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ANALYSIS OF THE POTENTIAL OF IMPLEMENTING METHANE-BASED CARBON TAX ON FOOD WASTE IN INDONESIA

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Abstract
Indonesia is the largest producer of food waste in Southeast Asia. Food waste is a contributor to greenhouse gases, therefore there needs to be a mechanism to reduce food waste and one of them is through a methane-based carbon tax. This research aims to discuss whether there is potential for implementing a methane-based carbon tax on food waste in Indonesia. This research is a qualitative research approach *systematic literature review* (SLR) and using the PRISMA method. The literature used is publications published from 2020 to 2024. From the results of the literature review it emerged that there is potential for implementing a methane-based carbon tax as well as implementing a carbon tax on food waste as has been done abroad. It is hoped that this research can become a reference for formulating tax policies related to carbon tax so that it can reduce the impact of food waste which will damage the environment. The limitation of this research is that it has not examined the Government's readiness to implement a methane-based carbon tax.
Keywords: Carbon tax, Food waste, Greenhouse gasses, Methane tax

INTRODUCTION

Food is a basic human need for life which consists of everything obtained through animal husbandry, fisheries, forestry, plantations, agriculture, water and other sources, both processed and unprocessed, including all ingredients used to produce food and other drinks (Daher et al., 2021). Along with human growth, the need for food is predicted to continue to increase every year. In fact, according to data published by FAO (2023), worldwide food needs in 2050 are predicted to reach 60-70% more than today's food needs. However, in reality, in the food supply chain process, almost a third of human food production is lost or wasted as waste every year (Faishal & Suprapto, 2022), both during the manufacturing process, production, consumption and retail level (Puriwat & Tripopsakul, 2021).

Indonesia itself is the country that contributes the largest food waste in the Southeast Asia region (United Nations Environment Programme, 2024). Every year, every person in Indonesia contributes 115-184 kg of household food waste (Bappenas, 2021). Fatally, this figure only considers food waste that comes from households, without taking into account other sources such as restaurants or retail. In other data processed by the SIPSN (2023), from 166 regencies/cities in Indonesia, it was found that 41% of all waste in Indonesia was food waste. This fact is ironic considering that until 2022, there will still be 70 districts that have a low Food Security Index (IKP) and are very vulnerable to experiencing a food crisis (Badan Pangan Nasional, 2022). Apart from that, there is a risk of a food crisis that Indonesia will have to face in the next 50 years due to climate change accompanied by quite high population growth (Lasminingrat & Efriza, 2020). Therefore, it is appropriate for the government to start drafting special regulations that can reduce the production of food waste in Indonesia.

In fact, there are several laws and regulations that regulate waste in Indonesia, including Law (UU) Number 18 of 2008 concerning waste management, Government Regulation (PP) Number 81 of 2012 concerning the management of household waste and similar waste. household waste, up to PP Number 27 of 2020 concerning specific waste management. However, of the several levels of regulation, the dominant waste management discussed is repressive waste management, there are no regulations that target preventive waste reduction strategies. Furthermore, of these regulations, there are no regulations that directly specifically discuss food waste management. In fact, in PP Number 86 of 2019 concerning food safety,

there is no mention at all about reducing waste as another effort to increase national food safety. (Farahdiba et al., 2023). In fact, food waste is a fertile ground for the formation of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (N_2O) (Galford et al., 2020). These various types of GHG will have a negative impact on the environment, namely damage to the ozone layer which will ultimately trigger global warming.

Of the various types of GHG produced by food waste, methane is the most dangerous compound. This is due to the potential damage to the ozone layer caused by methane which is 21 times more fatal than carbon dioxide (Lutviyani et al., 2022). Since the era of the Industrial Revolution, methane has contributed 30% of the total increase in earth's temperature (International Energy Agency, 2023). In fact, for every kilogram (kg) of food waste, it is estimated that 50 grams of methane gas will be produced (Lutviyani et al., 2022). Based on this value, it can be seen that in a year, each Indonesian will contribute an average of 7.5 kg of methane gas to global warming. In overcoming this phenomenon, *the Tax Foundation* in (Barus & Wijaya, 2022) states that for every methane production, a carbon tax can be imposed considering that methane is one of the carbon emissions that can have a negative impact on the environment. Referring to the explanation of Law Number 7 of 2021 concerning Harmonization of Tax Regulations, the basis for imposing carbon tax in Indonesia is carbon dioxide equivalent (CO_2e), that in each CO_2e also includes methane gas. However, according to Rabe et al.(2020), considering that the impact of methane is much more fatal than carbon dioxide, it is appropriate to separate the implementation of a methane tax from a carbon tax that uses carbon dioxide as the main base.

Parry et al. (2022) in their research stated that one of the countries that has implemented a tax on methane is Norway. Norway's methane tax is $50 per ton CO_2e on emissions resulting from oil and natural gas operators on the Norwegian Continental Shelf. Apart from that, in the United States the Inflation Reduction Act has also been passed, one of which includes the imposition of a methane fee of $50 per tone CO_2e starting in 2026. Neighboring Canada has also committed to reducing oil and gas methane emissions by at least 75% below 2012 levels by 2030 (ECCC, 2021). With many other countries that have implemented taxes on methane, it is fitting that Indonesia is ranked sixth as the largest methane producing country in the world. Parry et al. (2022) should start to consider its implementation. Based on data published by Transparency (2022), the largest methane producing sector in Indonesia is the waste sector with a percentage of 56%. Considering that the composition of waste in Indonesia is dominated by food waste and food waste is the most massive waste produced by each person, it is necessary to research the potential for imposing a methane tax on food waste in Indonesia.

Based on the carbon tax implementation roadmap in Indonesia, potential industries targeted for carbon tax imposition are fuel, power generation, pulp and paper, cement and petrochemical industries (Fitriya, 2022). Current policy does not yet consider imposing a methane-based carbon tax on food waste. This is different from what is done in developed countries where they have made it a priority to be taxed. Indonesia, as one of the largest producers of food waste, will benefit from the imposition of a tax on food waste. Apart from getting additional tax revenue, Indonesia will be able to reduce the impact on environmental damage. Moreover, Indonesia has ratified the Kyoto Protocol in 2004 and the Paris Agreement in 2016 where Indonesia has committed in its NDC (Nationally Determined Contributions) to target a reduction in GHG emissions of 29 percent with its own efforts, and 41 percent with international support (Handayani et al., 2023). By imposing a tax on food waste, it is hoped that it will help achieve Indonesia's NDC.

The implementation of a carbon tax on methane has been carried out in several countries abroad, as in research conducted by Parry et al. (2022) and ECCC (2021), but research on this matter in Indonesia has never been carried out. This research aims to discuss whether there is

potential for implementing a methane-based carbon tax on food waste in Indonesia. This research is expected to provide innovation in terms of research regarding the implementation of methane tax in Indonesia. Apart from that, in the research of Parry et al. (2022) and the article of Fitriya (2022), the sector that is the object of implementing the methane tax is the energy sector, but no one has targeted the waste sector, especially food waste. Carrying out this research will also provide Literary contributions in the form of thought contributions as well as a reference for further research regarding the implementation of methane tax in Indonesia. Furthermore, this research can also provide a practical contribution for the government to consider methane as a new object for taxation and for society it can be used as material for reflection regarding the dangers of food waste. This research is structured using the sequence of introduction, literature review, research methods, discussion and conclusion. In the closing, conclusions, suggestions and limitations of the research will be provided.

LITERATURE REVIEW

Food waste literally refers to two different terms in English, viz food loss and food waste. Food loss refers to waste generated during three series of food supply processes, including production, post-harvest and storage, and processing and packaging. Whereas food waste is defined as waste produced in the last two food supply chains, namely the distribution/marketing and consumption processes (Fajri & Shauki, 2023). Simply put, food loss occurs during the production process before the food is ready to be served to consumers, whereas food waste appears when the product has reached the hands of consumers and is missed in the consumption process. Generally, food is wasted due to consumer concerns about quality standards, aesthetics and even safety due to too much food and drink being cooked, prepared or served, or inappropriate use (Quested & Johnson in (Rahman et al., 2023).

Indonesia is the country that contributes the largest food waste in the Southeast Asia region (United Nations Environment Programme, 2024), that every person in Indonesia will contribute 115-184 kg of household food waste every year (Bappenas, 2021). Food waste has a negative impact on the environment in the form of global warming from GHG emissions that arise along the food supply chain (Bappenas, 2021). These GHG emissions include carbon dioxide, nitrogen oxide, methane and freon.

GHG refers to gasses with the ability to absorb solar radiation in the atmosphere which indirectly results in the earth's surface temperature remaining warm (Rahmadania, 2022). Based on the UN Convention on climate change, there are six types of gas that are categorized as GHG, namely Carbon Dioxide (CO_2), Dinitroxida (N_2O), Methane (CH_4), Sulfur Heksa Fluorida (SF_6) and Perfluorocarbons (PFC_s). GHGs are created because of natural processes and as a result of human activities such as industrial activities, transportation, and waste disposal (Siburian, 2020). However, excessive GHG production will actually cause unusual warming which is called global warming (Rahmadania, 2022). Global warming will have a direct impact on environmental change and endanger the survival of life on earth.

As a type of GHG, methane refers to a simple carbon molecule surrounded by four hydrogen atoms which is a short-lived climate pollutant (short-lived climate pollutant or SLCP). Most methane formation is aided by bacteria that feed on organic material. Compared to natural processes, much more methane gas released into the atmosphere comes from human (anthropogenic) activities, including biomass burning and several other activities originating from the decomposition of organic materials in anaerobic activities. Methane has a negative impact on human health. If a person comes into direct contact with methane gas, it is possible that damage to the respiratory system, prolonged headaches, narrowing of the blood vessels in the lungs, and even death can occur.

Methane also contributes to keeping the earth's temperature warm by locking rays from the sun in the earth's atmosphere, just like other GHGs. However, excessive amounts of methane gas in the atmosphere will also result in global warming. In fact, the IPCC is in Setiawan & Wright (2024) states that methane gas emissions are almost 30 times more powerful in heating the atmosphere than carbon dioxide. Therefore, at the Conference of the Parties 26 United Nations Framework Convention on Climate Change (COP26 UNFCCC), a global commitment to tackle methane was established, the Global Methane Pledge (GMP). This commitment is followed by 111 countries which are responsible for 45% of anthropogenic emissions. Countries that are members of the GMP are committed to reducing national methane gas emissions by 2030 by at least 30% of the 2020 methane emission level. The GMP commitment is carried out until the 2030 period which tends to be short because the significant reduction in methane gas can have a cooling effect on the earth in a short time. relatively short too. Thus, the world globally can achieve average temperature stabilization of 1.5^0 while on the other hand continuing to reduce CO_2 sustainably (International Energy Agency, 2022).

Gruber in Barus & Wijaya (2022) explains that externalities are impacts arising from the actions of one party in the market on other parties outside the market, in the form of either profits or losses. Before these actions have a further impact on the market, the government needs to intervene to correct the various externalities that occur through fiscal policy, both by providing subsidies and imposing taxes (Selvi et al., 2020). The provision of subsidies is related to actors in the market who provide benefits to other parties outside the market, while taxation applies to actors who cause losses to other parties outside the market. The application of taxes to actors who cause externalities is one form of tax's role as a regulator. More specifically, taxes on negative externalities are also known as pigouvian taxes (Selvi et al., 2020)

Pigouvian tax was introduced by Arthur C. Pigou as the application of a levy on each unit of output in an amount proportional to the marginal damage effect caused by the production of output from a polluting source by charging it to the efficient output (Selvi et al., 2020). The implementation of Pigouvian taxes will internalize negative externalities and improve inefficient market outcomes as much as the impact caused by the actions of related actors Tax Foundation (2024).

In relation to food waste, in this case food waste as a producer of methane emissions creates negative externalities for the environment, especially for the earth's atmosphere. Therefore, it is necessary to implement a methane tax in order to internalize the environmental costs that arise from methane emissions that arise from food waste.

A carbon tax is a concrete form of implementing a Pigouvian tax on negative externalities arising from GHG emissions, especially carbon. The implementation of a carbon tax is carried out as a form of commitment from various countries to prevent global warming from getting worse in the hope that this tax will reduce the volume of GHG produced (Lolo et al., 2022). The carbon taxation guide for developing countries published by (United Nations Tax Committee, 2020), mentioned four principles for implementing carbon taxation, which include principles the polluter pays principle, the principle of prevention, precautianory principle, as well as the principle of common but differentiated responsibilities.

In Indonesia, carbon taxation is regulated in Law no. 7 of 2021 concerning Harmonization of Tax Regulations. In this regulation, it is explained that carbon tax is imposed on equivalent carbon dioxide units (CO_2e). Every CO2e represents various types of GHGs, including carbon dioxide, nitrous oxide, and methane. However, to date, the implementation of carbon taxation in Indonesia has not yet been implemented. Initially, the carbon tax would begin to be piloted in Indonesia starting April 2022, but considering uncertainty at the global level, the plan has been postponed until 2025 (Badan Pemeriksa Keuangan, 2022). In fact, according

to Rabe (2021), considering the impacts contained in methane, the government should start considering implementing a methane tax.

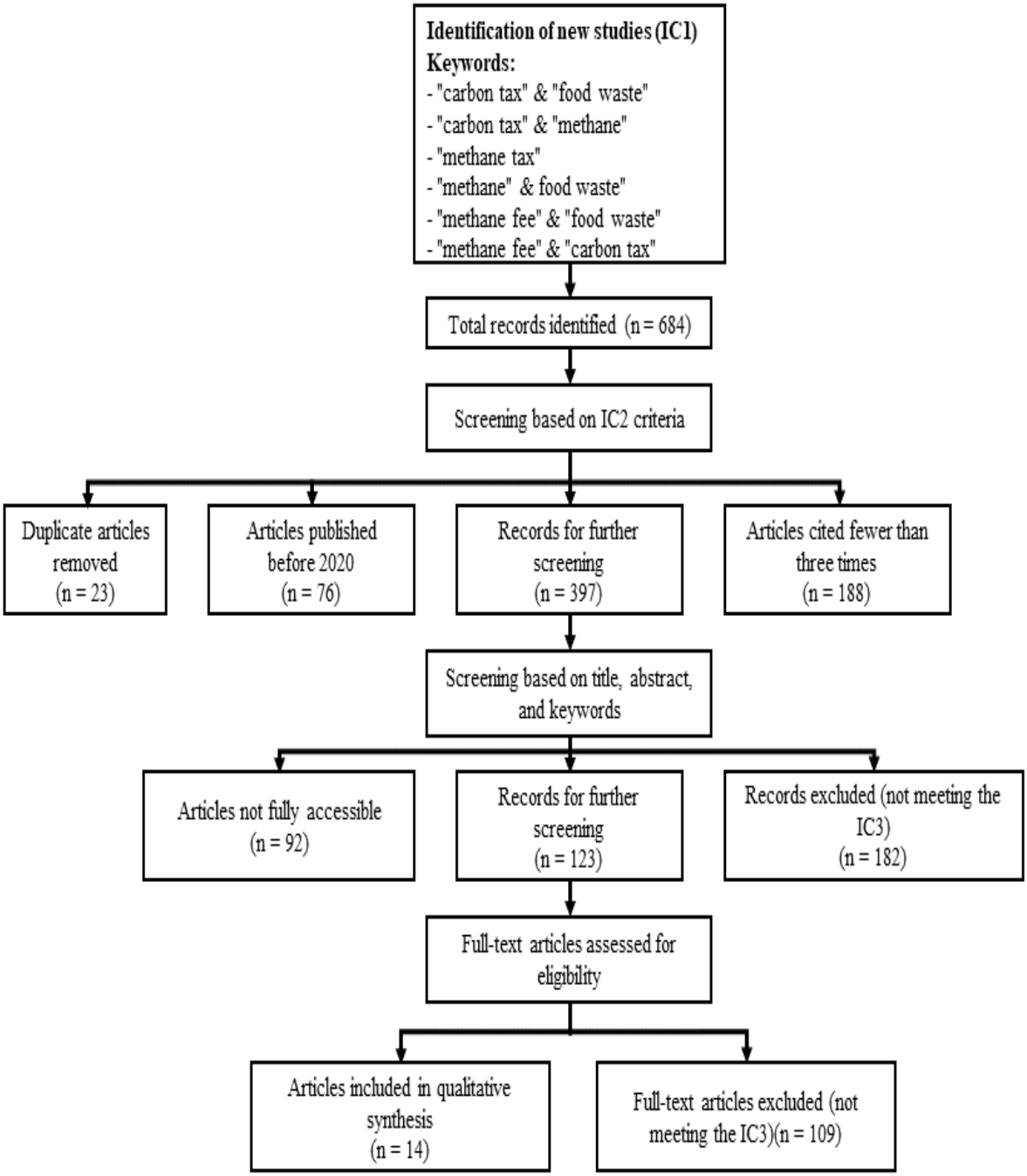
RESEARCH METHODS

This research uses a descriptive method to explain the potential for implementing a methane-based carbon tax on food waste in Indonesia. The approach used is a qualitative approach to build knowledge regarding the potential implementation of a methane-based carbon tax through understanding and discovery. In collecting and analyzing information from journals and articles related to research topics, the method used is systematic literature review (SLR) using techniques preferred reporting items for systematic reviews and meta-analysis (PRISMA).

There are five stages carried out in this research, including defining eligibility criteria, defining information sources, selecting literature, collecting data, and selecting data items. First, defining literature eligibility criteria is carried out through determining inclusion criteria (IC). This research includes three ICs: (1) IC_1: the article is original research that has been reviewed and written in Indonesian or English; (2) I.C_2 the article was published at least in 2020 and has been cited at least three times throughout its publication; and (3) IC_3: the article aims to determine the potential for implementing a methane-based carbon tax on food waste. Second, a literature search was carried out on an online database which has a large repository of academic studies, including searches of reference lists on articles that met the inclusion criteria.

Third, the literature selection stage is further broken down into four sub-stages, namely determining keywords, exploring and selecting titles, abstracts and keywords, reading complete or partial articles that have not been eliminated, and making a list of references from selected articles for review and finding studies. other related. Fourth, data collection was carried out manually by creating a data extraction form containing the author's name, title, year of publication, name of the publisher's journal or conference, country, type and methodology of research, as well as the results of related research. Finally, in selecting data items, there are two types of data that will be obtained, namely article demographics and research conclusions. The article demographics include the distribution of studies related to the application of a methane-based carbon tax on food waste, the countries conducting the studies, as well as the distribution of the types and research methods used, while the research conclusions relate to whether there is potential for implementing a methane-based carbon tax on food waste in Indonesia.

Figure 1. PRISMA Framework



Source: Processed by the Author

Based on the final filtering in Figure 1, the researchers obtained 14 articles in English that discussed the potential for implementing a carbon tax on methane and the potential for implementing a tax on food waste by eliminating articles that were less relevant to this research. In analyzing selected articles, the author identified the research methodology used, the research results related to the research questions, as well as the main limitations of the research in producing research conclusions. Next, all research results are summarized in order to answer the research questions. After carrying out these stages, a comprehensive understanding of the research results can be obtained based on all the articles reviewed. Table 1 shows the list of articles selected for review.

Table 1. List of Articles Selected for Review

No	Researcher, Year	Article Title	Journal Name	Journal Rankings	Country
1	L Chen, G Msigwa, M Yang, AI Osman, S Fawzy, DW Rooney, & PS Yap (2022)	Strategies to Achieve A Carbon Neutral Society: A Review	Environmental Chemistry Letters	Q1	German
2	BK Sovacool, M Bazilian, S Griffiths, J Kim, A Foley, & D Rooney (2021)	Decarbonizing The Food and Beverages Industry: A Critical and Systematic Review of Developments, Sociotechnical Systems and Policy Options	Renewable and Sustainable Energy Review	Q1	English
3	D Nong, P Simshauser, D B Nguyen (2021)	Greenhouse Gas Emissions vs CO2 Emissions: Comparative Analysis of A Global Carbon Tax	Applied Energy	Q1	English
4	GE Metcalf (2021)	Carbon Taxes in Theory and Practice	Annual Review of Resource Economics	Q1	United States of America
5	FM Alkaabneh, J Lee, MI Gómez, HO Gao (2021)	A Systems Approach to Carbon Policy for Fruit Supply Chains: Carbon Tax, Technology Innovation, or Land Sparing?	Science of the Total Environment	Q1	Dutch
6	EG Ryen, CW Babbitt (2022)	The Role of US Policy in Advancing Circular Economy Solutions for Wasted Food	Journal of Cleaner Production	Q1	English
7	F De Menna, J Davis, K Östergren, N Unger, M Loubiere & M Vittuari (2020)	A Combined Framework for The Life Cycle Assessment And Costing of Food Waste Prevention and Valorization:	Agricultural and Food Economics	Q1	English

		An Application to School Canteens			
8	A Rybak, J Joostberens, A Manowska, J Pielot (2022)	The Impact of Environmental Taxes on The Level of Greenhouse Gas Emissions in Poland and Sweden	Energies	Q1	Swiss
9	B Rabe, C Kaliban, I Englehart (2020)	Taxing Flaring and The Politics of State Methane Release Policy	Review of Policy Research	Q1	English
10	A Garvey, JB Norman, A Owen, J Barrett (2021)	Towards Net Zero Nutrition: The Contribution of Demand-Side Change to Mitigating UK Food Emissions	Journal of Cleaner Production	Q1	English
11	IWH Parry, MS Black, DN Minnett, MV Mylonas & N Vernon (2022)	How To Cut Methane Emissions	IMF Occasional Papers	No Q	United States of America
12	M Olczak, A Piebalgs, P Balcombe (2022)	Methane Regulation in The EU: Stakeholder Perspectives on MRV and Emissions Reductions	Environmental Science and Policy	Q1	Dutch
13	J Johannisson, M Hiete (2020)	A Structured Approach for The Mitigation of Natural Methane Emissions— Lessons Learned from Anthropogenic Emissions	Journal of Carbon Research	Q3	Swiss
14	U Singh, M Algren, C Schoeneberger, C Lavallais, MG. O'Connell, D Oke, C Liang, S Das, SD Salas, & JB Dunn (2022)	Technological Avenues and Market Mechanisms to Accelerate Methane and Nitrous Oxide Emissions Reductions	iScience	Q1	United States of America

Source: Processed by the Author

RESULTS AND DISCUSSION

A total of fourteen articles were selected through a screening process as described in the methodology section. Table 1 presents a list of selected article titles, researcher name and year of publication, journal name and country of publication, as well as the ranking of the journal. To answer the research question, an analysis was carried out on each article which included the research method used, the main results/findings, whether the research found that there was a potential for imposing a methane-based carbon tax and/or a potential for imposing a carbon tax on food waste or not, as well as the main limitations of reviewed articles. This information is summarized in Table 2. Further discussion was conducted to answer the research questions thoroughly.

Table 2. Articles Analyzing the Potential for Imposing a Methane-Based and/or Carbon Tax Potential Imposition of a Carbon Tax on Food Waste

Researcher	Research methods	Results and Discussion	Is there a potential for a methane-based carbon tax?	Is there a potential for a carbon tax to be imposed on food waste?	Research Limitations
L Chen, G Msigwa, M Yang, AI Osman, S Fawzy, DW Rooney, & PS Yap (2022)	The qualitative method uses literature study techniques on the implications of COP26 UNFCCC in order to achieve carbon neutrality.	In achieving the goal of carbon neutrality, mitigation and adaptation synergy between countries is needed, including through the implementation of laws that regulate carbon use, use of renewable energy, down to the smallest step, namely changing eating habits to minimize food waste.	Methane emissions actually tend to be focused on being used as alternative renewable energy for carbon-based energy, namely through biomethane.	The conclusion in this research is that the recommended step to reduce food waste is by changing diet, especially in meat consumption, not by implementing a tax on existing food waste.	The results of the research do not explain in detail the regulations needed for a country to achieve carbon neutrality, but only emphasize the analysis of life cycles that can be decarbonized.
BK Sovacool, M Bazilian, S Griffiths, J Kim, A Foley, & D Rooney (2021)	Qualitative method with a sociotechnical approach to develop an ideal model for decarbonizing the food supply sector.	The current food supply system has many negative impacts on the environment, including land degradation, energy and carbon emissions, and food	In this literature, the methane emissions highlighted are methane from the agricultural/livestock sector, so what is emphasized is the use of these methane emissions into biogas	Although it is not explicitly explained, it can be said that there is a potential for a carbon tax on food waste because the literature does not explain in detail the regulatory options	The literature has not discussed policy options and business models that can be implemented in the context of decarbonizing the food supply sector.

		waste. Interventions towards low carbon are needed from the collaboration of financial aspects, business models and policies.	through anaerobic reactors.	that must be implemented.	
D Nong, P Simshauser, & D B Nguyen (2021)	Quantitative method using the CGE model of climate change policy (GTAP-E-PowerS) to assess the impact of including non-CO emissions calculations$_2$ in climate change policy.	Carbon tax calculation model that includes CO emissions$_2$ dan non-CO_2 provides results on the impact of climate change policies that are more accurate and in-depth than calculations using CO emissions$_2$ just.	Yes	-	This research only used the 20 countries that produce the most pollution as samples. It is possible that in countries not studied, different conclusions would be drawn.
GE Metcalf (2021)	Qualitative method through literature study to find out the latest developments in carbon taxation and other policy instruments to reduce GHG emissions.	Carbon taxes are a key element in reducing a country's GHG emissions levels, because the costs of implementing, administering and complying with carbon taxes are much lower than	Yes, it is stated that there must be other regulations related to GHG emissions that cannot be covered using a carbon tax, one of which is methane emissions.	-	Limitations in this literature include not having discussed further the optimal price path for a carbon tax and an effective hybrid carbon tax system.

		other policy alternatives.			
FM Alkaabneh, J Lee, MI Gómez, HO Gao (2021)	Quantitative method using a food supply chain model to determine efficient policies in order to reduce CO emissions$_2$.	Reducing carbon emissions in the food supply chain is more effective through research and development in the field of technology compared to the imposition of a carbon tax.	No	Policies to reduce food waste are focused on agricultural intensification by saving agricultural production land and developing technology.	Researchers only used the apple supply chain in the United States as a model in this research, so it is possible that different conclusions would be produced in other models.
EG Ryen, CW Babbitt (2022)	Systematic analysis of United States state policies to identify the effectiveness of circular food waste management policies.	In overcoming the problem of food waste, the main priority steps are related to the standardization of regulations between states, including through food donations and prohibiting the processing of food waste in landfills.	-	In order to reduce food waste, what is emphasized in this research is through food donations, that if someone makes a donation, they will receive a tax incentive.	The research only focuses on field studies in the states of the United States, so it is possible that the policies in that country are not suitable for implementation in other countries.
F De Menna, J Davis, K Östergren, N Unger, M Loubiere & M Vittuari (2020)	Qualitative methods use life cycle methodology to identify prevention of food waste.	Preventing food waste can be done at all stages of the food supply chain.	-	Yes, a food waste carbon tax could be implied through the imposition of a surcharge for the disposal of food	The approach used in the research is a combination of LCA and LCC.

				waste, calculated based on CO_2e food on the carbon emissions trading system.	
A Rybak, J Joostberens, A Manowska, J Pielot (2022)	The quantitative method uses the ARMAX model to determine the impact of environmental taxation on GHG emission levels in the European Union.	The impacts resulting from the imposition of a carbon tax vary in each country. An increase in the level of carbon tax is not accompanied by a decrease in carbon emissions.	Yes, imposing a tax on methane separately from a tax on carbon dioxide will have a significant impact on countries that focus on the agricultural and mining sectors.	-	The research results only reflect policies in the European Union, not global carbon tax policies throughout the world.
B Rabe, C Kaliban, I Englehart (2020)	A qualitative model to determine the implementation of taxes on methane in the United States and its states.	There is no central regulation from the United States federal government regarding the imposition of taxes on methane releases, so the practice of taxing methane can only be found in a few states.	Yes	-	The research is only focused on the United States and its states, so it cannot necessarily be applied to other countries.
A Garvey, JB Norman, A Owen, J Barrett (2021)	Quantitative methods for identifying food waste reduction measures in the UK.	In tackling food waste while achieving the UK's goal of zero emissions by 2050, the most crucial step	-	A potential food tax would be imposed on meat consumption, not on food waste resulting from consumption.	The research base was conducted in England, so it is possible that the research results and conclusions may not

		is to change consumer demand.			be relevant for use in other countries.
IWH Parry, MS Black, DN Minnett, MV Mylonas & N Vernon (2022)	Quantitative method for assessing methane emission mitigation policies in relation to preventing global warming.	Reducing methane emissions is important in order to stabilize the global climate, including through setting prices for methane gas, or creating regulations and providing subsidies.	Yes	-	Research is based only on practical policy issues that are the subject of discussion at the IMF.
M Olczak, A Piebalgs, P Balcombe (2022)	Qualitative method through interviews with 59 professionals to determine the effectiveness of MRV implementation (*Measurement, Reporting, and Verification*) methane emissions in the oil and gas sector.	Several companies still experience difficulties in implementing MRV for methane emissions due to differences in knowledge and the very rapid development of methane measurement technology.	No, currently a tax on methane in the European Union cannot be implemented given the EU commission's policy.	-	The research only focuses on the implementation of the MRV system for methane emissions in the oil and gas sector in the European Union and interviews were conducted with parties who are active in the decision-making process in companies, so the research does not represent global conditions.
J Johannisson, M Hiete (2020)	Quantitative methods to identify the absence of	To reduce methane emissions, this can be done through the	Yes	-	This research has not discussed further regarding optimizing

	mitigation, approaches, methods and solutions to overcome methane problems.	imposition of a carbon tax and the provision of incentives and subsidies for climate mitigation services.			the use of technology to reduce methane emissions or details of policies related to the imposition of a carbon tax on methane.
U Singh, M Algren, C Schoeneberger, C Lavallais, MG. O'Connell, D Oke, C Liang, S Das, SD Salas, & JB Dunn (2022)	Quantitative method to determine effective mitigation measures to reduce the production of methane and nitrogen oxide emissions.	Strategies to reduce methane emissions include the introduction of incentives through inclusion in the carbon market and the use of technology to reduce methane emissions.	Yes	-	The accuracy of the data used in the research is still questionable, and the proposed mitigation trends are mitigation for the United States and globally, so they may not necessarily be applicable in certain countries.

Source: Processed by the Author

Is there a potential for a methane-based carbon tax?

Based on the article review that has been carried out, there are two approaches to answering this question. First, if it is looked at preventively before methane emissions have a wider impact on the atmosphere, then Chen et al. (2022), Sovacool et al. (2021), and Alkaabneh et al. (2021) agree that a carbon tax on methane should not be implemented, but that there are other policies that can be implemented. Methane can be used as an alternative renewable energy source as a replacement for carbon energy sources through processing in anaerobic reactors to produce biogas or biomethane. By using the help of technology, the carbon and hydrogen elements in methane can also be broken down so that the hydrogen can also be used as another alternative energy source. Meanwhile, according to Nong et al. (2021), Metcalf (2021), Rybak et al. (2022), Rabe et al. (2020), Parry et al. (2022), Johannisson & Hiete (2020), and Singh et al. 2022), a methane-based carbon tax is feasible to implement. This is because the existing carbon tax cannot cover other types of GHGs, including methane emissions (Metcalf, 2021). In addition, imposing a tax on methane separately from a carbon dioxide-based carbon tax will have a significant effect on reducing methane emissions, especially in countries that focus on the agricultural and mining sectors. However, even though there is a possibility of implementing a methane-based carbon tax, in fact calculating methane requires cutting-edge technology accompanied by developments in the knowledge of actors in related fields (Olczak et al., 2022). In research conducted by Olczak et al. (2022) also found that unsupportive regulations are also one of the obstacles to implementing a methane-based carbon tax.

Is there a potential for a carbon tax to be imposed on food waste?

In overcoming the problem of food waste, based on the articles that have been reviewed, the results show that imposing a carbon tax on food waste is not yet the main option. De Menna et al. (2020) which states that a carbon tax can be imposed by charging additional fees for the disposal of food waste based on each carbon dioxide equivalent produced, using rates that are equivalent to the rates found in the carbon emissions trading system. Sovacool et al. (2021) in their research stated that in minimizing carbon in the food supply sector, intervention is needed, one of which is through policy aspects. This statement indicates implicitly that the imposition of a carbon tax on food waste can also be implemented in order to minimize carbon emissions from food waste. Chen et al. (2022) and Garvey et al. (2021) do not agree with the imposition of a carbon tax on food waste, but according to them, a carbon tax should be applied to the consumption of food that produces carbon emissions, for example meat. In a different perspective, Ryen & Babbitt (2022) instead proposes a system for donating excess food in order to reduce food waste, so that every person who makes a donation will actually get a tax incentive. Lastly, according to Alkaabneh et al. (2021), handling food waste should be carried out from the first food supply chain, namely the production process, so that in providing food, it is best to intensify agriculture by saving land and developing technology.

What is the potential for implementing a methane-based carbon tax on food waste in Indonesia?

Considering that until now Indonesia has not implemented a carbon tax, it is necessary to consider the benefits and things that need to be prepared to be able to implement the carbon tax. Based on the articles that have been reviewed, there has been no research that discusses the implementation of a methane-based carbon tax or a carbon tax on food waste in the Southeast Asia region, especially Indonesia. However, even though there are no national level regulations governing the imposition of taxes on carbon and/or methane, stakeholders at the central and regional levels can still make their own regulations regarding this matter (Brown et al., 2024). Therefore, the Government must be able to prepare regulations or policies to implement a methane-based carbon tax and on food waste. This is in accordance with the statement Olczak

et al. (2022) which states that regulations are needed so that the implementation of a carbon tax on food waste-based methane can be implemented.

The benefits of implementing a carbon tax on methane are enormous in reducing carbon emission levels. De Menna et al. (2020) stated that to reduce food waste, additional costs need to be imposed through a carbon tax. The tariffs used in charging additional costs can be equated with the tariffs in the carbon emissions trading system. Then, research by Sovacool et al. (2021) supports the research of De Menna et al. (2020) which states that intervention is needed, one of which is through aspects of tax policy on the food waste produced. From several previous research results, the potential for implementing a methane-based carbon tax on food waste has the potential to be implemented but needs to be supported by appropriate regulations.

Another form of implementing a carbon tax to reduce the impact of food waste can be done on food consumption, not on the food waste produced. This is also in accordance with research by Chen et al. (2022) and Garvey et al. (2021). The implementation of taxes on food consumption is expected to provide awareness for people to consume food according to their needs so that it will reduce the impact of food waste. This may also be implemented in Indonesia if supported by existing regulations. The government can choose to impose a carbon tax on food at the time of food consumption or on remaining food waste. The government needs to conduct an in-depth study of these options and the potential and preparations that need to be made to implement the carbon tax.

Apart from using the implementation of a carbon tax, to reduce food waste, other strategies can be applied to process this waste into renewable energy using existing technology (Venkatesan et al., 2020) (Jiménez-Ocampo et al., 2021). Then, if methane emissions are quite high, stakeholders, for example agricultural or mining business owners, can break down methane atoms into carbon and hydrogen, so that the hydrogen produced can also be an alternative energy source (Kiani et al., 2021) (Pörzse et al., 2021) (Carrera & Azzaro-Pantel, 2021) (Bukkholm et al., 2021).

CLOSING

Summary

Human food needs continue to increase over time. However, ironically, a third of the food produced is wasted as waste. This is not only detrimental economically, but also has serious impacts on the environment. Food waste produces greenhouse gases (GHG) such as methane, which contributes to global warming and climate change. Indonesia, as one of the countries that contributes the largest food waste in Southeast Asia, needs to take concrete steps to overcome this problem.

One solution offered is through the implementation of a methane-based carbon tax on food waste. Although the research results show that there is potential for implementing a tax on methane, this solution cannot yet be implemented directly in Indonesia because carbon tax regulations are not yet in place.

Therefore, a more comprehensive and humane approach is needed to overcome the food waste problem in Indonesia. Finding environmentally friendly and humane solutions requires commitment and cooperation from all parties. With the right education, creative solutions and solid cooperation, Indonesian people can build a future that is more sustainable and responsible for the earth.

Research Limitations

In this research, the limitation experienced by the researcher is that the researcher only uses articles that are open access, so it is possible that there are other articles that are more relevant to study regarding the research topic if the researcher has access to all journals that are strictly accessible. Researchers also have not compared in detail the ideal practice of

implementing a carbon tax on methane in other countries with existing regulations in Indonesia. The author did not conduct an analysis of the Government's readiness to implement a methane-based carbon tax on food waste.

Suggestion

For the sake of improving future research, it would be good if future researchers could use journals with wider databases or only limit them to journals indexed by Scopus. Then, further research can also be carried out by quantifying the potential tax revenue that the Indonesian government will receive if it implements a methane-based carbon tax on food waste considering the large amount of food waste produced in Indonesia.

Then, in overcoming the problem of food waste in Indonesia, the government can start to mobilize appropriate technology to process waste into biogas or biomethane. Education is also important to make people aware of the dangers of food waste and the importance of good food management. Apart from that, to overcome the high level of production of methane emissions in Indonesia, the government must also start educating especially large companies in the agricultural and mining sectors to break down the methane molecules produced by their industry into hydrogen for alternative energy sources.

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