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1 **Energy and Environmental Life Cycle Assessment of an institutional catering service: An Italian case study**

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10 **Abstract**

11 Food production is recognised as one of the major drivers for global environmental pressure. In the last years, changes
12 in consumption models result in an increasing population consuming food out of home that pose the catering service
13 sector at the centre of the European Union policies aimed at improving the environmental sustainability of the food
14 sector. In this framework, better technical knowledge on the environmental impacts of catering service is essential in
15 order to identify potential actions towards a more sustainable food sector. This article presents an environmental
16 assessment of a school catering service operating in Italy and delivering approximately 2,518,128 meals per year.
17 Starting from primary data on the amount of each food consumed in the catering service examined, we perform an
18 environmental analysis of an equivalent meal ready to be consumed in the schools canteens by using the Life Cycle
19 Assessment methodology consistent with ISO 14040 standard. The system boundaries include food and tableware
20 production, food transport, food storage and cooking and waste treatment. Due to a lack of primary data tableware
21 production, food storage, cooking and waste treatment are modelled using literature data or models.

22 The results of the analysis show that the food production phase is relevant to almost all assessed impact categories
23 (contribution higher than 65%). The exception is represented by photochemical oxidation impact categories in which
24 the larger impact is linked to the transportation phase. The environmental impacts associated to the tableware
25 production, food storage and cooking are relevant to global warming and global energy requirement (contributions
26 higher than 7%).

27 The scenario analysis of potential actions aimed at reducing the environmental impacts of the catering service shows
28 that, to obtain a more sustainable food sector, strategies must be implemented along the entire food supply chain and
29 considering a wide range of environmental impact categories.

30 **Keywords:** Institutional catering, Food energy consumption, Food supply chain, Life cycle assessment

31 **1. Introduction**

32 The food system is a major consumer of energy and emitter of greenhouse gases and air pollution (European
33 Commission, 2014). In European Union (EU) the amount of energy necessary to cultivate, process, pack and bring food
34 accounted for 17% of the gross energy consumption in 2013, equivalent to about 26% of the EU's final energy
35 consumption that same year (Boyano et al., 2017). Moreover, it is responsible for around 20-30% of environmental
36 impacts caused by consumption in the EU in most impact categories (European Commission, 2008; European
37 Environment Agency, 2012). In particular, the sector is one of the leading causes of land-use change (and subsequent
38 biodiversity loss), climate change, water scarcity/pollution, soil degradation, eutrophication, acidification and toxic
39 impacts on human health and the environment and waste generation (European Commission, 2014, 2008). For example,
40 Ivanova et al. (2017) show that food is a significant source of household greenhouse gas emissions in EU, with
41 contributes ranging from 11% to 32% across regions. Then, the food sector plays a key role in the context of the EU
42 energy and climate targets defined in the 2030 Framework for climate and energy (European Commission, 2013) and in
43 the Roadmap 2050 (European Commission, 2012) and in general in the efforts aimed at achieving a more sustainable
44 economy.

45 In the last years, within the food sector, the catering service has gained a growing importance since population
46 worldwide is increasingly consuming food out of home (Schaubroeck et al., 2018; Sel et al., 2018)

47 Traditionally, catering has been divided into the “cost food service sector” or “contract catering”, which refers to non-
48 profit or institutional catering, including workplace canteens, hospitals and schools (Davis et al., 2008), and the “profit
49 sector” which refers to the profit-orientated establishments such as restaurants, fast-food chain outlets, cafes, takeaways,
50 pubs, leisure and travel catering outlets (Bourlakis and Weightman, 2003).

51 Companies, public authorities, schools, universities, retirement homes, hospitals and prisons are all increasingly relying
52 on contract catering (Food Service Europe, 2014; Orlando et al., 2018). In 2014, the contract catering industry had an
53 annual turnover of approximately €24 billion and approximately 33% of firms or collective organisations in the EU had
54 a contract with a catering company. The sector employed 600,000 people all over Europe and delivered approximately
55 6 billion meals each year (Food Service Europe, 2014). The most important sectors (in terms of purchase volume and
56 value) in EU are: health/welfare (42.7% of the total meals served), education (31.4% of the total meals served) and
57 business & industry (17.8% of the total meals served) (Food Service Europe, 2014).

58 Due to its significant size and economic value, the catering sector could play a key role in reducing the energy and
59 environmental impacts linked to the food sector. In particular, catering services has been identified as one of the sector
60 that can provide significant environmental improvement in the public sector since it accounts for a high share of public
61 purchasing and presents substantial improvement potential for environmental performance (Boyano et al., 2017). Public

62 authorities, by using their purchasing power to choose environmentally friendly goods (Green Public Procurement
63 (GPP)), can provide an important contribution to sustainable consumption and production.

64 The scientific literature in the field of food LCA has increased more than ten times during the last 15 years (Nemecek et
65 al., 2016). An increasing number of studies in the literature addresses the environmental assessment of individual food
66 products. For example, Berlin (2002) performed an LCA of Swedish semi-hard cheese; Del Borghi et al. (2014)
67 analysed the environmental sustainability of tomato products supply chain; Djekic et al. (2014) applied an LCA to dairy
68 products; Longo et al. (2017) compared the life cycle environmental impacts linked organic and conventional apple
69 supply chains. Other LCAs focused on baskets of products, like Notarnicola et al. (2017) and Castellani et al. (2017).

70 However, as highlighted by Fusi et al. (2016) there is currently scant information on the environmental impacts of the
71 catering sector. In the literature examined, few studies assess the environmental impact linked to it. Moreover, the
72 majority of previous studies only considers specific issues or partial stages of the catering services instead of the
73 catering system as a whole (Cerutti et al., 2018). For example, Fusi et al. (2016) address the impact assessment
74 associated with the preparation of pasta and compared different cooking technologies generally adopted in the catering
75 services. Caputo et al. (2017) develop a tool called Food Chain Evaluator (FCE), to evaluate the non-renewable energy,
76 productive land and productive cost associated with food production in institutional catering in the school sector in the
77 Lombardy Region (Northern Italy). Ribal et al. (2016) develop a model to identify the optimal menus for school, taking
78 into account nutritional, climate change and economic aspects.

79 Based on our knowledge, only two studies perform an environmental analysis of a whole catering service, i.e. Cerutti et
80 al. (2018) and Jungbluth et al. (2016), however both studies focus only on the global warming potential impact
81 category.

82 In detail, Cerutti et al. (2018) assess a set of procurement policies aimed at reducing the GHG emissions of public
83 catering in order to provide scientific guidance to public administrations and suppliers. The case study focuses on the
84 full school catering services of the city of Turin (Northern Italy). The impacts are assessed with reference to an average
85 meal (FU) calculated according to the standard menu. The phases included in the system boundaries are production,
86 transport, cooking and waste from packaging. From the study, it can be seen that there is a global warming potential of
87 1.67 kgCO_{2eq} per average meal.

88 Jungbluth et al. (2016) analyse the methodological issues for the application of the LCA to assess the global warming
89 potential of a catering service (public or otherwise) in Switzerland. The FU is an average meal. The system boundaries
90 include the production, processing (e.g. refrigeration), packaging, transport of food items to the canteen and the
91 operation (meal preparation at the canteen, cooling, cooking and food waste disposal). The study shows that an average
92 meal served in the canteen has a global warming potential of about 4.1 kg CO_{2eq}.

93 Achieving a more sustainable catering sector requires an assessment of the associated energy and environmental
94 impacts in order to identify the hot spots in terms of energy and environmental burdens. Moreover, an ex – ante
95 evaluation of potential improved scenarios could be useful in identifying the most effective–strategies to increase its
96 sustainability (Beccali et al., 2007; Giordano et al., 2014).

97 In such a context, Life Cycle Assessment (LCA) (ISO, 2006a, 2006b) represents a scientific methodology that helps in
98 assessing the whole food supply chains (from the resource extraction to the end-of-life treatment) in order to achieve
99 environmental sustainability goals, to support the identification of sustainable solutions for global food challenges
100 (Notarnicola et al., 2016), and to identify options aimed at improving the environmental performance of the food sector
101 (Filippini et al., 2018; Longo et al., 2017).

102 In detail, three distinct stakeholder groups could benefit from using LCA as a decision support tool (Cellura et al.,
103 2012):

- 104 • Producers: to improve the environmental performance of a productive system;
- 105 • Consumers: to orient purchasers;
- 106 • Policy-makers: to inform and direct long-term strategies.

107 The extension of the assessment to the whole supply chain enables the identification of “where” and “how” the
108 resources are consumed and the emissions occur (Cellura et al., 2012). The life-cycle thinking approach applied to
109 assess a wide range of environmental issues can ensure that environmental impacts throughout the life-cycle are viewed
110 in an integrated way and, consequently, that they are not just shifted from one step to another or from an impact
111 category to another (Ardente et al., 2006; Beccali et al., 2003; Cellura et al., 2018)

112 This article reports on an LCA carried out to assess the energy and environmental impacts of a school catering service
113 in the Lombardy Region (Northern Italy) and to identify the hotspots along the food supply chain. The assessment is
114 based on real data of the amount of each food items consumed by the investigated catering service. Moreover, a
115 scenario analysis integrated with the LCA methodology is performed, in order to identify potential environmental
116 improvements to the examined catering services from a life cycle perspective.

117

118 **2. Methods: Life Cycle Assessment**

119 **2.1 Goal definition**

120 LCA is a useful tool for assessing resource use (energy and raw materials) and environmental burdens related to the full
121 life-cycle of products and services. In this paper, we apply an attributional LCA approach according to the international
122 standards of series ISO 14040 (ISO, 2006a, 2006b). The goals of the study are:

- 123 • to assess the energy and environmental impacts (eco-profile) of institutional catering in the school sector in
124 Lombardy following a life cycle approach;
- 125 • to identify the hotspots of impacts along the food supply chain;
- 126 • to identify potential environmental improvement in institutional catering by analysing different scenarios from
127 a life cycle perspective.

128 **2.2 Scope definition**

129 The study presented here refers to a rural and urban district of municipalities in South-West of Lombardy, referred to
130 hereafter as Abbiatense, after the name of the main town in the area (Abbiategrasso). In the municipalities of
131 Abbiatense, the school catering service investigated serves 2,518,128 meals per year in nursery, primary and secondary
132 schools (Caputo et al., 2017). The catering service examined adopts the deferred system, in which the food preparation
133 and cooking are carried out in centralised kitchens, from which the prepared meals are distributed to consumers
134 (schools). The adopted cooking method is the cook-warm chain, i.e. the food is distributed at a temperature of 65 °C (to
135 avoid the risk of microbial growth) and the consumption should occur within 2 hours of cooking (Fusi et al., 2016).
136 Regarding serving, different options are adopted in the different schools within the analysed district: disposable
137 tableware, washable dishes, or compostable dishes. In all schools, tap water is consumed and served in washable plastic
138 or glass jugs and washable cutlery.

139 **2.2.1 Functional unit and system boundaries**

140 The function of the system product investigated is to provide an equivalent meal ready for the consumption in the
141 canteens. The equivalent meal is defined as the ratio between the amount of all the foods consumed and the number of
142 meals served in a year in the examined school catering service. Consequently, the functional unit (FU) selected as
143 reference for the LCA is an equivalent meal served at the school canteens of Abbiatense (for further details, please refer
144 to Caputo et al., 2017)). Considering the function chosen, the selected mass-based FU is the most suitable unit to
145 represent the mean composition of the school catering menus over a school year (Sonesson et al., 2017). In the cases of
146 function focused on the nutrients supply (protein content or caloric energy), other FUs based on the contribution of each
147 food product to provide the established nutritional function are more suitable.

148 According to the goals of the LCA, the system boundaries include the following phases (Fig.1):

- 149 • Food and tableware production, including raw materials and energy supply in the agricultural phase and in the
150 food processing phase.
- 151 • Food transport, including transport from the production sites to the central kitchen, and transport from the
152 central kitchen to the school canteens.
- 153 • Food storage, including the energy consumption (electricity) for storing the food in refrigerators and freezers.

- 154 • Food cooking, including the energy (electricity and heat) consumed in the cooking phase;
- 155 • Waste treatment.

156 The impacts linked to food production are based on real data on the amount of each food consumed in one year in the
157 investigated school catering services inferred from Caputo et al. (2017). As the energy consumption from the processing
158 phases (storage and cooking phases) is missing, it is estimated using literature data or models (Canals et al., 2007).

159 The cleaning cooking appliance phase and the water consumed during the meal preparation are not accounted for, due
160 to a lack of data. The electricity consumed in the school canteens is not accounted for because it is beyond the scope of
161 the study and often available only as aggregated data for all the electric end uses (lighting, appliances and office air
162 conditioning).

163 The impacts arisen from the tableware production are estimated based on literature studies (Cerutti et al., 2018; Fieschi
164 and Pretato, 2017). In detail, it is assumed that disposable tableware are made of petroleum-based plastic, the
165 compostable ones by Polyactide and finally the washable ones by Melamine Resin.

166 Due to a lack of information about the percentage of schools using disposable tableware, washable or compostable
167 dishes, it is assumed that they are used in equal proportions in the school canteens examined. Moreover, according to
168 Fieschi and Pretato (2017), for the disposable tableware the treatment in landfill (55%) and incineration (45%), it is
169 assumed. While for compostable and washable tableware, the treatment in a compost plant and in a landfill,
170 respectively, is considered.

171 Finally, we carry out a scenario analysis in order to identify, for each life cycle phase, potential environmental
172 improvements of the examined catering service considering a life cycle perspective.

173 **(FIGURE 1 HERE)**

174 **2.2.2 Impact assessment methodology and impact categories and data quality**

175 The life cycle impacts are calculated using SimaPro software¹. The characterisation models used are the Cumulative
176 Energy Demand) method for the Global Energy Requirement estimation (Frischknecht et al., 2007), and the
177 Environmental Product Declaration (EPD) characterisation factors for the environmental impacts assessment (EPD,
178 2016a). In detail, the assessed energy and environmental categories are:

- 179 • Global Energy Requirement ($\text{MJ}_{\text{primary}}$);
- 180 • Acidification ($\text{kg SO}_{2\text{eq}}$);
- 181 • Eutrophication ($\text{kg PO}_{4\text{eq}}^{3-}$);
- 182 • Global Warming ($\text{kg CO}_{2\text{eq}}$);

¹ <https://simapro.com/>

183 • Photochemical Oxidation (kgC₂H₄eq).

184 The eco – profiles of foods are based on the Ecoinvent 3 database (Wernet et al., 2016), on environmental product
185 declarations or certifications² and on the LCA food database (Nielsen et al., 2003). The eco – profiles of energy sources
186 and transportation are based on the Ecoinvent 3 database (Wernet et al., 2016).

187 **2.3 Life cycle inventory**

188 The inventory analysis is performed to quantify the environmental significance of the input and output of the examined
189 system, by means of mass and energy balances of the selected FU. In the following sections, we describe the examined
190 catering service, the data collection and the assumption made to model the life cycle phases within the selected system
191 boundaries and to perform the scenario analysis. In detail, in section 2.3.1, the we illustrate the “Baseline scenario”,
192 while in section 2.3.2 they describe the investigated configurations in the scenario analysis.

193 **2.3.1 Baseline scenario**

194 The quantity of each food included in the equivalent meal is inferred from Caputo et al. (2017). Table 1 shows the
195 amount of each food within the examined equivalent meal and the source of the eco-profiles used.

196 **(TABLE 1 HERE)**

197 In the baseline scenario, all the agricultural products are produced according to conventional agricultural practices. The
198 transportation distance for each food item is calculated, depending on current food procurement (local surveys and
199 typical origins of food consumed in Italy), and the distances between the food production site and the central kitchen
200 and the central kitchen and the served schools. The transportation distance between the central kitchen and the schools
201 is estimated to be 10 km. In the transportation phase, of 16 – 32 t capacity and trucks with refrigerated container in
202 cooling mode (temperature between 0°C and 20°C) and in freezing mode (temperature between -35°C and -18°C) are
203 considered, based on the temperature storage needed to guarantee the safe condition of each food item.

204 In the food storage phase, the energy consumption for food storage in refrigerators and freezers in the central kitchen is
205 assessed, based on the author’s assumption and literature studies (Canals et al., 2007), because real data collected is not
206 sufficiently complete and reliable. In detail, depending on the product type, it can be stored chilled or frozen. According
207 to Canals et al. (2007), the energy consumption for cooled products is 0.06 MJ/(l*day), while for frozen products 0.18
208 MJ/(l*day). For each food items, a maximum of 20 days of storage it is assumed. The electricity consumption for food
209 storage equals 0.261 kWh.

210 With regard to the cooking phase, it is assumed that the food is cooked on gas hobs (natural gas) and in electric ovens.
211 The energy consumption for cooking on hotplates (hobs) and roasting/baking in the oven is calculated by using the

² <http://www.environdec.com/>

212 models proposed by Sonesson et al. (2003). As Sonesson et al. (2003) provided only data for electric appliances, the
213 direct energy consumed by gas hobs is estimated considering an energy use ratio of gas hobs/electric hobs equal to 1.51
214 (Fawcett et al., 2005).

215 The electricity use for cooking on hotplates, $E_{C_{hp}}$ is calculated as in the following Equation 1 (Sonesson et al., 2003):

$$216 \quad E_{C_{hp}} = E_{HU} + E_{MT} + E_{HP} \quad (1)$$

217 Where:

218 E_{HU} = Energy for heating the water to the boiling point;

219 E_{MT} = Energy for maintaining the temperature of the water at the boiling point;

220 E_{HP} = Energy for heating the product.

221 The electricity use for food preparation in an electrical oven $E_{C_{eo}}$ is calculated as in the following Equation 2
222 (Sonesson et al., 2003):

$$223 \quad E_{C_{eo}} = E_{HUo} + E_{MTo} + E_{RTo} + E_{Ewo} + E_{TPo} \quad (2)$$

224 Where:

225 E_{HUo} = Energy for heating the oven to the desired temperature;

226 E_{MTo} = Energy for maintaining the temperature in the oven;

227 E_{RTo} = Energy for raising the temperature of the food to a level when it can be considered ready to eat;

228 E_{Ewo} = Energy for the evaporation of the water;

229 E_{TPo} = Energy for thawing, if frozen products are prepared.

230 The electricity consumption for food preparation in electric ovens is 0.060 kWh, while the energy consumption for
231 cooking on natural gas hotplates is 0.649 kWh.

232 The energy and environmental impacts linked to the electricity consumption for storing and cooking are calculated
233 according to the Italian electricity mix from the Ecoinvent 3 database (Wernet et al., 2016). Whereas, the impacts which
234 relate to gas consumption are calculated taking into consideration the production of heat from natural gas from the
235 Ecoinvent 3 database (Wernet et al., 2016).

236

237 **2.3.2 Description of the alternative scenarios for the examined institutional catering service**

238 In order to identify potential energy and environmental improvement for institutional catering, we define and analyse
239 different scenarios evaluating different actions, which refer to the examined life cycle phases. We assess the energy and
240 environmental impacts of each scenario through the LCA methodology and compare the results obtained with those of

241 the baseline scenario in order to highlight the potential achievable improvement. In detail, the following scenarios are
242 analysed:

- 243 • Scenario 1 aims at identifying how the adoption of different agricultural practices and the local provision of
244 food can reduce the energy and environmental impacts of the institutional catering service examined. Then, in
245 the food production phase, we assess the energy and environmental impacts, which relate to organic rather than
246 conventional agriculture. Due to a lack of data, a shift to the exclusive use of organic food cannot be taken into
247 account. The following food items are modelled taking into account organic agriculture practice: bread,
248 potatoes, salad, tomatoes, milk, rice, and yogurt. The environmental impact associated with organic milk and
249 yogurt production is inferred from the EPDs of these products (EPD, 2015b, 2016e). The eco-profiles of
250 organic bread, potatoes and flour are derived from Ecoinvent 3. Finally, the input data for the modelling of
251 organic rice and salad are taken from Caputo et al. (2017). With regard to the food provision (distance from
252 food production site to the centralised kitchen), it is assumed that, except for some fruits and ingredients, such
253 as orange, tangerines, bananas, olive oil, the food is produced in Lombardy or in the neighbouring regions
254 (according to a survey about the main production and distribution centre of food in Italy). The other life cycle
255 phases are unchanged compared to the baseline scenario.
- 256 • Scenario 2, defined in order to investigate the potential environmental improvement, which could be achieved
257 by adopting different cooking technologies, in respect of that adopted in the baseline. In detail, this scenario
258 assumes that the food cooking occurs on gas hobs and ovens. The food production and transportation phases
259 are unchanged compared to the baseline scenario.
- 260 • Scenario 3, defined in order to assess the potential energy and environmental improvement, which could be
261 achieved by substituting the electricity consumed from the national electric grid with electricity produced by
262 renewable energy technologies. In detail, in this scenario, it is assumed that the electricity, consumed for food
263 storage and food cooking in an electric oven, is generated locally by photovoltaic (PV) panels. The eco-profile
264 of the electricity generated from PV panels is derived from Ecoinvent 3. The other life cycle phases are
265 unchanged compared to the baseline scenario.
- 266 • Scenario 4, defined in order to identify the energy and environmental improvement, which could be achieved
267 by substituting the material of the tableware used in the catering service;
- 268 • Scenario 4, in which we combine the strategies considered in the previous scenarios, in order to assess the
269 overall potential environmental improvement, which could be achieved in the institutional catering service
270 examined, compared to the baseline scenario.

271 The main characteristics of the baseline and the examined scenarios are recapped in Table 2.

272

(TABLE 2 HERE)

273

274 3. Life cycle impact assessment and discussion

275 The life cycle impacts on global energy requirement and the environmental impacts of the baseline scenario are detailed
276 in Table 3; the contribution of each life cycle phase is illustrated in Fig.2.

277 Global energy requirement is 23.6 MJ_{primary}, of which 66% comes from non-renewable energy source consumption.

278 Food production involves the highest share of overall global energy requirement (about 66%), of which about 54% is
279 from non-renewable energy sources. With regard to the other life cycle phases, storage accounts for 10.4% of the total
280 global energy requirement, cooking for 7.4%, transportation for 5.6%, tableware production for 10.7% and waste
281 treatment for 0.03%.

282

(TABLE 3 HERE)

283 The global warming of the catering service examined is 1.43 kgCO_{2eq}. The production phase has the greatest impact
284 (69%), while transport, storage, cooking and tableware production are responsible, respectively, for about 6%, 10%, 7%
285 and 8% of the overall global warming (Fig.2). Finally, waste treatment presents contributions lower than 0.4% in all the
286 impact categories examined.

287 The food production phase accounts for the greatest impact also in acidification (86%), eutrophication (89%), whereas
288 in the photochemical oxidation impact category the highest contribution is associated with transportation (67%) (Fig.2).
289 These results highlight that a proper environmental assessment should include a wide range of environmental
290 categories, as according to Notarnicola et al. (2015) the environmental burdens of the agricultural phase of the food
291 supply chain are also related to eutrophication, acidification and toxic emissions.

292 In order to increase the environmental sustainability of the catering service and in general of the food sector, it is
293 important to identify strategies aimed at reducing the impacts of food production. However, non-negligible
294 improvement could be obtained also from the other life cycle phases in specific environmental categories, for example
295 in photochemical oxidation.

296 Fig.3 shows the contribution to the examined impact categories of the production stage for each food group considered
297 in the baseline scenario. In detail, the food items are grouped into “meat, fish products”, “vegetables”, “fruits”, “pasta,
298 bakery and grain mill products”, and “dairy and egg products”. With regard to the production stage, the “meat, fish
299 products” group represents 12% of the equivalent meal, and its share accounts for more than 45% in all the examined
300 impact categories. The reduction in the consumption of meat and fish products could reduce the energy and
301 environmental impacts of the institutional catering. However, this aspect is somewhat controversial, as the main
302 function of the food is to provide an optimum supply of nutrients through a full and varied diet, then any changes in the

303 menu have to be done adopting a multidisciplinary perspective that includes both environmental and nutritional
304 parameters. New menus should be defined in order to identify the alternative quantity of each food needed to balance
305 the reduction of meat.

306 **(FIGURE 2 HERE)**

307 Concerning the global warming, the comparison with the LCAs on catering service available in the literature (Cerutti et
308 al., 2018; Jungbluth et al., 2016) highlights that the result of the baseline scenario is consistent with Cerutti et al. (2018),
309 in which the global warming potential of an average meal is 1.67 kg CO_{2eq}. But significantly different than the result
310 obtained by Jungbluth et al. (2016), in which the global warming potential of an average meal is about 4.1 kg CO_{2eq}.
311 The discrepancy in the results could be related to the fact that the catering service examined in Jungbluth et al. (2016) it
312 is not exclusively for schools and then the average composition of the menu could be different, including food items
313 usually not served in school canteens, like wine and coffee. In fact, according to Jungbluth et al. (2016) in the product
314 group of beverages, coffee and wine are responsible for a relevant share of environmental impacts.

315 Concerning the contributions of the life cycle phases, the results are similar in the three studies. In detail, the food
316 production and processing are the phases responsible for the highest contributions to global warming, accounting for
317 78% in Cerutti et al. (2018) and for 58% in Jungbluth et al. (2016) and for 74% in this study. The contribution of
318 transport is similar, accounting for about 6%. Differences are obtained for the cooking, storage and waste management
319 phases maybe related to the fact that in this study the missing data is estimated using literature data or models, while
320 both Cerutti et al. (2018) and Jungbluth et al. (2016) refer to primary data. Then, to increase the reliability of the
321 assessment is of paramount importance to use primary data collected in the canteens to model the whole life cycle of the
322 catering service. The relative impacts of meat are also similar in the three studies, 51% in Cerutti et al., (2018), 48% in
323 Jungbluth et al. (2016) and 63% in this study.

324 **(FIGURE 3 HERE)**

325
326 Table 4 shows the percentage variations of the energy and environmental impacts in each assessed scenarios, in
327 comparison with the baseline one.

328 **(TABLE 4 HERE)**

329 The analysis shows that, in scenario S1, the adoption of different agricultural practices and the local provision of food,
330 which involves reduced transport distances, enables a reduction in the impact on cumulative energy demand, the global
331 warming and the photochemical oxidation impact categories. However, a detailed analysis highlights that the most
332 significant reduction of impacts comes from the adoption of the local provision of food practice. In fact, the adoption of
333 organic agriculture practices is responsible for the increase in some examined impact categories. In particular, the

334 impact of food production increases by about 4% in acidification, 3% in eutrophication and decreases by 5.1% in
335 photochemical oxidation and 2.3% in global warming if compared to the baseline scenario, whereas the impact on
336 cumulative energy demand decreases by 0.1%. A detailed analysis of the impact on cumulative energy demand reveals
337 that non-renewable energy demand decreases by about 1.5% while the renewable energy demand increases by about
338 1.6%.

339 A further analysis of the food production phase was carried out in order to show the detailed contribution to the impact
340 of foods produced using organic agriculture practices. The analysis highlights that, compared to conventional
341 agriculture practices, organic yogurt production involves an increased impact in almost all the examined impact
342 categories with the exception of photochemical oxidation, organic milk production in acidification and eutrophication
343 and flour in acidification and eutrophication impact categories. On the other hand, the other organic foods (bread,
344 potatoes, lettuce, tomatoes, rice) involve a reduction of impacts in all the examined impact categories.

345 Different source of data are used to assess the energy and environmental impacts of the production of the different food
346 items. For example, the environmental impacts of milk and yogurt production, both conventional and organic, are
347 inferred from the EPDs, while the impacts of bread, potatoes, lettuce, tomatoes and rice, both conventional and organic,
348 are assessed through the LCI of the Ecoinvent database (Wernet et al., 2016). The products modelled starting from the
349 Ecoinvent Database present better environmental performance when are produced by means of organic practices instead
350 of conventional ones in all the examined impact categories (Table 5). Instead, the product modelled using the EPDs,
351 have worse energy and environmental performances when they are produced by means of organic agriculture (Table 5).
352 The use of secondary data involves uncertainty in a LCA study significantly.

353 **(TABLE 5 HERE)**

354 This essentially occurs because their accuracy and reliability, and their collection method may not be known (Reap et
355 al., 2008). This issue is amplified when different sources of secondary data are used because each of them is
356 characterized by a different level of data quality. Thus, to limit as far as possible the number of data sources is highly
357 recommended. Moreover, the development of more complete databases is needed in order to obtain robust conclusions
358 and recommendation.

359 With reference to the transportation phase, the local provision of food enables the impact in all the examined impact
360 categories to be reduced consistently (more than 65%) with the exception of the photochemical oxidation impact
361 category in which the reduction is negligible (about 1%), if compared to the baseline scenario. The local provision of
362 food is thus a viable strategy towards sustainable food consumption and could be a practice that a municipality can
363 adopt to improve its climate performance for example in the context of the Covenant of Major Initiative (European
364 Union, 2010) or as GPP criteria (European Commission, 2016). However, the effect of local provision of food on the

365 whole life-cycle impacts is quite limited, ranging from -0.8% (for the photochemical oxidation) to -4% (for global
366 warming).

367 The substitution of the electric oven with a natural gas oven (S2) increases the impact on the global energy requirement,
368 due to the higher consumption of energy when cooking in a gas oven compared to an electric oven. In this scenario, the
369 impact on global energy requirement of the cooking phase increases by about 40% if compared to the base case. The
370 contribution on the other impact categories shows a decrease ranging from 22% (for the global warming) to 61% (for
371 eutrophication). These results are essentially due to the better eco-profile of natural gas when compared with the Italian
372 electricity mix.

373 In the S3 scenario, the adoption of electricity generated from renewable energy sources (solar photovoltaic in the
374 examined scenario) enables a reduction in all the impact categories examined. In detail, the impacts relating to the food
375 storage and cooking phases decrease by 33% in cumulative energy demand, 65% in acidification, 49% in
376 eutrophication, 58% in global warming and 55% in photochemical oxidation, when compared to the baseline scenario.
377 These results are essentially due to the substitution of the electricity from the grid (Italian electricity mix) with
378 electricity generated by PV panels for food storage and roasting/baking in an electric oven. The environmental benefits
379 referred to the full service are small. However, they remain significant for the global warming and global energy
380 requirement, in which the impacts decrease, respectively, by 10% and 6% compared to the baseline scenario. In this
381 situation, the use of electrical appliances coupled with renewable energy resources can significantly reduce the energy
382 and environmental impact of the catering service. It could be a viable practice to reduce the environmental burdens of
383 the catering services and a key strategy in the current energy and climate policy of the European Union (e.g. Covenant
384 of Majors, 2030 Energy and climate framework (European Commission, 2013), Energy Roadmap 2050 (European
385 Commission, 2018))

386 In the S4 scenario, the adoption of bio-based tableware decreases the impact on global energy requirement related to the
387 tableware production and end of life treatment of about 7%, however the improvement referred to the whole life cycle
388 impact is -1%. The environmental contributions of tableware production and end of life treatment decrease in almost all
389 the examined impact categories with the exception of eutrophication, in which the impact increases by 19%. In global
390 warming and photochemical oxidation, the impacts decrease of about 45%, while in acidification of 26%. The
391 environmental benefits are small (lower than 0.5%) if they are referred to the whole supply chain.

392 Finally, in scenario S5, although the combination of the strategies, examined one by one in the other scenarios, results
393 in a reduced impact on global energy requirement (-10%), acidification (-2%), global warming (-16%) and
394 photochemical oxidation (-5%), the impact on eutrophication increases of 1% when compared to the baseline scenario.
395 This outcome demonstrates that, in moving towards more environmentally sustainable institutional catering and, more

396 in general, a more sustainable food and drink sector, strategies should be implemented along the whole food supply
397 chain and the assessment should include a wide range of environmental impact categories.

398 The life cycle contribution analysis of each investigated scenario highlights that food production remains the most
399 significant life-cycle phase, since it involves the highest contribution in all the examined impact categories with the
400 exception of photochemical oxidation (Fig.4). Then, strategies to reduce the impacts of this phase must be implemented.

401 Food storage and cooking represents a non-negligible contribution on global energy requirement and global warming.
402 The highest contributions are observed in Scenarios 1 and 2, in which the overall share is of about 20% on primary
403 energy consumption and 17% on global warming. The lowest impacts occur in Scenarios 3 and 5 (about 15% on
404 primary energy consumption and 8% on global warming). This is essentially due to the consumption of electricity
405 generated by PV systems, instead of electricity from national electric grid. In the other examined impact categories,
406 food storage and cooking contribute less than 6% in all the examined scenarios.

407 Food transportation accounts for more than 70% in the photochemical oxidation impact category and less than 7% in
408 the other ones in each examined scenario. Tableware production contributes for about 10% in global energy
409 requirement and global warming in all the examined scenarios, and it presents shares lower than 6% in the other impact
410 categories.

411 **(FIGURE 4 HERE)**

412

413 **4. Conclusions**

414 This paper presents a LCA of a catering service aimed at identifying the related eco-profile and the life cycle phases
415 responsible for the larger contributions. Moreover, we have analysed different scenarios in order to identify potential
416 strategies to improve the environmental sustainability of the catering service and of the food provision in general. The
417 case study is a school catering service operating in the North of Italy.

418 The results of the LCA confirms, as stated in the literature examined, that the food production stage provides the
419 highest contribution in almost all the categories examined (greater than 70%).

420 Therefore, in order to achieve a more sustainable food sector, in the context of the EU climate and energy targets,
421 strategies aimed-at reducing the impact of food production are crucial and should be the first area of intervention in
422 order of priority, in the food supply chain. Among the food categories consumed in the examined canteens, meat and
423 fish products represent the largest share of the examined impact categories. Then, although this item is not investigated
424 in the presented paper, the reduction in meat consumption, which is compatible with the nutritional requirements of a
425 balanced and varied diet, can make a significant contribution towards improving the environmental sustainability of the
426 school catering service.

427 Considering the high relevance of the food production phase, in order to obtain reliable environmental assessment, it is
428 of paramount importance to use primary data about the amount of food items consumed. Moreover, further efforts are
429 necessary in the development of more complete databases on foods production chains in order to improve the
430 robustness of the analyses and consequently of the conclusions and recommendations.

431 The second main area of intervention is represented by food storage and cooking phases. The energy used to both cook
432 and store food (heat and electricity) represents an important share of the overall impact on global energy requirement
433 and global warming. The environmental improvement of these life cycle phases can be achieved more easily than
434 during the food production stage, e.g. by consuming electricity produced by renewable energy technologies and or by
435 purchasing highly energy efficient appliances. In particular, significant improvements are achieved in global energy
436 requirement and global warming impact categories. Thus, coupling electricity with renewable energy sources could be a
437 key strategy to improve the environmental sustainability of the food sector and in a wide perspective to achieve the
438 energy and climate targets of the European Union.

439 Food transportation only has a high level of impact on the photochemical oxidation impact category and accounts for
440 about 5% in the other impact categories examined. The adoption of local provision of food allows to reduce
441 significantly the environmental impacts of the transportation phase, however the relative reduction assessed for the full
442 catering service results in small benefits. This outcome confirms the importance of performing an ex-ante evaluation of
443 the potential strategies aimed at improving the environmental sustainability of the different economic sectors.

444 Data and results from this study can provide an interesting insight into the primary energy consumption and
445 environmental impacts associated with the catering service and a rough assessment of the environmental improvement
446 associated with some practices.

447 The adoption of the LCA approach ensures a systemic accounting of primary energy consumption and other
448 environmental impacts, like GHGs emission, linked to the food catering supply chain, avoiding the shift from one life
449 cycle phase to another. Moreover, it allows to identify the main area of intervention and the and the most effective
450 strategies. Public authorities and other stakeholders involved could benefit from basing the management practices and
451 climate strategies upon scientific evidence, e.g. in the context of GPP strategies in the public catering sector.

452 Future research of this study should focus on the development of a simplified tool that allows to integrate
453 environmental, nutritional and economic parameters in the choice of the menus served in the canteens.

454

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