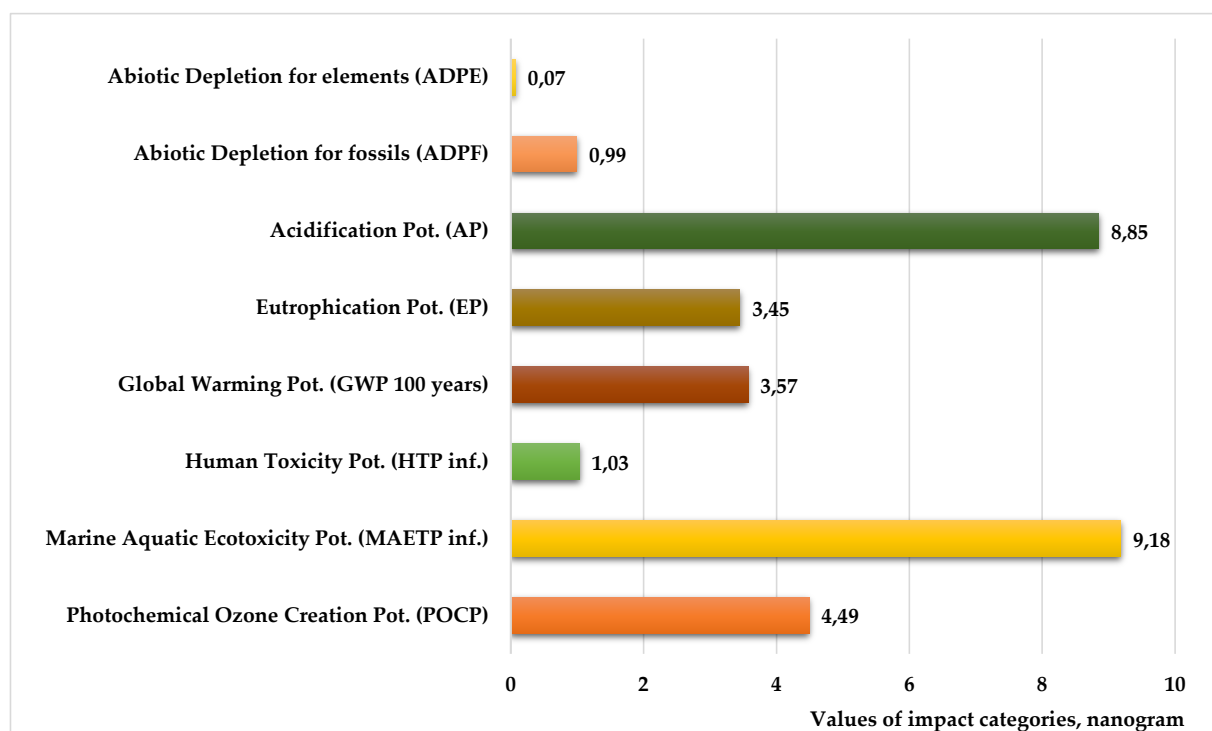
Figure 5. Environmental impact categories in the preparation phase with transport in nanograms (functional unit: food product of 0.427 kg^{-1} portion. Normalisation reference: CML 2016, EU 25 + 3, year 2000, excl. biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excl. biogenic carbon).

Figure 6. Environmental impact categories in the cooking/frying phase with transport (functional unit: food product of 0.471 kg^{-1} portion. Normalisation reference: CML 2016, EU 25 + 3, year 2000, excl. biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excl. biogenic carbon).
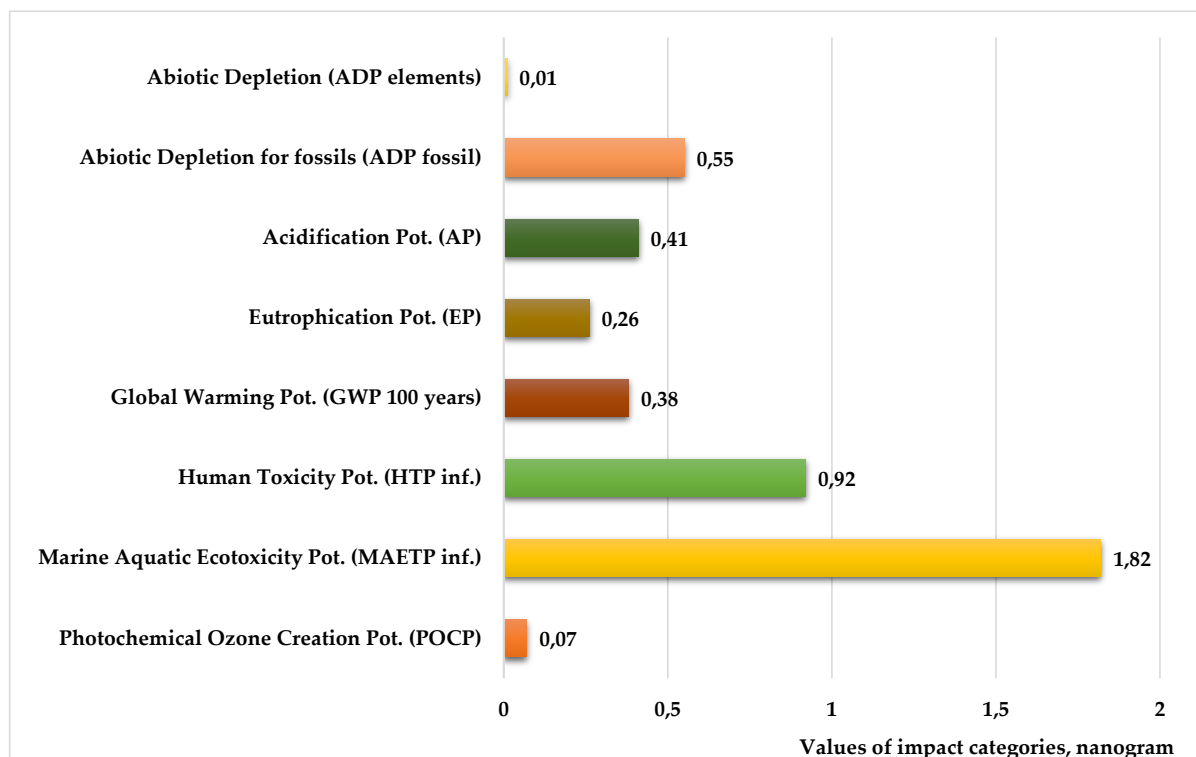
Table 2. Environmental impacts in the preparation and cooking/frying phases of the examined product in nanograms (functional unit: one portion product). Normalisation reference: CML 2016, EU 25 + 3, year 2000, excluding biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excluding biogenic carbon).

Name of Impact Categories	Preparation Phase	Cooking/Frying Phase
Abiotic Depletion *ADP elements*	0.071	0.014
Abiotic Depletion *ADP fossils*	0.986	0.549
Acidification Potential *AP*	8.850	0.413
Eutrophication Potential *EP*	3.450	0.261
Global Warming Pot. *GWP 100 years*	3.570	0.382
Human Toxicity Potential *HTP inf.*	1.030	0.921
Marine A. Ecotox. Pot. *MAETP inf.*	9.180	1.820
Photochem. Ozone Creat. Pot. *POCP*	4.490	0.072

Table 3. Primary energy values in the preparation and cooking/frying phases in MJ (functional unit: one portion product).

Type of Primary Energy	Preparation	Cooking/Frying
Primary energy demand from ren. and non ren. resources (gross cal. value)	33.4	7.24
Primary energy demand from ren. and non ren. resources (net cal. value)	32.9	6.93
Primary energy from non renewable resources (gross cal. value)	7.63	3.69
Primary energy from non renewable resources (net cal. value)	7.13	3.38
Primary energy from renewable resources (gross cal. value)	25.8	3.55
Primary energy from renewable resources (net cal. value)	25.8	3.55

Based on the summary results of Figures 5 and 6 and Table 2, it can be said that the environmental load of the preparation phase is much higher than the load of the cooking/frying phase.

3.3. Environmental Impact Results for the End-of-Life Stage

In the whole life cycle of the product, the EoL stage should be highlighted, and the environmental impacts of the product waste should be examined separately at this stage. The examined life cycle stage starts at the end-of-life of the product, depending on the choice of the product's end-of-life scenario. Results are declared in modules, which allows the structured expression of results throughout the life cycle. To compare the environmental loads of food waste during waste treatment processes, first it is important to set up a whole life cycle analysis of the product for different EoL scenarios. In our research work, the end-of-life stage of the food product as organic waste was modelled with food waste on landfill, conventional incineration, and composting. The examined end-of-life stage of the food product was based on the environmental product declaration technological modules in the European Union. Figure 6 represents the percentage distribution of examined categories at the EoL stage of the food waste product for Scenario 1. The aggregated life cycle assessment process is a landfill process with gas utilisation, leachate treatment, and sewage sludge treatment process (landfill height: 30 m, landfill area: 40,000 sqm; deposit: 100 years, net calorific value: 9.7 MJ/kg). Environmental impacts of the landfill process are valid for 100 years. Landfill gas production was calculated according to GaBi software, where the distribution of landfill gas was: 22% flare, 28% used and 49% emissions [71]. The use of landfill gas represents an industrial country standard. The average landfill gas composition and the amount belonging to the stable methane phase were determined. A transpiration/runoff ratio of 60% is assumed. In the case of leachate, we assumed the exponential solubility of liquids. Solubility factors were used for different solubility calculations [71,72]. Leachate and landfill bodies were assumed to be homogeneous. The landfill body was considered as saturated, including a non-circulating leachate treatment system. Basic sealing effectiveness for leachate was 70%. Figure 7 represents the percentage distribution for the examined environmental impact categories in the end-of-life stage of the food waste product for

Scenario 1. The applied normalisation and weighting methods were the same as in the earlier chapters. In the second scenario, the product was treated with incineration, and we determined the impact categories of a conventional incineration system. The transport distance was 100 km with utilisation of 80%, considering road transport in the European Union. Figure 8 shows the percentage distribution of environmental impacts for Scenario 2. The displayed value of ADPE is so small that it cannot be measured in either case, and the value of EP is zero for the second end-of-life scenario.
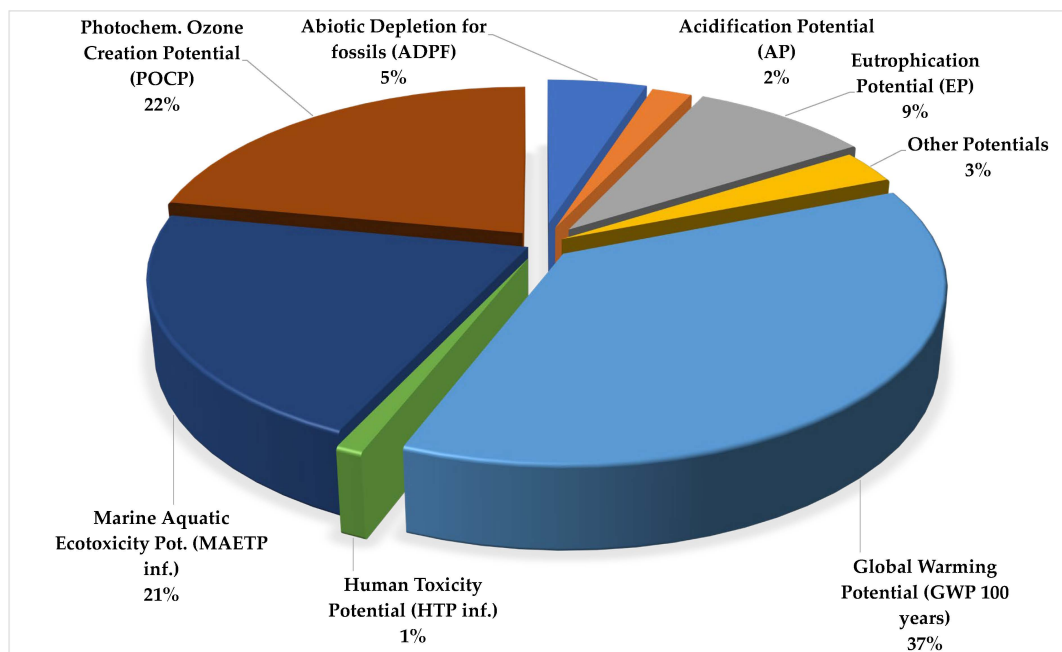

Figure 7. Environmental impact categories for Scenario 1 of the end-of-life stage with transport (functional unit: food waste of 0.05 kg. Normalisation reference: CML 2016, EU 25 + 3, year 2000, excl. biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excl. biogenic carbon).

Figure 8. Environmental impact categories for Scenario 2 of the end-of-life stage with transport (functional unit: food waste of 0.05 kg. Normalisation reference: CML 2016, EU 25 + 3, year 2000, excl. biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excl. biogenic carbon).
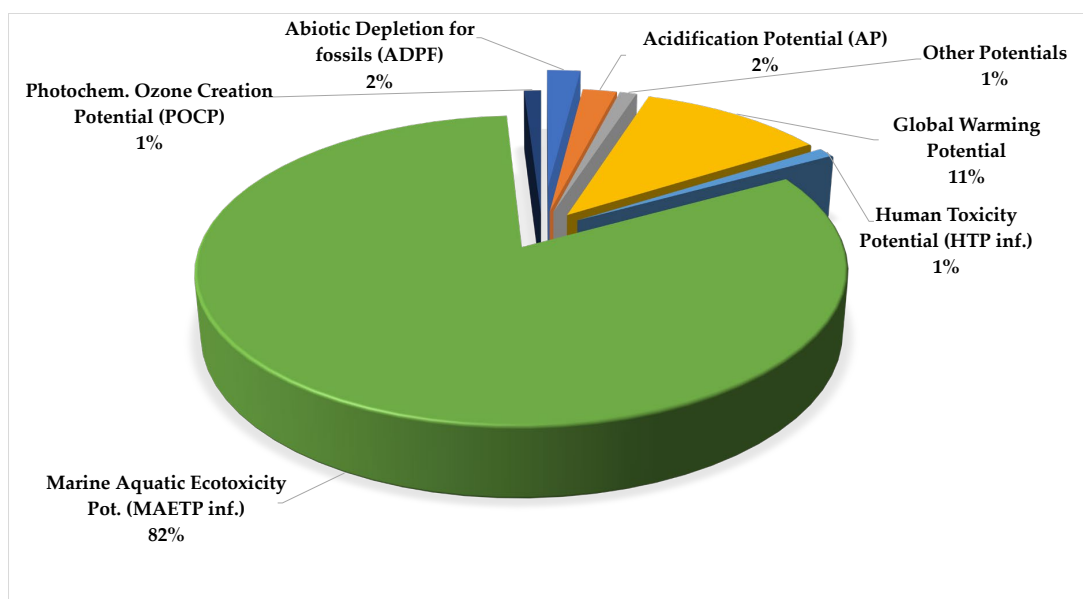
According to Figure 7, we can determine that the global warming potential for 100 years is higher (37%) compared to other environmental impact categories. This result is not surprising because this impact category is basically the highest for the total municipal solid waste in the landfill results in the EU based on the results of our previous research works. According to Figure 8, we can determine that the marine aquatic ecotoxicity value is very high (82%) compared to other environmental impact categories. In the third scenario the food waste was composted, and the environmental loads were determined for a composting system in the European Union. The input–output data for the end-of-life stage of the three scenarios were calculated considering the reference material and energy flows. In the case of composting, the value of each impact category is close to zero. In the case of MAETP and HTP, negative values very close to zero are obtained. Table 4 shows the primary energy values for the preparation and cooking/frying phases of one portion product in MJ.

Table 4. Primary energy values for the end-of-life scenarios in MJ. (Functional unit: food waste of 0.05 kg).

Type of Primary Energy	Scenario 1 Landfilling	Scenario 2 Incineration	Scenario 3 Composting
Primary energy demand from ren. and non ren. resources (gross cal. value)	0.110	0.083	0.004
Primary energy demand from ren. and non ren. resources (net cal. value)	0.102	0.078	0.001
Primary energy from non renewable resources (gross cal. value)	0.103	0.072	0.034
Primary energy from non renewable resources (net cal. value)	0.095	0.067	0.032
Primary energy from renewable resources (gross cal. value)	0.007	0.011	−0.030
Primary energy from renewable resources (net cal. value)	0.007	0.011	−0.030

3.4. Comparison of Traditional and Sous Vide Cooking Technologies

In the last part of our research, we compared the traditional cooking technique with the modern "sous vide" technology. Table 5 presents the normalised and weighted global warming potential value for the two examined cooking technologies in nanograms.

Table 5. Global warming potential in the life cycle phases in nanograms (functional unit: one portion food product). Normalisation reference: CML 2016, EU 25 + 3, year 2000, excluding biogenic carbon. Weighting method: thinkstep LCIA Survey 2012, Europe, CML 2016, excluding biogenic carbon).

Name of Life Cycle Phase	Traditional Technique	Sous Vide Technique
Preparation	4.280	1.860
Cooking/Frying	0.391	0.775
End-of-life (Scenario 1)	0.031	0.029
Total life cycle	4.702	2.664

According to Table 5, we can determine that the global warming potential for 100 years is higher by application of traditional cooking technology. This difference is best shown in the preparation phase. This is because if we use a sous vide cooking technique instead of a traditional one, you will only lose 8% of the meat instead of 20%, or 2% of the potatoes instead of 5%. Applying this modern method, the amount of food waste generated is reduced, and no waste cooking oil is produced. This technique is also advantageous because vacuum packaging reduces the amount of air around the food; thus, avoiding harmful oxidative effects (e.g., oxidation of fats/oils).

4. Discussion

Europe is trying to achieve climate neutrality by 2050 in the context of the European Green Deal, SDGs and Circular Economy Strategy (CES) [74,75]. For this purpose, it is inevitable and important that our research results help to reach the proposed goals with the EGD, the CES and the SDGs. In our proposed research hypothesis, we assumed that knowing the environmental impacts of the lifecycle for an examined restaurant product, we can set up a complex life cycle model in the context of the circular economy. Civancik-Uslu et al. [76,77] have already before raised the idea of using a complex life cycle model for solid municipal waste, and complex LCA models have been continuously developed ever since. Alwaeli and his co-author developed [78], not long ago, a life cycle assessment model for the municipal solid waste management. According to the approach of Szita [79], one requirement for sustainable environmental management is an understanding of all lifecycle phases. In view of this, it is important to examine the EoL phase of products separately. In recent years, the examination of the end of the waste lifecycle through the choice of appropriate waste management methods has come to the fore in some research studies [80–82]. Therefore, we supplemented our LCA model by setting up EoL scenarios. Regarding the different lifecycle stages and end-of-life scenarios, values of different impact categories and primary energy were examined to identify which approach is more optimal. In our examined EoL scenarios, goals of the circular economy are basically applied by the fact that used material and energy sources can be reduced in preceding lifecycle phases of the product with the help of optimal waste treatment processes, and the food waste as compost or energy can be recycled. This fact shows in landfill gas and treated sludge that can be used during disposal, in the form of produced and recyclable thermal energy and electricity during incineration, and in the compost during composting. Compost utilisation means the application of compost on agricultural lands. We were not surprised by the result that the impact category values for scenario of incineration caused almost twice the environmental load as the disposal of food waste. Our previous research results [60,81] also prove this statement. In this context, da Silva et al. [83] proposed a circular ecosystem in which waste follows a reuse flow according to its properties. Here, incineration can be an option depending on the end-of-life stage and benefits generated from the removal of MSW from the ecosystem. Composting has the lowest environmental impact. The primary reason for this may be that the method we have chosen is windrow composting. Here, the windrows are generally turned to improve porosity and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile with the help of wheel loaders. The rotting process is an aerobic biological degradation and alteration process influencing nearly solely the organic compounds of the rotting feedstock. For this method the collection of waste air is not foreseen, but leachate is collected. Environmental impacts for waste collection and transport are not included. The used degradation rate in the compost model is 60% for carbon and 50% for nitrogen. Nitrogen emissions are not emitted as N_2O or NH_3 are assumed to be N_2 emissions with no further environmental relevance. Therewith, N_2 emissions can be neglected. Of course, these results can be influenced by changing the composting method and input–output parameters. The Easewaste [84] LCA model developed in 2011 provides examples discriminating the environmental performance of alternative biological treatment technologies in relation to mass and energy flows, gaseous emissions, biogas recovery and utilisation of the compost. Our developed LCA model can be supplemented and integrated with additional environmental indicators. In accordance with the LCA approach, the carbon footprint separately associated with the waste management processes can also be calculated [85]. For building of circular economy and its index systems, Wang et al. [86] recommended an evaluation system for CE development that applies the improved entropy methodology. The combination of LCA and CE can be very well combined with economic indicators too. For example, Symeonides et al. [87] evaluated the tire waste management by SWOT analysis and proposed a holistic management system in Cyprus to reach the targets set by the concept of CE. Loizia et al. [88] established indicators to evaluate the environmental performance of an area with the help

of hybrid approach, which cover primarily waste compositional, SWOT and PESTEL analysis. Voukkali et al. [89] used several key performance indicators, such as accumulation rate, and the waste accumulation index, to calculate the level of environmental performance. Their results are very helpful to reach the proposed goals with the EGD and the SDGs.

As can be seen in the reviewed research works [66–69,90–94], it can be observed based on also our results that "sous vide" could be an efficient technique at more optimal and sustainable cooking/frying life cycle phase. This technique is also advantageous because vacuum packaging reduces the amount of air around the food; thus avoiding harmful oxidative effects (e.g., oxidation of fats/oils).

5. Conclusions

Today, for a sustainable catering industry, it is essential to know the characteristics of the restaurant products and their preparation processes. On the one hand, this article appreciates life cycle phases for a restaurant main dish (Wiener schnitzel with boiled potatoes and orange rings) with a comparison of different environmental burdens. On the other hand, it appreciates and compares three end-of-life stage scenarios. At the same time, this study compares the conventional and "sous vide" cooking technologies. In addition to the analyses and evaluations of results, this work presents a review of the application of life cycle assessment in food industry with the help of different standards and the professional literature.

During the LCA analysis, the GaBi 9.0 software database has been continuously refreshed and expanded, which helped define the potential environmental loads from the cradle to the grave. This research work determines eight impact categories and primary energy demand from renewable and non-renewable resources. By quantifying the environmental impacts, CML 2016 impact method was used. The normalisation and weighting methods were the same for all examinations. The functional unit was defined as the mass of one portion product for all life cycle phases.

According to the research results of the life cycle assessment, it can be said that the environmental load of the preparation phase is much higher than the load of the cooking/frying phase. The reason for this is that our analysis also includes the loads related to the production of raw materials and the production of meat itself basically involves a large environmental load. The biggest differences, where the impacts are three to four times higher, can be seen in relation to MAETP, POCP, EP and GWP. The AP value is 17 times higher for the preparation phase. As far as the primary energy values are concerned, there are big differences between the two examined life cycle phases. The values of the primary energy from renewable resources and the total primary energy for the preparation phase is 5–6 times higher than that of the cooking phase. In these lifecycle phases, we can reduce the transport distances both for the supply of raw materials and for the removal of food waste (currently 100 km by road and 80% utilization rate). At the same time, we can use renewable energy sources and reduce the water use throughout the lifecycle.

When considering the case where food waste is landfilled at the end of its lifecycle, the highest values for GWP (37%), POCP (22%), MAETP (21%), EP (9%) and ADPF (5%) and the lowest values for AP (2%) and ADPE (0.01%) are observed for the whole life cycle of the product. We can state that the landfilling mainly causes a larger change in the relative contribution values of the environmental impact categories GWP, POCP, and MAETP. In the case where waste is incinerated, the highest values for MAETP (82%) and GWP (11%). Our research results confirm that the composting is the most favourable scenario among the three examined scenarios. As far as the primary energy values are concerned, there are low differences between the three examined end-of-life scenarios. The values of the primary energy from renewable resources and the total primary energy for the composting process have rather low value. Composting and anaerobic digestion have a great future in the case of food municipal solid waste.

Preparation and cooking technologies of different dishes is an actual research and development area in the hospitality industry. Our research results allow to optimise the

input–output parameters in the different lifecycle phases to achieve ideal environmental burdens of restaurant dish preparations while avoiding major food waste. The introduction of "sous vide" cooking technology becomes a good alternative that allows the production of healthier and tastier food while reducing environmental loads. If we use the sous vide cooking technique instead of traditional cooking, we lose 8% from the meat instead of 20%, and 2% from the potatoes instead of 5% at the cooking/frying lifecycle phase. Applying this modern cooking, the amount of generated food waste can be reduced, and no waste cooking oil is produced. This technique is even healthier for consumers. The inevitably generated waste can be used for the feeding of companion animals or for dark fermentation. That is, conversion of volatile fatty acid (VFA) to polyhydroxyalkanoates (PHAs) to produce natural-based pharmaceutical polymers. Cooking oil can be utilised as biofuel.

Basically, there are very poor professional studies with life cycle assessment for the catering industry and cooking technologies. We did not find an LCA study for the whole life cycle of restaurant dishes. However, this manuscript sets up a complex life cycle model for preparation and cooking/frying processes while optimising the mass of produced food waste. With this model, the ecological performance of catering products can be improved, and the food waste can be reduced. Our research results from this study can assist in the development of directed, valid emissions reduction measures for food waste treatments in the catering industry to reduce the environmental impacts, resources, and primary energies. Our research work provides new information regarding the objective environmental impacts associated with the preparation and cooking of food products in the European Union by comparing different scenarios for the end-of-life waste treatment technologies. These results can be useful for catering and restaurant units which aims to realise optimal food preparation, cooking, and food waste treatment in the context of the EGD, the SDGs, and the CE.

Author Contributions: Methodology, investigation, original draft preparation, data curation, resources, conceptualisation, supervision, funding acquisition, J.L.A.; visualisation, diagrams, review, writing and editing, V.M. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ADPE	Abiotic Depletion Potential for Elements
ADPF	Abiotic Depletion Potential for fossils
AP	Acidification Potential
CE	Circular Economy
CES	Circular Economy Strategy
EGD	European Green Deal
EFSA	European Food Safety Authority
EoL	End-of-Life
EP	Eutrophication Potential
EPD	Environmental Product Declaration
EU	European Union

FU	Functional Unit
GWP	Global Warming Potential
HTP	Human Toxicity Potential
IPCC	Intergovernmental Panel on Climate Change
ILCD	International Reference Life Cycle Data System
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MAETP	Marine Aquatic Ecotoxicity Potential
MSW	Municipal Solid Waste
NÉBIH	National Food Chain Safety Office
POCP	Photochemical Ozone Creation Potential
SDGs	Sustainable Development Goals

References

1. Borsato, E.; Marinello, F.; Tarolli, P. Sustainable patterns of main agricultural products combining different footprint parameters. *J. Clean. Prod.* **2018**, *179*, 357–367. [CrossRef]
2. Grygierek, K.; Ferdyn-Grygierek, J.; Gumińska, A.; Baran, Ł.; Barwa, M.; Czerw, K.; Gowik, P.; Makselan, K.; Potyka, K.; Psikuta, A. Energy and Environmental Analysis of Single-Family Houses Located in Poland. *Energies* **2020**, *13*, 2740. [CrossRef]
3. Kim, M.J.; Hall, C.M. Can Climate Change Awareness Predict Pro-Environmental Practices in Restaurants? Comparing High and Low Dining Expenditure. *Sustainability* **2019**, *11*, 6777. [CrossRef]
4. Baldwin, C.; Wilberforce, N.; Kapur, A. Restaurant and food service life cycle assessment and development of a sustainability standard. *Int. J. Life Cycle Assess.* **2010**, *16*, 40–49. [CrossRef]
5. Kaza, S.; Yao, L.; Bhada-Tata, P.; Van Woerden, F. What a waste 2.0: A global snapshot of solid waste management to 2050. In *Urban Development Series*, 1st ed.; World Bank Group: Washington, DC, USA, 2018; pp. 17–37. [CrossRef]
6. Stahel, W.R. Circular economy. *Nature* **2016**, *531*, 435–438. [CrossRef] [PubMed]
7. D'Adamo, I. Adopting a Circular Economy: Current Practices and Future Perspectives. *Soc. Sci.* **2019**, *8*, 328. [CrossRef]
8. D'Adamo, I.; Falcone, P.; Huisingh, D.; Morone, P. A circular economy model based on biomethane: What are the opportunities for the municipalty of Rome and beyond? *Renew. Energy* **2021**, *163*, 1660–1672. [CrossRef]
9. Göbel, C.; Langen, N.; Blumenthal, A.; Teitscheid, P.; Ritter, G. Cutting food waste through cooperation along the food supply chain. *Sustainability* **2015**, *7*, 1429–1445. [CrossRef]
10. Brancoli, P.; Bolton, K. Life Cycle Assessment of Waste Management Systems. In *Sustainable Resource Recovery and Zero Waste Approaches*, 1st ed.; Taherzadeh, M.J., Bolton, K., Pandey, A., Eds.; Elsevier: Philadelphia, PA, USA, 2019; pp. 23–33. [CrossRef]
11. Kuznets, S. Economic Growth and Income Inequality. *AER* **1955**, *45*, 1–28. Available online: http://www.jstor.org/stable/1811581 (accessed on 15 October 2021).
12. Grossman, G.; Krueger, A. Economic Growth and Income Inequality. *Q. J. Econ.* **1995**, *110*, 353–377. [CrossRef]
13. Friedl, B.; Getzner, M. Determinants of CO_2 emissions in a small open economy. *Ecol. Econ.* **2003**, *45*, 133–148. [CrossRef]
14. United Nations Department of Economic and Social Affairs Statistics Division. Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development. Available online: https://unstats.un.org/sdgs/indicators/indicators-list (accessed on 15 October 2021).
15. Bjørn, A.; Owsianiak, M.; Molin, C.; Laurent, A. Main Characteristics of LCA. In *Life Cycle Assessment*, 1st ed.; Springer: Cham, Switzerland, 2018; pp. 9–16. [CrossRef]
16. Brusseau, M.L. Sustainable Development and Other Solutions to Pollution and Global Change. *Environ. Pollut. Sci.* **2019**, *3*, 585–603. [CrossRef]
17. McManus, M.C.; Taylor, M. The changing nature of life cycle assessment. *Biomass Bioenergy* **2015**, *82*, 13–26. [CrossRef] [PubMed]
18. Borodin, Y.V.; Aliferova, T.E.; Ncube, A. Waste management through life cycle assessment of products. *IOP Conf. Ser. Mater. Sci. Eng.* **2015**, *81*, 012085. [CrossRef]
19. Curran, M. Life-Cycle Assessment. In *Encyclopedia of Ecology*, 2nd ed.; BAMAC, Ltd.: Rock Hill, SC, USA, 2016; Volume 4, pp. 359–366. [CrossRef]
20. Society of Environmental Toxicology and Chemistry (SETAC). Guidelines for Life-Cycle Assessment: A 'Code of Practice' from the Workshop Held at Sesimbra. *Environ. Sci. Pollut. Res.* **1994**, *1*, 55. [CrossRef]
21. Longo, S.; Mistretta, M.; Guarino, F.; Cellura, M. Life Cycle Assessment of organic and conventional apple supply chains in the North of Italy. *J. Clean. Prod.* **2017**, *140*, 654–663. [CrossRef]
22. Tsangas, M.; Gavriel, I.; Doula, M.; Xeni, F.; Zorpas, A.A. Life Cycle Analysis in the Framework of Agricultural Strategic Development Planning in the Balkan Region. *Sustainability* **2020**, *12*, 1813. [CrossRef]
23. Iannone, R.; Miranda, S.; Riemma, S.; De Marco, I. Improving environmental performances in wine production by a life cycle assessment analysis. *J. Clean. Prod.* **2016**, *111*, 172–180. [CrossRef]

24. Masuda, K. Measuring eco-efficiency of wheat production in Japan: A combined application of life cycle assessment and data envelope analysis. *J. Clean. Prod.* **2016**, *126*, 373–381. [CrossRef]

25. EFSA. Register of Questions. 2018. Available online: http://registerofquestions.efsa.europa.eu/roqFrontend/login?4 (accessed on 27 June 2017).

26. Kharrazi, A.; Kraines, S.B.; Hoang, L.; Yarime, M. Advancing quantification methods of sustainability: A critical examination emergy, exergy, ecological footprint, and ecological information-based approaches. *Ecol. Indic.* **2014**, *37*, 81–89. [CrossRef]

27. Arbault, D.; Rugani, B.; Barna, L.; Benetto, E. A semantic study of the emergy sustainability index in the hybrid lifecycle-emergy framework. *Ecol. Indic.* **2014**, *43*, 252–261. [CrossRef]

28. Cano, N.; Hasenstab, C.; Velasquez, H. Life-Cycle Assessment (LCA) of Exergy Indicators in the Colombian Gold Mining Sector: A Case Study in an Open-Pit and in an Alluvial Mining Processes. In Proceedings of the 32nd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, Wrocław, Poland, 23–28 June 2019. Available online: https://jsm.gig.eu/journal-of-sustainable-mining/vol19/iss3/2/ (accessed on 14 October 2020).

29. Giannetti, B.F.; Bonilla, S.H.; Almeida, C.M.V.B. An emergy-based evaluation of a reverse logistics network for steel recycling. *J. Clean. Prod.* **2013**, *46*, 48–57. [CrossRef]

30. Sanyé-Mengual, E.; Sala, S. Life Cycle Assessment support to environmental ambitions of EU policies and the Sustainable Development Goals. *Integr. Environ. Assess. Manag.* **2022**. [CrossRef]

31. *ISO 14040:2006*; Environmental Management—Life Cycle Assessment—Principles and Framework. ISO: Geneva, Switzerland, 2006. Available online: https://www.iso.org/standard/37456.html (accessed on 6 June 2019).

32. *ISO 14044:2006*; Environmental Management—Life Cycle Assessment—Requirements and Guidelines. ISO: Geneva, Switzerland, 2006. Available online: https://www.iso.org/standard/38498.html (accessed on 6 June 2019).

33. Amoo, L.M.; Fagbenle, L. *Climate Change in Developing Nations of the World*; Woodhead Publishing Series in Energy; Applications of Heat, Mass and Fluid Boundary Layers; Woodhead Publishing: Cambridge, UK, 2020; pp. 437–471, ISBN 9780128179499. [CrossRef]

34. Farinha, C.; de Brito, J.; Do Veiga, M. *Eco-Efficient Rendering Mortars*; Woodhead Publishing Series in Civil and Structural Engineering; Woodhead Publishing: Cambridge, UK, 2021; pp. 205–234. [CrossRef]

35. Dincer, I. Refrigerants. *Compr. Energy Syst.* **2018**, *2*, 435–474. [CrossRef]

36. Managi, S.; Jena, P.R. Environmental productivity and Kuznets curve in India. *Ecol. Econ.* **2008**, *65*, 432–440. [CrossRef]

37. Narayan, P.K.; Saboori, B.; Soleymani, A. Economic growth and carbon emissions. *Econ. Model.* **2016**, *53*, 388–397. [CrossRef]

38. Zhang, M.; Li, B.; Yin, S. Is Technological Innovation Effective for Energy Saving and Carbon Emissions Reduction? Evidence from China. *IEEE Access* **2020**, *8*, 83524–83537. [CrossRef]

39. Zhang, Y. The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy* **2011**, *39*, 2197–2203. [CrossRef]

40. Zhang, N.; Yu, K.; Chen, Z. How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. *Energy Policy* **2017**, *107*, 678–687. [CrossRef]

41. Rauf, A.; Zhang, J.; Ji, J.; Amin, W. Structural changes, energy consumption and carbon emissions in China: Empirical evidence from ARDL bound testing model. *Struct. Chang. Econ. Dyn.* **2018**, *47*, 194–206. [CrossRef]

42. Huppes, G.; Ishikawa, M. Eco-efficiency and Its xs Terminology. *J. Ind. Ecol.* **2005**, *9*, 43–46. [CrossRef]

43. Kruszelnicka, W.; Kasner, R.; Bałdowska-Witos, P.; Flizikowski, J.; Tomporowski, A. The Integrated Energy Consumption Index for Energy Biomass Grinding Technology Assessment. *Energies* **2020**, *13*, 1417. [CrossRef]

44. Farr-Wharton, G.; Foth, M.; Choi, H.J. Identifying factors that promote consumer behaviours causing expired domestic food waste. *J. Consum. Behav.* **2014**, *13*, 393–402. [CrossRef]

45. Stancu, V.; Haugaard, P.; Lähteenmäki, L. Determinants of consumer food waste behaviour: Two routes to food waste. *Appetite* **2016**, *96*, 7–17. [CrossRef] [PubMed]

46. Stangherlin, I.C.; Barcellos, M.D. Drivers and barriers to food waste reduction. *Br. Food J.* **2018**, *120*, 2364–2387. [CrossRef]

47. Grosso, M.; Niero, M.; Rigamonti, L. Circular economy, permanent materials and limitations to recycling: Where do we stand and what is the way forward? *Waste Manag. Res.* **2017**, *35*, 793–794. [CrossRef]

48. European Commission DIRECTIVE (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2008/98/EC on Waste. Available online: https://eur-lex.europa.eu/eli/dir/2018/851/oj (accessed on 30 May 2018).

49. European Commission (2019) Supplementing Directive 2008/98/EC of the European Parliament and of the Council as Regards a Common Methodology and Minimum Quality Requirements for the Uniform Measurement of Levels of Food Waste. Available online: http://ec.europa.eu/transparency/regdoc/rep/3/2019/EN/C-2019-3211-F1-EN-MAIN-PART-1.PDF (accessed on 14 May 2019).

50. Oláh, J.; Kasza, G.; Szabó-Bódi, B.; Lakner, Z. Household Food Waste Research: The Current State of the Art and a Guided Tour for Further Development. *Front. Environ. Sci.* **2022**, *10*, 1–18. [CrossRef]

51. Szabó-Bódi, B.; Kasza, G.; Szakos, D. Assessment of domestic food waste in Hungary. *Br. Food J.* **2018**, *120*, 625–638. [CrossRef]

52. Evans, D. Beyond the throwaway society: Ordinary domestic practice and a sociological approach to household food waste. *Sociology* **2012**, *46*, 41–56. [CrossRef]

53. Mallinson, L.J.; Russell, J.M.; Barker, M.E. Attitudes and behaviour towards convenience food and food waste in the United Kingdom. *Appetite* **2016**, *103*, 17–28. [CrossRef]

54. Djekic, I.; Miloradovic, Z.; Djekic, S.; Tomasevic, I. Household food waste in Serbia–attitudes, quantities and global warming potential. *J. Clean. Prod.* **2019**, *229*, 44–52. [CrossRef]
55. Kasza, G.; Dorkó, A.; Kunszabó, A.; Szakos, D. Quantification of Household Food Waste in Hungary: A Replication Study Using the FUSIONS Methodology. *Sustainability* **2020**, *12*, 3069. [CrossRef]
56. Peattie, K.; Crane, A. Green marketing: Legend, myth, farce or prophesy? *Qual. Mark. Res.* **2005**, *8*, 357–370. [CrossRef]
57. Larsson, S.; Khan, M.A. A Study of Factors That Influence Green Purchase. *Adv. Mater. Res.* **2014**, *1051*, 1035–1039. Available online: http://www.diva-portal.org/smash/get/diva2:614312/FULLTEXT02 (accessed on 1 July 2022).
58. Lee, T.M.; Markowitz, E.M.; Howe, P.D.; Ko, C.Y.; Leiserowitz, A.A. Predictors of Public Climate Change Awareness and Risk Perception around the World. *Nat. Clim. Chang.* **2015**, *5*, 1014–1020. [CrossRef]
59. Dal, B.; Alper, U.; Özdem-Yilmaz, Y.; Öztürk, N.; Sönmez, D. A model for pre-service teachers' climate change awareness and willingness to act for pro-climate change friendly behavior: Adaptation of awareness to climate change questionnaire. *Int. Res. Geogr. Environ. Educ.* **2015**, *24*, 1–17. [CrossRef]
60. Mannheim, V. Life Cycle Assessment Model of Plastic Products: Comparing Environmental Impacts for Different Scenarios in the Production Stage. *Polymers* **2021**, *13*, 777. [CrossRef]
61. Zimon, D.; Madzik, P.; Domingues, P. Development of Key Processes along the Supply Chain by Implementing the ISO 22000 Standard. *Sustainability* **2020**, *12*, 6176. [CrossRef]
62. Voběrková, S.; Vaverková, M.D.; Burešová, A.; Adamcová, D.; Vršanská, M.; Kynický, J.; Brtnický, M.; Adam, V. Effect of inoculation with white-rot fungi and fungal consortium on the composting efficiency of municipal solid waste. *Waste Manag.* **2017**, *61*, 157–164. [CrossRef] [PubMed]
63. Koda, E.; Miszkowska, A.; Sieczka, A. Levels of Organic Pollution Indicators in Groundwater at the Old Landfill and Waste Management Site. *Appl. Sci.* **2017**, *7*, 638. [CrossRef]
64. Kiss, N.É.; Tamás, J.; Szőllősi, N.; Gorliczay, E.; Nagy, A. Assessment of Composted Pelletized Poultry Litter as an Alternative to Chemical Fertilizers Based on the Environmental Impact of Their Production. *Agriculture* **2021**, *11*, 1130. [CrossRef]
65. Norouzi, O.; Dutta, A. The Current Status and Future Potential of Biogas Production from Canada's Organic Fraction Municipal Solid Waste. *Energies* **2022**, *15*, 475. [CrossRef]
66. Onyeaka, H.; Nwabor, F.O.; Jang, S.; Kechrist, O.; Hart, A.; Miri, T. Sous vide processing: A viable approach for the assurance of microbial food safety. *J. Sci. Food Agric.* **2022**, *102*, 9. [CrossRef]
67. Bhuyan, A.; Hussain, I.A.; Sarma, P. Sous-Vide Technique. *Agric. Food E-Newsl.* **2022**, *4*, 5.
68. Karki, R.; Bremer, P.; Silcock, P.; Oey, I. Effect of Sous vide Processing on Quality Parameters of Beef Short Ribs and Optimisation of Sous vide Time and Temperature Using Third-Order Multiple Regression. *Food Bioprocess Technol.* **2022**, *15*, 1629–1646. [CrossRef]
69. Schellekens, M. New research issues in sous-vide cooking. *Trends Food Sci. Technol.* **1996**, *7*, 256–262. [CrossRef]
70. Kalakul, S.; Malakul, P.; Siemanond, K.; Gani, R. Integration of life cycle assessment software with tools for economic and sustainability analyses and process simulation for sustainable process design. *J. Clean. Prod.* **2014**, *71*, 98–109. [CrossRef]
71. CML. Institute of Environmental Sciences, Leiden University. CML-IA Characterisation Factors Portal. 2016. Available online: https://www.universiteitleiden.nl/en/research/researchoutput/science/cml-ia-characterisation-factors (accessed on 29 June 2018).
72. Van Oers, L.; De Koning, A.; Guinée, J.B.; Huppes, G. Abiotic resource depletion in LCA. In *Improving Characterisation Factors for Abiotic Resource Depletion as Recommended in the New Dutch LCA Handbook*; RWS-DWW: Delft, The Netherlands, 2002. Available online: http://www.leidenuniv.nl/cml/ssp/projects/lca2/report_abiotic_depletion_web.pdf (accessed on 29 February 2016).
73. Kupfer, T.; Baitz, M.; Colodel, C.M.; Kokborg, M.; Schöll, S.; Rudolf, M.; Thellier, L.; Bos, U.; Bosch, F.; Gonzalez, M. GaBi Database & Modeling Principles. In *GaBi Thinkstep AG*; Sphera: Chicago, IL, USA, 2018.
74. *The Global Risks Report 2020*; The World Economic Forum: Geneva, Switzerland, 2020. Available online: https://www.weforum.org/reports/the-global-risks-report-2020 (accessed on 15 October 2021).
75. Kaczmarczyk, B.; Urych, I. Perception of the Transition to a Zero-Emission Economy in the Opinion of Polish Students. *Energies* **2022**, *15*, 1102. [CrossRef]
76. Civancik-Uslu, D.; Ferrer, L.; Puig, R.; Fullana-i-Palmer, P. Are functional fillers improving environmental behavior of plastics? A review on LCA studies. *Sci. Total Environ.* **2018**, *626*, 927–940. [CrossRef]
77. Civancik-Uslu, D.; Puig, R.; Ferrer, L.; Fullana-i-Palmer, P. Influence of end-of-life allocation, credits and other methodological issues in LCA of compounds: An in-company circular economy case study on packaging. *J. Clean. Prod.* **2019**, *212*, 925–940. [CrossRef]
78. Alwaeli, M.; Mannheim, V. Investigation into the Current State of Nuclear Energy and Nuclear Waste Management—A State-of-the-Art Review. *Energies* **2022**, *15*, 4275. [CrossRef]
79. Szita, K. The Application of Life Cycle Assessment in Circular Economy. *Hung. Agric. Eng.* **2017**, *31*, 5–9. [CrossRef]
80. Bałdowska-Witos, P.; Kruszelnicka, W.; Tomporowski, A. LCA analyzes were also performed for the production of PET bottle. Life cycle assessment of beverage bottles. *J. Phys. Conf. Ser.* **2020**, *1426*, 012038. [CrossRef]
81. Mannheim, V.; Simenfalvi, Z. Total Life Cycle of Polypropylene Products: Reducing Environmental Impacts in the Manufacturing Phase. *Polymers* **2020**, *12*, 1901. [CrossRef] [PubMed]
82. Bianco, I.; Panepinto, D.; Zanetti, M. End-of-Life Tyres: Comparative Life Cycle Assessment of Treatment Scenarios. *Appl. Sci.* **2021**, *11*, 3599. [CrossRef]

83. Da Silva, L.F.; Resnitzkyd, M.H.C.; Santibanez Gonzalez, E.D.R.; de Melo Conti, D.; da Costa, P.R. Management of Plastic Waste and a Circular Economy at the End of the Supply Chain: A Systematic Literature Review. *Energies* **2022**, *15*, 976. [CrossRef]

84. Boldrin, A.; Neidel, T.L.; Damgaard, A.; Bhander, S.G.; Møller, J.; Christensen, T.H. Modelling of environmental impacts from biological treatment of organic municipal waste in EASEWASTE. *Waste Manag.* **2011**, *31*, 619–630. [CrossRef] [PubMed]

85. Erdélyi, É.; Avató, L.J.; Kocsis, T. A new trend in education and research at Budapest Business School: Green Catering. *Georg. Agric.* **2019**, *23*, 16–30. Available online: https://georgikon.szie.hu/egyetemi-elet/kiadvanyaink/georgikon-for-agriculture (accessed on 28 June 2019).

86. Wang, N.; Lee, J.C.K.; Zhang, J.; Chen, H.; Li, H. Evaluation of urban circular economy development: An empirical research of 40 cities in China. *J. Clean. Prod.* **2018**, *180*, 876–887. [CrossRef]

87. Symeonides, D.; Loizia, P.; Zorpas, A.A. Tire waste management system in Cyprus in the framework of circular economy strategy. *Environ. Sci. Pollut. Res.* **2019**, *26*, 35445–35460. [CrossRef]

88. Loizia, P.; Voukkali, I.; Zorpas, A.A.; Pedreño, J.N.; Chatziparaskeva, G.; Inglezakis, V.J.; Vardopoulos, I.; Doula, M. Measuring the level of environmental performance in insular areas, through key performed indicators, in the framework of waste strategy development. *Sci. Total Environ.* **2021**, *753*, 141974. [CrossRef] [PubMed]

89. Voukkali, I.; Loizia, P.; Pedreño, J.N.; Zorpas, A.A. Urban strategies evaluation for waste management in coastal areas in the framework of area metabolism. *Waste Manag. Res.* **2021**, *39*, 448–465. [CrossRef] [PubMed]

90. Gibbs, W.; Myhrvold, N. The Science of Sous Vide. *Sci. Am.* **2010**, *304*, 24. [CrossRef]

91. Baldwin, D.E. Sous Vide Cooking: A Review. *Int. J. Gastron. Food Sci.* **2012**, *1*, 15–30. [CrossRef]

92. Kilibarda, N.; Brdar, I.; Branislav, B.; Baltic, M.; Stanišić, S. The Safety and Quality of Sous Vide Food. *Meat Technol.* **2018**, *59*, 38–45. [CrossRef]

93. Modzelewska-Kapituła, M.; Pietrzak-Fiečko, R.; Zakrzewski, A.; Więk, A. The Influence of Sous Vide Parameters on Nutritional Characteristics and Safety of Pikeperch Fillets. *Foods* **2022**, *11*, 1605. [CrossRef]

94. Cui, Z.; Yan, H.; Manoli, T.; Zhang, H.; Zhen, H.; Ji, M.; Bi, C. Advantages and challenges of sous vide cooking. *Food Sci. Technol. Res.* **2021**, *27*, 25–34. [CrossRef]