Available online at http://journal-of-agroalimentary.ro

Journal of Agro-alimentary Processes and Technologies 2024, 30 (2), 179-186

Journal of Agroalimentary Processes and Technologies

Consequences of increasing greenhouse gas emissions: case study on the impact of the food industry

Adelina Ioana Moja[1], Vasile Pădureanu[1*], Cristina Canja[1], Geronimo Răducu Brănescu[1], Gavrilă Calefariu[2]

[1] Transilvania University of Brasov, Faculty of Food and Tourism, Street Castelului, no.148, Brasov, Romania
[2]Transilvania University of Brasov, Faculty of Industrial Engineering and Management, Street Univesitatii, no. 1, Brasov, Romania

**Corresponding author: padu@unitbv.ro*

Abstract
The global carbon footprint has increased to frightening heights due to rising greenhouse gas emissions, mainly from the energy and industrial sectors, which include the food industry. This case study examines how the industry's carbon emissions have changed over time, highlighting the sector's major environmental impact and the pressing need to implement decarbonization plans. The particularity of the study lies in the analysis of the crucial role that emissions from the food industry play in global emissions. An overview of the global industrial carbon footprint was created through an analysis of carbon emissions data from multiple sources, with a particular focus on the food industry.
Since the Industrial Revolution, carbon dioxide emissions have increased dramatically worldwide, reaching a record high of 36.3 billion tons in 2019. With around 23% of global emissions coming from industry, the energy sector is the largest emitter. The main cause of emissions is the use of fossil fuels in heavy industries such as steelmaking, cement, and chemicals; the two largest emitters are China and the United States.
Achieving the goals outlined in the Paris Agreement and halting climate change requires reducing carbon emissions from the food industry. The adoption of low-carbon technologies, increased energy efficiency and a shift to cleaner energy sources are essential remedies. The industrial sector needs to decarbonize faster, and this can only be achieved through international cooperation and strong government regulations.
Keywords: carbon footprint, emissions, food industry, greenhouse gas.

1. Introduction

Climate change is one of the most pressing issues facing our planet today. The main cause of climate change is the emission of greenhouse gases (GHGs) into the atmosphere from various anthropogenic sources, such as fossil fuel burning, deforestation and industrial agriculture [1]. GHGs act as an invisible blanket around the Earth, trapping solar heat and causing global temperatures to rise. This temperature increase has serious consequences, including increased extreme weather events, rising sea levels, melting glaciers and changes in biodiversity [2].

The global carbon footprint has increased significantly in recent decades, reflecting an increase in human activities that generate greenhouse gas (GHG) emissions. According to data from the Global Carbon Budget, global CO_2 emissions reached a record 53.2 billion tons in 2020, an increase of 2.3% compared to the previous year [3].

The Carbon Footprint (CF) is widely recognized as a comprehensive and standardized measure for assessing the

DOI: 10.59463/JAPT.2024.2.12

environmental impact of direct and indirect greenhouse gas (GHG) emissions in the context of production and consumption [4,5].

The CF methodology has gained significant importance as a valuable tool in assessing greenhouse gas emissions due to its alignment with international conventions.

Anthropogenic greenhouse gas (GHG) emissions from the agricultural and post-production sectors of the food system are widely recognized [6]. Emissions are released at various stages, including agricultural and livestock production, food processing, transportation, and consumption. Tubiello et al. highlights a significant reduction in emissions from agricultural land use between 1990 and 2018 [7].

The Human Development Report 2007–2008, published by the United Nations Development Program (UNDP), highlighted the need for global cooperation in addressing climate change in the 21st century. It highlighted the limitations of relying solely on market forces to address environmental issues and warned that if we fail to effectively address the escalating global climate crisis, it could lead to the largest and most pervasive market failure ever recorded in human history. It is therefore imperative to urgently confront this challenge by implementing effective policies to reduce greenhouse gas emissions and address market failure [8].

In response to climate change, China has adopted and revised the Energy Conservation Law and the Circular Economy Promotion Law, establishing a solid national legal framework for environmental governance. China has also submitted its "nationally determined contribution" to the Paris Agreement, which includes peaking CO_2 emissions around 2030, reducing carbon emissions per unit of GDP by 60-65% from 2005 levels, and increasing the share of non-fossil energy in primary energy consumption to around 20% [9,10].

The need to promptly address climate change, mainly stemming from greenhouse gas emissions from human activities, including agriculture, is crucial. To this end, key international agreements have been concluded, such as the Paris Agreement and the UNFCCC, which were created to set targets and a framework for reducing emissions.

Paris Agreement

The EU's plan for climate neutrality by 2050 includes ambitious measures such as reducing carbon emissions in key sectors, promoting renewable energy, improving energy efficiency, and investing heavily in green technologies. These efforts demonstrate the EU's commitment to reduce emissions by at least 55% before 2030 compared to 1990 levels. In addition, the EU and its member states have jointly agreed to update the EU's climate plans in 2023. By adopting this plan and its strong commitment to fighting climate change, the EU is demonstrating that it is possible to achieve sustainable economic development while protecting the environment. In addition, European leaders take responsibility to protect the planet for future generations and help build a safer and more prosperous future for all inhabitants of the Earth.

The EU is therefore positioning itself as a successful example in the fight against climate change and encouraging other nations to join in its efforts to create a more sustainable future for all. It is essential that all countries cooperate and take responsibility for protecting the environment and combating climate change, because these problems know no borders and affect the entire planet.

The Paris Agreement presents a comprehensive action plan to mitigate the effects of global warming. Its fundamentals include:

1. ong-term goal: Governments unanimously agreed to limit the increase in global average temperature to well below 2°C above pre-industrial levels, making further efforts to limit the increase to 1.5°C.
2. Contributions: Before and during the Paris conference, countries submitted comprehensive national climate action plans, called NDCs, outlining their emission reduction strategies.
3. Ambition: Governments committed to communicating their action plans regularly, setting more ambitious targets with each subsequent plan, which will be reviewed every five years.
4. Transparency: Countries committed to informing each other, as well as the public,

about their progress towards it
5. Solidarity: Countries will continue to provide financial support to fight climate change, helping vulnerable nations reduce emissions and increase their resilience to the impacts of climate change.
The Paris Agreement entered into force on 4 November 2016, after the condition for ratification by at least 55 countries responsible for at least 55% of global greenhouse gas emissions had been met. All Member States of the European Union have ratified the agreement [11].

UNFCCC: International Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) is an important international agreement on climate action, in which the European Union (EU) is a participant. This convention was one of three conventions that were adopted at the Rio Earth Summit in 1992, where the global community recognized the need for collective action to protect both people and the environment, as well as mitigate greenhouse gas emissions.
Almost all countries around the world have ratified this convention, demonstrating its widespread acceptance. Recognizing the need for more robust measures to reduce emissions, UNFCCC signatories realized in the mid-1990s that stronger provisions were needed.
Consequently, in 1997, they reached an agreement known as the Kyoto Protocol. This protocol marked a significant milestone, as it set legally binding emission reduction targets for developed countries, an innovative development at the time. However, the Kyoto Protocol expired in 2020. To further address the pressing issue of climate change, countries reaffirmed their commitment to tackling it through the Paris Agreement.
This agreement not only renewed their commitment to take action, but also set new targets to accelerate efforts to limit global warming [11].

2.Material and methods

This case study examined the evolving impact of the food industry on global carbon emissions. The research aimed to highlight the significant contribution of industry to the environment and highlight the need for decarbonization strategies.
Global carbon footprint data was obtained from academic databases such as Web of Science, Scopus or Elsevier, but also sources such as Global Carbon Budget, Intergovernmental Panel On Climate Change or Paris Agreement on climate change were used.
Information on greenhouse gas emissions per kilogram of food product was obtained from an LCA study published by Poore &; Nemecek [12], and data on global food emissions by life cycle stage were taken from a scientific article by Crippa et al. [13].
Descriptive statistics were used to analyze data collected on global carbon footprint and food-related emissions. The figures were created to illustrate trends and variations in emissions across different food sectors and categories.
The study was based on existing data from secondary sources and there could be potential inconsistencies in inter-source data collection methodologies. LCA data used for food emissions may not reflect the latest developments in agricultural practices.
The study focused exclusively on greenhouse gas emissions and did not consider other environmental impacts of the food industry, such as water pollution and biodiversity loss.
Further research could involve conducting a meta-analysis of LCA studies to get a more comprehensive picture of food-related emissions in different regions and agricultural practices.
Investigating the effectiveness of existing and potential decarbonization strategies in the food industry could be another valuable area of future research.

3.Results and discussion

3.1.Increase in average annual temperatures due to human emissions

Human activities, such as emissions of carbon dioxide and other greenhouse gases, have been identified as the main causes behind rising global temperatures [14]. The correlation between global temperature trends and the concentration of greenhouse gases, especially CO_2, has been consistent throughout Earth's long history [15].
The data shown in Figure 1. illustrates the increase in global average temperature

relative to a reference period, derived from the average temperature between 1961 and 1990. Since then, average temperatures have risen by more than 0.8°C.

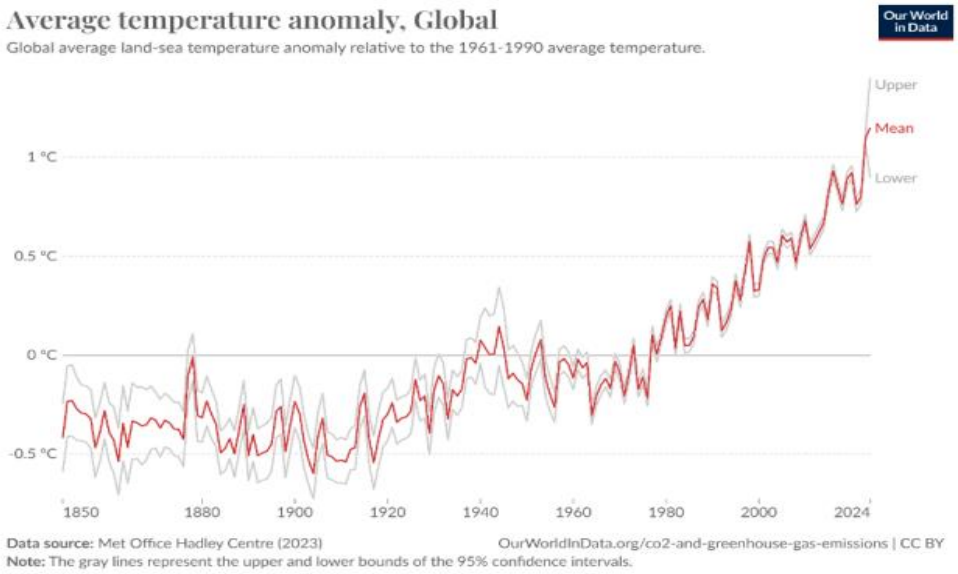

Figure 1. Average temperature anomaly[16]

Temperature records indicate that global temperatures in 1850 were about 0.4°C lower than the reference period, resulting in a cumulative temperature increase of about 1.2°C compared to pre-industrial times. In addition, the uneven distribution of this warming phenomenon is evident, with the Northern Hemisphere experiencing more significant warming than the Southern Hemisphere, especially pronounced in polar regions where temperatures have risen by more than 5°C. This spatial variability can be visualized through maps provided by Berkeley Earth [17].

3.2.Annual CO_2 emissions per country

Annual CO 2 emissions for each country are often aggregated and reported at national level. These emissions give us information about how much each country emits each year and allow us to observe the geographical distribution of current emissions around the world. On the graph, we can see how much each country issued in the most recent year on record. It is important to note that reported emissions come from fossil fuels and industry, excluding land-use change.

Figure 2 reveals a concentration of high CO_2 emissions in developed economies, particularly in North America, Europe, and East Asia. This reflects the strong dependence on fossil fuels for power generation and industrial activities in these regions.

While emissions are generally lower in developing regions, some countries, such as India, Brazil, and South Africa, show significant emissions. This trend is likely driven by rapid economic growth and urbanization.

Sub-Saharan Africa stands out as a region with relatively low CO_2 emissions. This is primarily due to the limited industrialization of the region and dependence on renewable energy sources.

Developed countries, with their historically and currently high emissions, have a greater responsibility to take meaningful steps to reduce their emissions. Developing countries, while facing the challenge of balancing economic growth with environmental sustainability, can benefit from technological advances and international support to pursue low-carbon development paths.

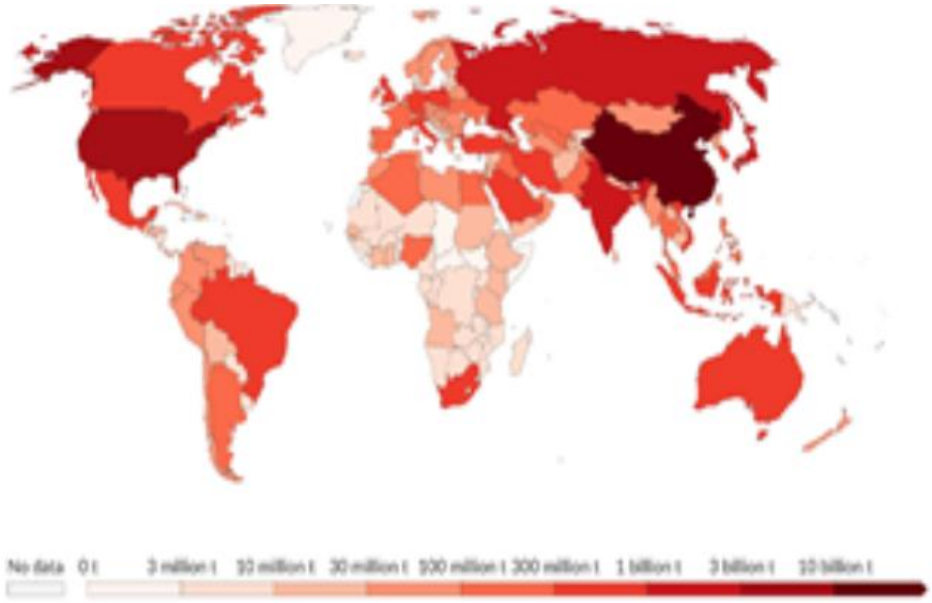

Figure 2. Annual CO_2 emissions, 2022 [18]

The map does not include emissions from land use change, which can also contribute significantly to greenhouse gas emissions. Deforestation and other land-use changes release CO_2 into the atmosphere and reduce carbon sinks.

The data used for the map may have limitations, such as potential inaccuracies or inconsistencies in emission estimates between countries.

3.3. Greenhouse gas emissions per kilogram of food product

Figure 3 shows greenhouse gas (GHG) emissions per kilogram of food, based on 2018 data. Beef (beef herd) has the highest GHG emission per kilogram with a value of 99.48 kg CO_2-equivalent and is followed as lamb & mutton emissions with a value of 39.72 kg CO_2-equivalent. Dairy products have significantly lower GHG emissions than red meat, ranging from 23.88 kg CO_2-equivalent (cheese) to 3.15 kg CO_2-equivalent (milk).

Cereals and vegetables have the lowest GHG emissions per kilogram, ranging from 1.57 kg CO_2-equivalent (wheat and rye) to 0.46 kg CO_2-equivalent (potatoes).

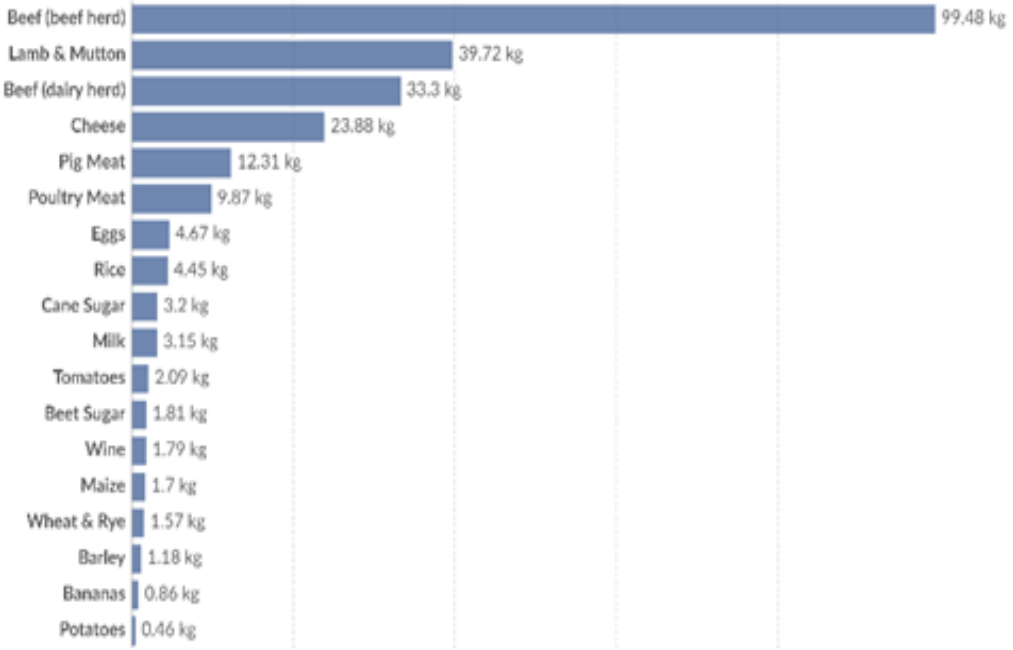

Figure 3. Greenhouse gas emissions per kilogram of food product [12]

The graph shows a significant variation in GHG emissions per kilogram of food. Red meat has a disproportionately high climate impact, generating GHG emissions tens of times higher than grains and vegetables. Dairy products are at an intermediate level in terms of GHG emissions.

Food choices can have a significant impact on GHG emissions. Reducing red meat consumption and replacing it with lower-emitting foods such as cereals, vegetables and dairy products can help mitigate climate change. The graph is based on data from 2018 and GHG emissions per kilogram of food may have varied since then. The graph also fails to consider other aspects of the climate impact of food systems, such as deforestation and food waste.

3.4.Global food emissions by life cycle stage: total greenhouse gases (GHGs)

Figure 4 shows global food emissions by life cycle stage, with total greenhouse gas (GHG) emissions in gigatons of carbon dioxide equivalent (Gt CO_2-equiv) for each step.

Consumer waste generates the highest GHG emissions, accounting for 6.2 Gt CO_2-eq. Agricultural production contributes the second highest value to emissions, with 5.4 Gt CO_2-eq. Land use has the third highest emissions, totaling 4.7 Gt CO_2-eq. Packaging, transport, retail, energy used by consumers emit between 2.1 and 0.7Gt CO_2-eq.

The graph highlights the significant contribution of consumer waste and agricultural production to global GHG emissions from food. These two steps account for more than half of all emissions. Land use, packaging, transport, and retail also contribute substantially to emissions, while energy used by consumers has the least impact.

The graph does not consider other environmental impacts from food production, such as water pollution and biodiversity loss.

Reducing food waste and improving food waste management practices can significantly reduce GHG emissions from the food system. Increasing agricultural efficiency and shifting towards sustainable farming practices can reduce emissions from agricultural production.

Implementing sustainable packaging solutions, optimizing food transport routes, and improving energy efficiency in retail and consumers' energy consumption can further reduce emissions.

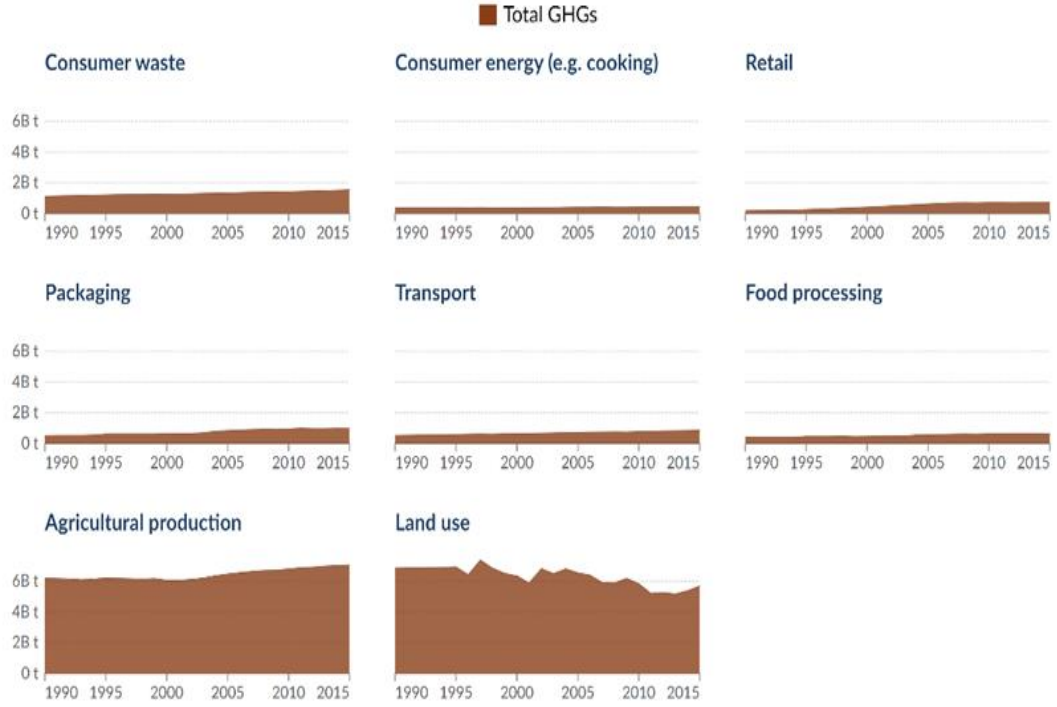

Figure 4. Global emissions from food by life-cycle stage, Total GHGs [13]

4. Conclusions

This study presented a comprehensive analysis of climate change, greenhouse gas (GHG) emissions and its impact on the environment. The data and figures presented underline the urgent need to take concrete measures to reduce GHG emissions and mitigate the effects of global warming.

Human activities, especially the burning of fossil fuels and deforestation, are the main contributors to rising global temperatures.

The Paris Agreement provides a global framework for climate action, setting ambitious GHG emission reduction targets.

CO_2 emissions vary significantly between countries, and developed countries bear greater responsibility for reducing their historical and current emissions.

Food choices can influence GHG emissions, low consumption of red meat and adoption of a diet based on grains, vegetables and dairy can help reduce climate impact.

Food waste and agricultural production are the stages in the food life cycle that contribute most to GHG emissions. Reducing food waste, improving sustainable agricultural practices, and implementing sustainable solutions throughout the food chain are key to reducing emissions from this sector.

To successfully combat climate change, collective action is needed from governments, industry, communities, and individuals. Effective strategies to reduce GHG emissions need to be developed and implemented in all sectors, including energy, transport, agriculture, and waste management. Continued investment is also needed in research and development of clean technologies and sustainable practices that can help reduce our carbon footprint.

Every individual can contribute to reducing GHG emissions by making more sustainable choices in their daily lives. This may include reducing energy consumption, choosing alternative means of transport, reducing food waste, and adopting more environmentally friendly farming practices (where appropriate).

Climate change is a global threat with severe consequences. Through international cooperation, effective environmental policies and changing individual behaviors, we can reduce GHG emissions, mitigate the effects of global warming and create a more sustainable future for future generations.

References

1. Schulz, C. *IPCC Report 2022 AR6: Summary Part 1*. For Tomorrow. **2022** https://www.fortomorrow.eu/en/blog/ipcc 2022-part1
2. Climate Change 2021: *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* **2021**, 33–144. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/
3. Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Olsen, A., Peters, G. P., Peters, W., Pongratz, J., Sitch, S., Le Quéré, C., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S., Aragão, L. E., Arneth, A., Arora, V., Bates, N. R., Zaehle, S. Global Carbon Budget *Earth System Science Data*, **2020.**, *12*(4), 3269–3340. https://doi.org/10.5194/essd-12-3269-2020
4. Pertsova, C. C. *Ecological Economics Research Trends*. Nova Publishers. **2007.** https://www.semanticscholar.org/paper/Ecological-economics-research-trends-Pertsova-Cochrane
5. Yang, Y., & Meng, G. The evolution and research framework of carbon footprint: Based on the perspective of knowledge mapping. *Ecological Indicators*, **2020,** *112*, 106125. https://doi.org/10.1016/j.ecolind.2020.106125
6. Tubiello, F. N., Karl, K., Flammini, A., Gütschow, J., Oblilaryea, G., Conchedda, G., Pre- and Post-Production Processes Increasingly Dominate Greenhouse Gas Emissions From Agri-Food Systems. *Earth System Science Data*, **2022,** *14*(4). https://doi.org/10.5281/zenodo.5615082
7. Tubiello, F. N., Rosenzweig, C., Conchedda, G., Karl, K., Gütschow, J., Xueyao, P., Obli-laryea, G., Wanner, N., Qiu, S. Y., Barros, J. D., Flammini, A., Mencos-Contreras, E., Souza, L., Quadrelli, R., Heiðarsdóttir, H. H., Benoit, P., Hayek, M., & Sandalow, D. Greenhouse gas emissions from food systems: Building the evidence base. *Environmental Research Letters*, **2021,** *16*(6), 065007. https://doi.org/10.1088/1748-9326/ac018e
8. Spash, C. L. Book Review: The Economics of Climate Change: The Stern Review. *Environmental Values*, **2007,** *16*(4), 533–535. https://doi.org/10.3197/096327107X243277a

9. Li, J., & Lin, B. The sustainability of remarkable growth in emerging economies. *Resources, Conservation and Recycling*, **2019,** *145*, 349–358. https://doi.org/10.1016/j.resconrec.2019.01.036
10. Sun, C., Ding, D., Fang, X., Zhang, H., & Li, J. How do fossil energy prices affect the stock prices of new energy companies? Evidence from Divisia energy price index in China's market. *Energy*, **2019,** *169*, 637–645. https://doi.org/10.1016/j.energy.2018.12.032
11. *Paris Agreement on climate change*. (n.d.). Retrieved April 29, 2024, from https://www.consilium.europa.eu/en/policies/climate-change/paris-agreement/
12. Poore, J., & Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science*, **2018**. *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216
13. Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*, **2021,** *2*(3), 198–209. ttps://doi.org/10.1038/s43016-021-00225-9
14. Intergovernmental Panel On Climate Change (IPCC). *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (1st ed.). **2023.** Cambridge University Press. https://doi.org/10.1017/9781009157896
15. Lacis, A. A., Schmidt, G. A., Rind, D., & Ruedy, R. A. Atmospheric CO2: Principal Control Knob Governing Earth's Temperature. *Science*, **2010,** *330*(6002), 356–359. https://doi.org/10.1126/science.1190653
16. *Met Office Hadley Centre – Processed by Our World in Data*, **2023** https://www.metoffice.gov.uk/weather/climate/met-office-hadley-centre/index
17. Rohde, R. *Global Temperature Report for 2022*. Berkeley Earth. **2023,** https://berkeleyearth.wpengine.com/global-temperature-report-for-2022/
18. Global Carbon Budget – with Major Processing by Our World in Data, **2023**) https://globalcarbonbudget.org/carbonbudget2023/