Reducing the carbon footprint and environmental emissions of us fast food through the introduction of oil-free technologies

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Abstract. The article is devoted to the study of the problem of excessive carbon load of the US fast food industry and innovative approaches to its reduction, including the author's methodology for systemic modernization of professional kitchens. The purpose of the article is to substantiate the need to reduce the carbon footprint and environmental emissions in the US fast food sector by optimizing the use of cooking oil and implementing oil-free technologies. During the scientific study, general scientific methods of cognition were used, in particular, analysis, synthesis, induction, deduction, systematization, generalization and modeling. The results of the study show that the US fast food industry is a source of significant environmental load due to the volume of food waste (up to 60 million tons each year), the disposal of 249 million gallons of used cooking oil and excessive energy consumption (up to 4750 kWh/m² per year in kitchen areas). It is shown that effective emission reduction is possible through multi-level measures: the introduction of energy-efficient equipment (fryeres, grills), kitchen electrification, composting, behavioral interventions (menu labeling), which increase the choice of ecological dishes. Particular attention is paid to the initiative of Manko Yu. (Profstore Equipment LLC, Texas), which involves the introduction of oil-free cooking systems (UNOX, VENIX, SIRMAN, Rational, etc.) for small and medium-sized businesses. The planned modernization of 60 kitchens can provide savings of about 360,000 kWh of energy and reduce the use of up to 12,000 gallons of oil per year, which directly affects the reduction of emissions and contributes to the sustainable development of the food environment. The practical significance of the study is to create an effective model for decarbonization of the fast-food sector through innovative modernization of kitchen infrastructure.

Keywords: fast food, carbon footprint, cooking oil, environmental emissions, oil-free technologies.

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Introduction

The relevance of the problem of carbon dioxide emissions by food companies is growing every year, which is largely due to political and economic factors. In particular, in 2025 the United States introduced a tariff on the import of cooking oil from China, which sharply limited access to low-carbon raw materials [13]. The main goal of this decision was to reduce the environmental impact of using oil in cooking.

This situation artificially increases the dependence on virgin vegetable oils, which have higher carbon values, and has also created additional pressure on the already resource-intensive fast-food sector. Parallel trends recorded by Mackie [8] indicate that food away from home consumption in the US has increased from 17% of daily calories in the 1970s to 34% in 2013–2014, confirming the increasing burden on the oil- and energy-intensive segment. Against this background, interventions related to the optimization of cooking oil use — reducing its volume, upgrading equipment, switching to oil-free technologies, improving collection and recycling — are becoming critically important tools for decarbonization. This is because they simultaneously reduce direct CO_2e emissions from thermal processes and indirect emissions associated with raw material production, logistics, storage and disposal.

Literature Review

Issues of emissions and food contamination are widely studied in the scientific literature. Among the works that are of great importance for this study, it is worth highlighting M. Carvalho, M.M. de S. Grilo, R. Abrahão [1]; M. Eid, I.A. Waggag, A.A. Mohamed, M.S. Elshahed [3]; C. Mackie, A.P. Wemhoff [9]; A. Payne, E.M. Kwofie, P. Agyemang, J.I. Baum [11]; V. Prado, J.S. Daystar, A. Pires, M. Wallace, L. Laurin [12]; J. A. Wolfson, A.A. Musicus, C.W. Leung, A.N. Gearhardt, J.Falbe [17]. Also important are the articles in Environmental Progress & Sustainable Energy [1]; Energy [3]; Journal of Cleaner Production [9]; npj Science of Food [11]; Transactions of the ASABE [12]; JAMA Network Open [17].

These studies highlight that the US fast food industry is one of the largest and most resource-intensive segments of the food economy, contributing significantly to the country's overall carbon footprint. According to RTS [5], the country disposes of about 60 million tonnes of food waste each year, or 120 billion pounds, which is almost 40% of the national food supply, while methane emissions from this waste contribute up to 3.3 billion tonnes of CO_2e globally. According to Frylite [6], global food losses will exceed 2.5 billion tonnes by 2025, while more than 2.3 billion people will remain food insecure, highlighting the systemic inefficiency of the food infrastructure. In the same context, commercial kitchens in the US demonstrate disproportionately high energy intensity: according to Eid [3], the energy consumption of QSR kitchen areas reaches 4750 kWh/m^2 per year, more than ten times the average commercial standard, while the total national volume of used cooking oil is about 249 million gallons per year [15]. A typical fast-food restaurant generates approximately 35 pounds of used cooking oil per day, and the production, processing and reheating of vegetable oils are accompanied by significant emissions, as confirmed by LCA studies by Prado [12] and Carvalho [1], which record a significant difference in CO_2 equivalent between deep frying in soybean oil and hot air methods. Additionally, according to Payne [11], extending potato storage can increase the integral environmental damage by 2–2.2 times, and compared to the "fresh" scenario, by more than 50 times, which enhances the cumulative effect of the use of oil and temperature treatment in culinary processes.

The aim of the article is to substantiate the need to reduce the carbon footprint and environmental emissions in the US fast food sector by optimizing the use of cooking oil and implementing oil-free technologies. To achieve this goal, the following tasks will be performed during the study: to analyze statistical indicators of emissions and energy consumption in the US fast food industry; to assess the impact of cooking oil on the formation of the carbon footprint at different stages of the technological cycle; to identify innovative technologies and interventions that can reduce oil use and reduce related environmental emissions.

Research Results

The global food system, which simultaneously provides nutrition and economic development, remains one of the largest sources of environmental burden, since 26–35% of global greenhouse gas emissions fall on the food sector, and another 18–29% are formed along the supply chain, including production, transport, refrigeration and retail [3].

The global imbalance between production and consumption is causing enormous resource losses: by 2025, more than 2.5 billion tons of food are expected to be lost or wasted, while more than 2.3 billion people will remain food insecure [6]. At the same time, food waste accounts for about 25% of global emissions from the food system, generating 3.3 billion tons of CO_2e annually through methane emissions from landfills [5]. Within the United States, the scale of the problem is even more pronounced: the country disposes of about 60 million tons of food waste each year, or 120 billion pounds of food, which is almost 40% of the national food supply and is equivalent to about 325 pounds of waste per person, making food waste the largest component of US solid waste landfills [5].

This inefficiency of the system leads to a rapid increase in environmental costs in the catering sector, which has been going on for several decades. Food away from home consumption increased from 17% of daily calories in the late 1970s to 34% in 2013–2014, surpassing food at home consumption for the first time in 2010 [9]. This growth is correlated with social changes, including rising incomes, changing family structures, and the increasing value of household time. After a temporary decline during the Great Recession, demand for food away from home has recovered rapidly, confirming its sensitivity to economic trends and its role in overall sector growth [9].

As the popularity of food-away-from-home has grown, the quick-service industry accounts for one of the highest concentrations of energy consumption and related CO_2e emissions in the food service sector. A typical QSR restaurant has an energy index of 650 to 1,000 kWh/m^2 per year, and kitchen areas can exceed 4,750 kWh/m^2 per year, making them more than ten times more energy intensive than most other commercial spaces [3]. Around 73% of total gas consumption in foodservice establishments is for food preparation processes, while more than half of the electricity is used to cool and operate kitchen equipment [3]. The scale of these figures is due to the growth of the global QSR market, which reached $978.4 billion in 2023, as well as the intensive operation of refrigeration systems, which in the UK alone generated 1.93 million tonnes of CO_2e in 2019 [3].

In addition to environmental aspects, the QSR sector is subject to strict regulatory oversight, not only regarding food ingredients but also cooking techniques. In the United States, the FDA oversees the safety of food ingredients, regulating the use of food additives, processing agents, stabilizers, fat substitutes, and processing aids, including oil [7]. Any change in process parameters, substitution of ingredients, or introduction of new technologies, such as oil-free cooking methods, requires compliance with strict GRAS procedures or the submission of a food additive petition, which includes toxicological assessments, exposure modeling, and evidence of safety of use [7]. This creates a regulatory framework within which the modernization of fast-food kitchens – including the transition to technologies that reduce oil consumption –is not only a technological but also a legally determined process.

The carbon footprint of cooking oil in US fast food is a pressing issue for the US environment and economy, and in this context, the state is adopting a number of regulatory decisions that affect the circulation of used oil.

US trade policy on biofuel feedstocks includes, in particular, a 125% tariff on imports of used cooking oil (UCO) from China, introduced in 2025, which has sharply reduced the flow of low-carbon feedstock to US refineries, while the US Environmental Protection Agency (EPA) has required the US to provide a record 5.6 billion gallons of biomass diesel by 2026 under the Renewable Fuel Standard [13].

In parallel, there are regulatory requirements for the mandatory collection and recycling of used cooking oil in restaurants, while the EPA recognizes that UCO biodiesel can reduce greenhouse gas emissions by ≈86% compared to fossil diesel [15]. The formation of such a regulatory framework is further supported by the results of LCA studies, which show that vegetable oils are one of the key sources of climate impact in processed foods [12], that traditional deep frying in vegetable oil has significantly higher CO_2-equivalent emissions than hot air frying technologies [1], and the choice of storage and thermal processing method for potatoes can change the environmental damage to human health, ecosystems and resources by more than 50 times [11]. Taken together, this leads to increasing pressure on fast food operators from climate, trade and health policies to optimize their work with cooking oil.

The US fast food industry has formed one of the most extensive and economically significant food service sectors, determining the structure of employment, consumer patterns and investment flows into related industries. QSR chains provide annual formation of tens of billions of dollars of system sales, support hundreds of thousands of jobs, accelerate the development of technological innovations, in particular the implementation of AI infrastructure, intelligent kitchen systems, automation and digitalized service formats, and at the same time reflect nationwide social and technological trends, including the transition to energy-efficient, more environmentally friendly and oil-free equipment. Although the source does not provide direct data on the volume of cooking oil use, the nature of the menus of the leading segments – in particular, chains specializing in fried chicken, burgers, French fries or other deep-fried products – allows us to draw scientifically based conclusions about the level of their technological dependence on oil in production processes.

Table 1. Main operators of the US fast food market and their characteristics

№	Network name	Economic impact and operational specifics	Menu and technological profile
1	McDonald’s	In 2024, the chain expanded to 13,559 restaurants, showing the fastest growth since 2013. The company invested $100 million in a recovery program after a sales decline, reinforcing its role as one of the strongest market drivers.	The menu focuses on burgers, fries, and other deep-fried items, indicating a high technological dependence on cooking oil.
2	Starbucks	In 2024, Starbucks opened 589 new locations, growing its network to 16,935 restaurants and maintaining the fastest growth rate in the QSR sector. Significant investments were directed at service modernization and internal process optimization.	The product range is dominated by beverages and baked goods, requiring minimal oil use and no deep-frying technologies.
3	Chick-fil-A	The chain reached $22.7 billion in systemwide sales in 2024, maintaining one of the highest AUVs in the industry — $9.227 million for drive-thru locations; the network grew by 132 restaurants.	The menu is based on fried chicken, which implies intensive use of frying equipment and significant volumes of vegetable oil.
4	Taco Bell	The company achieved $1 billion in profit for the first time, with a restaurant margin	The menu combines Tex-Mex elements and various

		exceeding 24%, and the number of U.S. locations reached 7,604. Digital sales accounted for 35% in 2024 and are expected to exceed 60% by 2030.	fried items, resulting in a medium level of oil dependence in production.
5	Wendy's	The company is working on an extensive expansion program and aims to increase systemwide sales to $17.5–18 billion by 2028, optimizing the network by closing unprofitable restaurants.	The menu includes burgers, fries, and fried chicken dishes, which leads to significant oil use in production processes.
6	Dunkin'	Systemwide U.S. sales in 2024 totaled $12.47 billion, with 9,768 restaurants. The brand continues steady expansion and product range growth.	A large portion of the products includes donuts and other fried items, which requires active use of cooking oil.
7	Chipotle	The company reached 3,644 restaurants and plans to expand to 7,000, showing high AUVs — $3.2 million in 2024.	The menu is based on heat treatment methods without deep-frying, indicating a low level of oil use.
8	Burger King	Total investments in the Reclaim the Flame program exceeded $2 billion, and the chain operates 6,701 restaurants in the U.S.; major efforts are focused on restaurant modernization.	The technological profile involves extensive use of frying equipment for fries and other items, meaning a high level of oil use.
9	Subway	Despite a reduction in the network to 19,502 locations, the company is actively pursuing digitalization and restaurant redesign through the Fresh Forward 2.0 program.	The menu is based on sandwiches and salads; the technological processes do not include deep-frying, resulting in minimal oil use.
10	Domino's	The chain includes 7,014 restaurants and is actively developing aggregator partnerships; the strategy focuses on strengthening its position in the delivery market.	The main cooking method is pizza baking, which implies a low level of oil application.

Note: Compiled by the author based on QSR 50: 2025 Annual Report [14]

In the practice of American fast-food establishments, cooking oil is used on an industrial scale, forming a significant carbon and environmental footprint at all stages of the life cycle – from growing raw materials to disposing of the used product. A typical quick-service restaurant in the United States generates about 35 pounds of used oil per day (≈16 kg), which corresponds to 150–250 pounds per week, while the total volume of UCO for all QSRs is estimated at approximately 249 million gallons per year [15]. This oil already has a significant "built-in" carbon footprint due to the intensive resource and energy costs at the cultivation stage (fertilizers, pesticides, soil cultivation), processing and refining, which LCA analysis clearly demonstrates for cottonseed, soybean, canola and palm oils [12]. In addition, reheating of oil in fryers, long-term operation of equipment and energy losses during frying increase specific CO_2-equivalent emissions, with deep-frying scenarios in soybean oil being more environmentally "punitive" than hot-air frying scenarios without oil [1]

At the level of the consumer chain, potato storage and the choice of processing technology (boiling, baking, frying in oil) can increase the integral environmental damage by a factor of 2–2.2 just due to the extended storage time, and in comparison, with the "fresh" scenario – by more than 50 times [11], which emphasizes the cumulative nature of the environmental consequences of long-term storage and intensive frying. Against this background, used cooking oil is a critical low-carbon feedstock for biodiesel production, but the imposition of tariffs on UCO imports encourages a return to higher-emission virgin vegetable oils and additional pressure on land use [13], which reinforces the importance of optimizing the use, collection, and recycling of oil in the fast-food sector as a decarbonization tool [15].

The US National Strategy for Reducing Food Losses and Recycling Organic Materials is the main vector of the state's environmental policy. The strategy helps prevent the formation of food waste. At the same time, it helps expand the possibilities of recycling food waste and create a circular economy that can simultaneously reduce methane emissions and increase resource efficiency [10]. The national strategy is directly aimed at achieving a national goal. In particular, it is planned to reduce food losses by 50% by 2030. At the same time, the recycling of organic materials should increase by 50%, which meets the requirements of SDG 12.3. In general, this approach forms the political basis for the emergence of new technological solutions in the food sector, and their use by restaurants and commercial kitchens becomes the most effective strategic decision at the microeconomic level with the achievement of the national strategy. At a practical level, reducing emissions in the fast-food industry relies on a combination of technological, behavioral and organizational solutions. In particular, kitchens consume 10 times more energy per square meter than commercial spaces, making them an important target for modernization. In turn, the most energy-intensive processes, such as cooking, ventilation, cooling and air conditioning, are becoming key areas for reducing carbon emissions [16].

Here, innovations in thermal processing play an important role. For example, the use of high-efficiency fryers, which are installed in some restaurants, can reduce energy consumption by 40–50%, as well as save at least one therm of gas per day, while increasing production capacity [8]. Such models can also be used for grills, which is actively described in the literature [8], according to which the replacement of non-thermostatic models with thermostatic ones reduces energy use and provides a stable thermal regime [8].

Another important area of innovative technical solutions for reducing carbon emissions includes the gradual electrification of kitchens. In particular, in some restaurants, the complete replacement of gas equipment with electric or induction hobs allows for a significant reduction in emissions, since induction systems, according to experts [16], allow for a halving of emissions compared to gas hobs. If such induction hobs are powered by renewable sources, such solutions can result in zero carbon emissions. This type of kitchen can reduce the heat load, as well as improve working conditions, which is critically important for the technological modernization of restaurants and fast-food establishments.

The behavioral direction of kitchen modernization is also important, in particular in the study [17], in which the authors conducted a survey among five thousand American adults and showed that if the menu is marked with climate impact labels, their choices change. In particular, the change in choice can vary by up to 20% [17]. This shows that such marketing tools are important means of decarbonization that cannot be ruled out against the background of technological updates in the fast-food sector.

Modernizing waste processing systems is also important. In particular, fast food restaurant kitchens have significant food surpluses, and organic waste accounts for a significant share of methane emissions. That is why composting, which is already used by many restaurants in the United States, is important. Today, composting is one of the most effective tools that contributes to a positive climate effect, since this waste is sent not to landfills, but to special storage sites, which can then become the basis for agriculture. In turn, this contributes to changing the infrastructure, reusing waste and modernizing the general infrastructure of the business. It is important to combine this technology with packaging modernization, since a significant reduction in plastic in packaging creates a multiplier effect in reducing emissions.

In general, the cooking oil processing segment is also undergoing modernization. By 2024, oil recycling had already decreased to $2.1 billion, with an average rate of decline of about 7%, driven by more affordable oil substitutes [2]. However, increased regulation and mandatory government requirements for oil recycling are creating additional incentives for the development of circular models that can support the overall decarbonization of the sector.

Thus, innovative approaches to reducing emissions in the fast-food sector include public policies, technological solutions, equipment upgrades, changes in consumer behavior, and the development of circular models. Oil-free cooking technologies, kitchen electrification and systematic optimization of energy use play a particularly important role, which together form the basis for a significant reduction in the carbon footprint.

The combination of engineering solutions, optimized technological processes and digital tools based on artificial intelligence makes it possible to practically implement national strategies for decarbonization and increasing resource efficiency in the catering sector. For this, small innovative initiatives that operate at the intersection of environmental modernization, food safety and economic efficiency are of particular importance. One of these is the initiative of Manko Yu., the essence of which is the systematic modernization of professional kitchens based on certified oil-free and energy-efficient equipment using auxiliary tools of artificial intelligence. Through Profstore Equipment LLC (Texas), this initiative targets small and medium-sized food service businesses and institutional kitchens in the United States and involves the implementation of oil-free air and convection cooking systems from leading manufacturers (UNOX, VENIX, SIRMAN, FIMAR, Prizma Food, RATIONAL, OZTI, FAGOR), replacing traditional fryers and reducing the use of cooking oil, fat content in products and, accordingly, the associated carbon footprint. The planned modernization of 60 kitchens during the first year provides for an estimated savings of about 360,000 kWh of energy and a reduction in the use of approximately 12,000 gallons of cooking oil per year, which directly correlates to a reduction in operational emissions and contributes to a healthier food environment.

Table 2 - Summary of innovative approaches to reducing emissions

Innovation category	Essence of the solution	Effect / data
National strategy for food-waste reduction	policies focused on preventing losses, processing organic waste, cutting methane, and advancing a circular economy	the goal is a 50% reduction in waste and organic processing by 2030 [10]
Energy-efficient fryers	replacement of basic models with high-efficiency units	40–50% less energy use; savings of ≥1 therm/day [8]
Energy-efficient grills	thermostatic systems and infrared burners	savings of 1 therm/day; more stable heat output [8]
Kitchen electrification	induction cooktops and electric ovens	GHG emissions cut in half compared with gas; potential for zero-emission operation [16]
Food-waste composting	elimination of landfill methane	major methane reduction; food waste causes up to 8% of global GHG emissions [16]
Behavioral interventions	climate labeling on menus	+23.5% increase in choosing sustainable meals [17]
Cooking oil	segregation and reuse	market valued at $2.1 billion in

recycling		2024; declining demand, but important for circularity [2]
Innovative initiative for commercial kitchen modernization (Manko Y. initiative)	comprehensive implementation of certified oil-free and energy-efficient technologies (UNOX, FAGOR, Rational, convection and air systems, etc.), supported by an AI platform for staff training, energy optimization, and 3D kitchen design; focused on small and medium businesses in the US	modernization plan includes 60 kitchens in the first year; expected savings of ~360,000 kWh of energy and reduction of ~12,000 gallons of oil annually; reduced operational emissions, improved menu health characteristics, and alignment with national strategic priorities

Note: Systematized by the author based on sources [2, 8, 10, 16, 17]

Structurally, the initiative combines three interrelated components: the supply of certified energy-efficient equipment (Energy Star, NSF, UL), oil-free cooking technologies that reduce the consumption of trans fats and carcinogenic compounds and are consistent with the priorities of obesity and cardiovascular disease prevention, as well as a digital platform for kitchen modernization based on artificial intelligence. The latter includes interactive staff training modules (AI trainer with step-by-step instructions for operating convection ovens, air fryers, etc., multilingual video guides and knowledge testing), as well as an energy-economic analytics module that collects data on the type and operating mode of equipment, tariffs, climatic conditions and, on this basis, generates individual recommendations for switching to induction hobs, modern refrigeration systems and other highly efficient equipment with a calculation of expected savings (for example, about 95 USD per month and 1140 USD per year when replacing a fryer with a payback of about 18 months). Thus, Manko Y.'s initiative can be considered as an example of an applied platform for decarbonization of professional kitchens that integrates oil-free technologies, energy-efficient equipment and AI-driven optimization, combining national emission reduction goals with specific tools for fast food and catering operators.

Conclusions

The carbon footprint of the US fast food industry is a complex issue, each with a clearly quantified dimension. Globally, more than 2.5 billion tons of food waste are generated each year, while in the US, the amount of waste is 60 million tons, or 120 billion pounds, which is almost 40% of the entire national food system. At the same time, the fast-food segment generates approximately 249 million gallons of used cooking oil each year, while each individual restaurant produces about 35 pounds of waste oil per day. Together, this creates significant CO_2 and methane emissions, tied to both the production of oils and the decomposition of organic residues.

In the practice of fast-food restaurants, the problem is exacerbated by the extremely high energy intensity of commercial kitchens. The energy index in this sector is 650–1000 kWh/m^2 per year, and kitchen areas can exceed 4750 kWh/m^2 per year, which is more than ten times higher than most other commercial spaces. Approximately 73% of the gas consumption of establishments is accounted for by food preparation processes, and more than half of the electricity is spent on cooling and equipment operation. Given the technological profile of the segment, in particular the dominance of deep-frying, the widespread use of vegetable oils, the need for intensive ventilation, the modernization of technologies will have a cumulative environmental effect.

The accumulation of the problem makes it necessary to move to multi-level solutions, covering both technological and behavioral and organizational changes. The most effective areas include the introduction of energy-efficient fryers, modernization of grills, electrification of kitchens (40-50% energy and emissions savings), composting of food waste and behavioral marketing innovations, including menu labeling about eco-choices. Additionally, circular models for the disposal of cooking oil and new kitchen modernization initiatives (including oil-free technologies and digital AI solutions) demonstrate the potential for integrated emission and energy reduction in the sector.

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