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Estimating Greenhouse Gas Emissions from a Seafood Processing Facility

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ABSTRACT

At the end of COP26, Vietnam has developed many institutions and policies to fulfill its commitment to bring net emissions to "zero" by 2050 and reduce methane (CH_4) to at least 30% below the 2020 levels by 2030. In order to gradually achieve the above goal, an inventory of facilities with greenhouse gas emissions plays a very important role. This study was conducted to estimate the greenhouse gas emissions at a seafood export processing factory. The study was carried out based on the method of collecting data from different emission sources and calculating emissions based on the activity data and emission factors from reliable sources. The research results show that, during the study period from March 2022 to March 2023, the total emissions at the facility were 19,144.14 tons of CO_2eq, of which the indirect emissions from waste and electricity accounted for the high rate of about 60.37% and 36.55% of the total CO_2eq, respectively. Research results also show that CO_2 is the most emitted gas into the environment and is present in most of the waste sources, in which electricity consumption and CO_2 emissions are the most significant, indirectly emitting 7,102.85 tons of CO_2/year (accounting for 98.51% of total waste sources). For daily waste, landfilling indirectly releases into the atmosphere an amount of methane (CH_4) approximately 410 tons/year, accounting for more than 95% of the total emissions. In addition, in the process of using fuel (gasoline and DO) at the facility, a large amount of N_2O gas enters the atmosphere (nearly 70% of emissions from DO and 30% from gasoline). Reduction of greenhouse gas emissions at the facility could be achieved by saving water, reducing wastewater and using clean energy.

Keywords: CO_2eq, fuel, emission, energy, seafood.

INTRODUCTION

Greenhouse gas (GHG) emissions are the main factor causing climate change (Hardy, 2003). In the context of complex developments of climate change, its volume and strong impact on a global scale, therefore at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26 – Conference of the Parties) countries around the world have made strong commitments to address issues related to climate change. Accordingly, Vietnam has participated and committed to many important issues, typically bringing net emissions to "zero" by 2050, using domestic resources, along with support and cooperation of the international financial and technological community and commits to reducing global methane (CH_4) emissions by at least 30% below 2020 levels by 2030. To perfect institutions, policies and strategies related to climate change with global trends is an urgent requirement. In the 2014 Law on Environmental Protection (Environmental Protection), Vietnam has stipulated climate change response in chapter IV with 11 articles (The National Assembly, 2014), however, in the 2020 Law, Vietnam has more clearly stipulated the response to climate change in Chapter VII with 6 articles (The National Assembly, 2020). As soon as the Law on Environmental Protection took effect, the Government issued Decree No. 06/2022/ND-CP on mitigating greenhouse gas emissions and protecting the ozone layer (GOV, 2022a) and Decree 08/2022 /ND-CP regulates in detail a number of articles of the Law on Environmental Protection (GOV, 2022b). In addition, the Ministry of Natural Resources and Environment (MONRE) has also issued Circular No. 01/2022/TT/BTNMT detailing the implementation implement a number of articles of the Law on Environmental Protection on responding to climate change (MONRE, 2022a).

On the other hand, to concretize the implementation of commitments at COP26, the Prime Minister approved the National Strategy on Climate Change for the period up to 2050 in Decision No. 896/QD-TTg (Prime Minister, 2022a), stating a specific target for reducing GHG emissions by reducing CO_2 equivalent (CO_2eq) – the GWP value used to convert different GHG amounts to a common unit – for sectors energy, agriculture, forestry – land use, waste, industrial processes and GHG emitting facilities. In addition, the decision also mentions the implementation of GHG inventory and GHG emission reduction for the facilities that emit annual emissions, specifically 2,000 tons of CO_2eq or more from 2030; 500 tons of CO_2eq or more from 2040; 200 tons of CO_2eq or more from 2050 (Prime Minister, 2022b). All public sector establishments must conduct GHG inventory and reduce GHG emissions. At the same time, the Prime Minister issued Decision No. 01/2022/QD-TTg on Promulgating a list of GHG-emitting sectors and facilities that must conduct GHG inventories for six sectors, including: Energy; Transportation; build; industrial processes; agriculture, forestry and land use and waste and facilities belonging to four industry groups, including: Industry and Trade, transportation, construction and natural resources and environment (Prime Minister, 2022c).

Emission inventories have become fundamental tools for air quality management. Emission estimates are important for developing emission control strategies, determining the applicability of permitting and control programs, determining source impacts, and appropriate mitigation strategies (Arrioli et al., 2020; Kongboon and Sampattagul, 2022). Although GHG inventory is an important basis for implementing GHG emission mitigation policies, the available data on GHG emission sources are still very limited (Eduardo et al., 2020), especially in developing countries. In Vietnam, studies mainly estimate GHG emissions from household scale (Diep et al., 2022), traffic (Trung et al., 2021), construction (Mai et al., 2021), and some agricultural production fields, such as pig farming (Thuan et al. 2017), rice farming (Huan et al. 2020), vegetable farming (Phuoc and Liem, 2023), etc. Meanwhile, a field with a large amount of waste generated such as the seafood processing industry is ignored. The waste from the seafood processing includes wastewater and solid waste that are characterized by organic pollution. In particular, anaerobic decomposition of organic waste releases large amounts of carbon dioxide, methane, ammonia, hydrogen sulfide as well as unpleasant odors (Venugopal and Sasidharan, 2017). During the entire processing, a large amount of water and electricity was supplied (Gokoglu and Yerlikaya, 2015; Venugopal and Sasidharan, 2017). Heat treatment stages are also considered a major cause of air pollution (Venugopal and Sasidharan, 2017). With a production scale that not only provides products for the domestic market but also exports to many countries around the world; it is forecast that there will be a huge amount of waste generated into the environment (Tseng et al., 2022). Therefore, this study was conducted to identify sources and estimate the greenhouse gas emissions for seafood processing facilities in Vietnam. The results of the study can not only support decision-making on solutions to mitigate greenhouse gas emissions at research facilities, but also help bridge the gaps in current research in Vietnam.

MATERIALS AND METHODS

The research was conducted at a seafood processing company in the An Giang province during the period from March 2022 to March 2023. Within the scope of the research, the study calculated GHG emissions according to the instructions of the IPCC 2006 version, improved in 2019 according to Eq. 1:

$$E_{Fa} = E_f + E_{fug} + E_{\mathrm{p}} + E_W + E_{other\,1} + E_{other\,m} \quad (1)$$

where: E_{Fa} – total emissions of the facility; E_f – total emissions from energy consumption sources; E_{fug} – total emissions relative to other inputs; E_p – total emissions during production; $E_{other\,l}$, $E_{other\,m}$ – total emissions from other sources (wastewater, used materials, etc.)

The method for estimating GHG emissions is based on two main sources, including direct and indirect emissions. The emission (*E*) calculation method is carried out according to the general formula of *ABC EIM* (Atmospheric Cloud Browns Emission Inventory Manual) (Shrestha et al., 2013), which is the product of activity data (A) and emission factor (EF),

$$E = A \times EF \quad (2)$$

where: *A* – activity metrics are quantitative measures of a level of activity that causes GHG emissions and removals occurring over a specified period of time; *EF* – Emission coefficient is a unit of measurement of GHG emissions and absorption compared to a unit of activity.

Calculated emission sources have different units so they are converted to CO_2 equivalent units (CO_2eq). The annual emissions of GHGs converted to global warming potential (GWP – Global Warming Potential) values are shown in detail in Table 1. The larger the GWP, the more that gas warms the Earth compared to CO_2 in the same amount of time. The time period used for GWP is typically 100 years. Within the scope of the research, the project will calculate emissions for three types of gases: CO_2, CH_4, N_2O according to GWP in the IPCC 2015 assessment report (AR5).

Sources of GHG emission

Power consumption

Every year, the Department of Climate Change – Ministry of Natural Resources and Environment announces the CO_2 emission coefficient of Vietnam's power grid. The emission coefficient of Vietnam's power grid is presented in Table 2. Therefore, the business electrical energy consumption will be calculated according to the CO_2 emission coefficient of Vietnam's power grid in 2021 of 0.7221 tCO_2/MWh.

Fuel consumption

In order to implement the regulations related to GHG inventory, as prescribed in the Law on Environmental Protection 2020 as well as the Government's commitment to net zero emissions by 2050 at COP26, the Ministry of Natural Resources and Environment has announced Emission coefficient announcement for GHG inventory (MONRE, 2022c). The GHG emission factors from fuel consumption are presented in Table 3.

Table 1. Global warming potential of greenhouse gases in IPCC assessment reports

Chemical	Formula	GWP value			
		2nd report (*a)	3rd report (*b)	4th report (*c)	5th report (*d)
Carbon dioxide	CO_2	1	1	1	1
Methane	CH_4	21	23	25	28
Nitrous oxide	N_2O	310	296	298	265
Sulfur hexafluoride	SF_6	23.900	22.200	22.800	23.500
Carbon tetrafluoride	CF_4	6.500	5.700	7.390	6.630
Hexafluoroethane	C_2F_6	9.200	11.900	12.200	11.100
HFC-23	CHF_3	11.700	12.000	14.800	12.400
HFC32	CH_2F_2	650	550	675	677
HFC-41	CH_3F	150	97	92	116
HFC-125	C_2HF_5	2.800	3.400	3.500	3.170
HFC-134	$C_2H_2F_4$	1.000	1.100	1.100	1.120
HFC-134a	CH_2FCF_3	1.300	1.300	14.300	1.300
HFC-143	$C_2H_3F_3$	300	330	353	328
HFC-143a	$C_2H_3F_3$	3.800	4.300	4.470	4.800
HFC-152a	$C_2H_4F_2$	140	120	124	138
HFC-227ea	C_3HF_7	2.900	3.500	3.220	3.350
HFC-236fa	$C_3H_2F_6$	6.300	9.400	9.810	8.060
HFC-245ca	$C_3H_3F_5$	560	950	1.030	716
Nitrogen trifluoride	NF_3	-	-	17.200	16.100

Note: Sources: *a IPCC (1995), *b IPCC (2001), *c IPCC (2007), *d IPCC (2015).

Table 2. CO2 emission coefficient of Vietnam's power grid

Year	2014	2015	2016	2017	2018	2019	2020	2021
EF (tCO_2/MWh)	0.6612	0.8154	0.9185	0.8649	0.9130	0.8458	0.8041	0.7221

Note: Source – MONRE, 2022b.

Table 3. Greenhouse gas emission coefficient from emission source

Emission source	CO_2	CH_4	N_2O
Gasoline (kg/TJ)	69,300	10	0.6
DO oil (kg/TJ)	74,100	10	0.6

Note: Source: MONRE, 2022c.

Domestic solid waste

The waste in the study area is collected and treated by landfilling. In this case, waste is listed as an indirect emission type, because the waste treatment location is located outside the scope of the research topic. The emission coefficient from household waste is 1.453 for CO_2 and 6.50 for CH_4 (ABC EIM, 2013).

Hazardous waste

$$\text{Amount of } ACO_2 \text{ from hazardous waste} = A_{hazardous\ waste} \times B_{hazardous\ waste} \quad (3)$$

where: $A_{hazardous\ waste}$ – volume of hazardous waste generated at the facility to be collected, transported and treated; $B_{hazardous\ waste}$ – CO_2 emission coefficient when sending hazardous waste for treatment ton of CO_2/ton, has a value of 0.034, determined on the basis of Bilan Carbone. In this case, hazardous waste is listed as an indirect emission type because the waste treatment site is located in an area outside the facility.

CH_4 emissions from industrial wastewater treatment

$$CH_4 = \Sigma i\ [(TOW_i - S_i)\ x\ EF_i - R_i]\ x\ 10^{-3} \quad (4)$$

where: total CH_4 emissions (tons/year), TOW_i – total organic content in wastewater (kg COD/year), S_i – organic components removed as sludge (kg COD/year), EF_i – Emission coefficient (kg CH_4/kg COD), R_i – amount of CH_4 recovered (kg CH_4/year).

During the research period, the facility did not have a sludge treatment plan or a CH_4 recovery plan, so S_i and R_i could not be collected, so $S_i = 0$, $R_i = 0$, and $i = 1$ because there is only one industrial sector which is seafood processing. While TOWi value is determined according to Eq. 5 as follows:

$$TOW_i = P_i\ x\ W_i\ x\ COD_t \quad (5)$$

where: P_i – total industrial product for industry i (tons/year). In this study, P_i value = 7,965 tons of product/year (average daily production output is 45 tons/day, during the production facility research period of 177 days), W_i – wastewater generated (m^3/ton of product). According to the results collected from the facility, the amount of wastewater generated is about 8.87 m^3/ton of product. COD_i – chemical oxygen demand (for the amount of decomposable organic waste in industrial wastewater i) (kg COD/m^3).

According to Ngan et al. (2023), the input COD in seafood processing wastewater is 1,645.4 mg/L and according to the results of output analysis at the facility wastewater treatment system, the concentration is 1,645.4 mg/L. COD is only 30 mg/L. Therefore, the amount of COD that can be decomposed in wastewater is 1,6154 kg COD/m^3. Thus TOW_i = 7,965 × 8.87 × 1,615.4 = 114,127.28 kg COD/year. The value of *EFj* is determined according to Eq. 6 as follows:

$$EF_j = B_0\ x\ MCF_j \quad (6)$$

where: B_0 – the maximum amount of CH_4j gas generated, kg CH_4/kg BOD. The default value according to the provisions of the 2006 IPCC Guidelines is Bo = 0.6 kgCH_4/kg BOD, MCF_j – the correction factor for methane gas emissions according to each treatment method. The facility wastewater is treated by a system so the CH_4 emission adjustment factor is 0.3.

RESULTS AND DISCUSSION

Sources of greenhouse gas emissions at seafood processing factory

Direct emission

The results show that for direct emission sources, DO oil is the fuel consumed the most. DO oil is used to serve vehicles transporting raw materials from the port to the facility and to run backup generators. DO oil consumption ranges from 240–370 liters/month. During the research period, fuel consumption was estimated at nearly 3,500 liters/year. Gasoline is used to a lesser extent, for tree clearing activities around the facility and for transportation of the Company's leadership, ranging from 100-180 liters/month. Direct emissions also arise from the movement of employees: According to research results, at the facility every day there are about 600 motorbikes of employees commuting to the facility. Working hours are from Monday to Friday, the average distance from residence to work is 15 km/trip.

Indirect emission

Indirect emission is an emission from a source generated during the process of consuming energy from electricity. The electricity industry deals with the production, transmission and distribution of electricity. CO_2 makes up the majority of greenhouse gas emissions from the sector, but smaller amounts of CH_4 and nitrous oxide N_2O are also emitted. These gases are released during the burning of fossil fuels, such as coal, oil and natural gas to produce electricity. Less than 1% of GHG emissions from this sector come from sulfur hexafluoride (SF6), an insulating chemical used in electrical transmission and distribution equipment. For indirect emission sources, electricity is used in lighting activities, operating machinery and production equipment, as well as machinery and equipment of underground water treatment systems and wastewater treatment systems. Although electricity consumption is an indirect source of emissions, the risk of GHG emissions is very significant with a consumption of nearly 9.7 million kWh/year.

During the study period, the total production days at the facility were 177 days. The results show that in March 2022 the production facility has the largest power consumption for 23 days with a consumption of more than 1 million kWh, January 2023 has the lowest power consumption with more than 570,000 kWh in 08 days. Non-production days, the facility consumes electricity for office operations, product storage in cold storage, and other activities.

Emissions due to waste

Domestic solid waste arising from the daily activities of staff and employees working at the facility are mainly biological, easily degradable ingredients such as leftover food, bottles, food packaging, plastic bottles, etc. Actual generation is about 175 kg/day, equivalent to about 5,250 kg/month. Domestic solid waste from workers is collected in six 120-liter containers with lids located on the premises of the facility. At the end of the day, the factory sanitation workers collect, then gather in front of the company gate to let the Urban Environmental Enterprise waste collection vehicle collect, transport and treat according to regulations with collection frequency is 1 time/day.

Solid waste from the production process is mainly processing waste such as fish heads, internal organs, skin, etc., generating about 748.5 tons/month and actual packaging of about 1.4 tons/month. Waste during the processing process is conveyed by conveyor belt to the outside, then dumped directly onto the vehicle of the collection unit. Packaging of all types is collected and stored at scrap gathering places with the collection frequency every 2 weeks.

The sludge from the 03-compartment septic tank for preliminary treatment of domestic wastewater before collection into the wastewater treatment system fluctuates at 6.1 kg/day and night, equivalent to 183 kg/month. Sewage sludge is hired by the facility owner to vacuum up and take away for treatment according to regulations with a collection frequency of every 6 months. In addition, sludge is also generated at the facility from the wastewater treatment system. Currently, there is no sludge collection and treatment unit in the province; thus, the amount of sludge generated is stored in sludge compression tanks. In the near future, the company will contact functional units to collect and process in accordance with regulations.

The hazardous waste generated from the production and maintenance of machinery, equipment, and wastewater treatment systems is mainly LED light bulbs, batteries, waste accumulators, waste oils, chemicals, and waste. The laboratory chemical mixture with the actual volume generated is about 21.8 kg/month, equivalent to 262 kg/year. Hazardous waste is classified in accordance with the provisions of Circular No. 02/2022/TT-BT-NMT. Hazardous waste is stored in two 60-liter barrels, then stored at the facility hazardous waste warehouse. Currently, the facility owner has contracted with a fully functional unit to periodically collect, transport and process in accordance with regulations with a frequency of 2 times/year.

Wastewater treatment: During the research period, the following wastewater sources were generated at the facility: (i) Domestic wastewater: Generated from the process of going to the toilet and cleaning hands and feet after each shift of workers, officers and employees. Domestic wastewater contains polluting organic components such as: BOD, COD, TSS, Coliform and pathogenic microorganisms that generate about 24.4 m^3/day and night. Domestic wastewater is collected and preliminarily treated by a 3-compartment septic tank, applying biological treatment technology with automatic continuous operation 24 hours/day and night. The technology does not use chemicals or biological products and does not consume electricity; (ii) Wastewater from the cafeteria: At the facility, no food processing activities take place, wastewater mainly arises from washing vegetables and fruits, cleaning cups and bowls. The main components of this wastewater source are suspended solids and detergents. The amount of wastewater generated is relatively small, actually generating about 1 m^3/day and night; (iii) Wastewater generated from cleaning water supply tanks. It is cleaned once a day. The amount of wastewater generated is about 2 m^3/time of cleaning; (iv) Production wastewater: Generated from seafood processing activities and factory cleaning and this wastewater source contains many components such as COD, BOD, SS, oil and grease, NH_4^+,... generated flow ranges from 400–450 m^3/day and night. All wastewater sources, after preliminary treatment, are collected into the facility wastewater treatment system with a capacity of 600 m^3/day and night for treatment. The treated wastewater meets QCVN 11-MT:2015/BTNMT (column A, K_q= 0.9, K_f= 1) – national technical regulation on seafood processing industrial wastewater before draining into the sewer in industrial cluster water and drain into canals.

Chemicals

Through research, the chemicals used at the facility during operations included chlorine used as a disinfectant chemical in the wastewater treatment system with a usage amount of about 300 kg/year, PAC (Poly aluminum chloride) is used as a flocculating chemical in wastewater treatment systems about 11,450 kg/year. In addition, during the research process, the amount of refrigerant Ammonia NH_3 (R717) used in the factory refrigeration system was recorded. Ammonia is a colorless, pungent, liquid gas that boils at atmospheric pressure at -33.35°C. Ammonia is widely used in industry, but is not used in turbine compressors because of its low-pressure ratio.

Greenhouse gas emission load at seafood processing factories

Direct emission

In the period from March 2022 to March 2023, the facility will consume nearly 5,300 liters of gasoline, resulting in a total emission of 14.11 tons of CO_2eq. The results show that the use of gasoline to move and transport production materials of the facility has a great impact on GHG emissions, especially CO_2 emissions (Table 4). For wastewater treatment at the facility, the lowest amount of wastewater treated per day during the study period was 307 m^3/day and the highest was 491 m^3/day. This source emits a very large amount of CH_4, accounting for 20.54 tons/year and has an impact on the facility GHG emissions.

It is estimated that the highest proportion of CO_2 emissions (99.4%) comes from the use of gasoline and DO oil, while the total CH_4 and N_2O gases only account for about 0.6% of emissions to the environment. Among this direct emission source, wastewater is the source that generates the most total CO_2eq. The calculation results show that the facility needs to pay more attention to CH_4 gas recovery to reduce the GHG emissions. The recovery of CH_4 in wastewater has great value both environmentally and economically, so it is necessary to promote the implementation of research on technical and technological solutions to recover and convert the CH_4 gas into useful energy, which helps protect the environment and brings economic benefits.

Indirect emission

Regarding indirect emissions, waste including household waste and hazardous waste has the highest total emission of 11,557.55 tons CO_2eq, followed by emissions from electricity

Table 4. Emissions from direct sources

Sources of emission	Greenhouse gas emissions (tons/year)			Total CO_2eq (tons/year)
	CO_2	CH_4	N_2O	
Gasoline	4.05	0.00	0.00	4.08
DO	9.97	0.00	0.00	10.03
Wastewater	-	20.54	-	575.20

Notes: Calculation sources have different units so they should be converted to a common unit of CO_2 equivalent (CO_2eq). According to IPCC (2013), emissions of CH_4 and N_2O are converted to global warming potential (GWP) values. Conversion coefficient 1CO_2 = 1 CO_2eq; 1CH_4 = 28 CO_2eq; 1CO_2 = 265 CO_2eq.

consumption, from March 2022 to March 2023, the facility has consumed a total of 9,690.18 MW of electricity, indirectly emitting 6,997.28 tons of CO_2eq (Table 5).

The use of electricity is an essential need of the facility. However, in reality, electricity consumption in 2023 has decreased significantly compared to 2021 and 2022 due to difficulties in exporting products to market countries. Through research, the amount of the GHG emissions from direct emission sources of the facility accounts for a lower proportion than indirect emission sources, but the emission of dust, SO_2, CO, NO_x and VOCs from direct sources is one of the causes of air pollution. These gases cause direct harm to human health, the economy and the environment and cause global environmental problems.

During the study period, the total GHG emissions at the seafood processing facility was 19,144.14 tons CO_2eq, including direct emissions and indirect emissions. The emissions at the facility are mainly from indirect sources, depending greatly on the production volume of the facility. The results in Figure 1 show that waste accounts for the highest proportion of emissions, accounting for 60.37% of the total CO_2 output, followed by emissions due to electricity consumption, accounting for 36.55%, and the lowest are direct emissions sources from gasoline and DO oil accounts for about 0.02–0.05%.

The results of analyzing GHG emissions from waste sources (direct and indirect) in Figure 2 shows that CO_2 is the most emitted into the environment and is present in most waste sources. In particular, electricity consumption generates the most significant CO_2 emissions, indirectly emitting 7,102.85 tons of CO_2/year (accounting for 98.51% of total waste sources). Regarding the amount of daily waste, treatment by incineration is effective, but the waste indirectly releases into the air an amount of methane gas (CH_4) of approximately 410 tons/year, accounting for more than 95% of the total components causing emissions. In addition, during the process of using fuel, at the facility, a large amount of N_2O gas is released into the air environment (nearly 70% of emissions are from DO and 30% from gasoline).

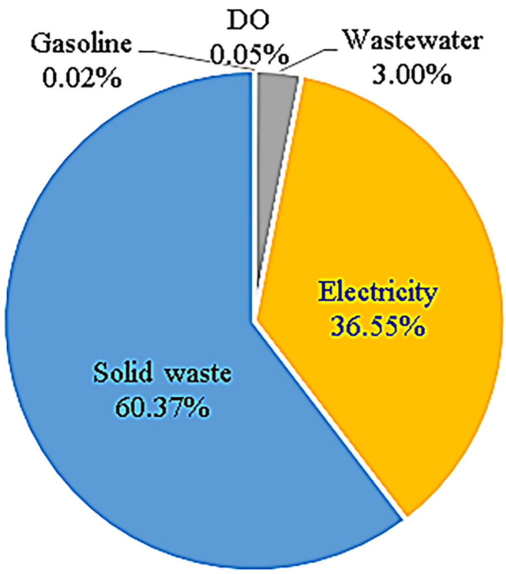

Figure 1. CO_2 emission rate across emission sources

Table 5. Emissions from indirect sources

Sources	Greenhouse gas emissions (tons/year)			Total CO_2eq (tons/year)
	CO_2	CH_4	N_2O	
Electricity	6,997.28	-	-	6,997.28
Waste	91.55	409.50	-	11,557.55

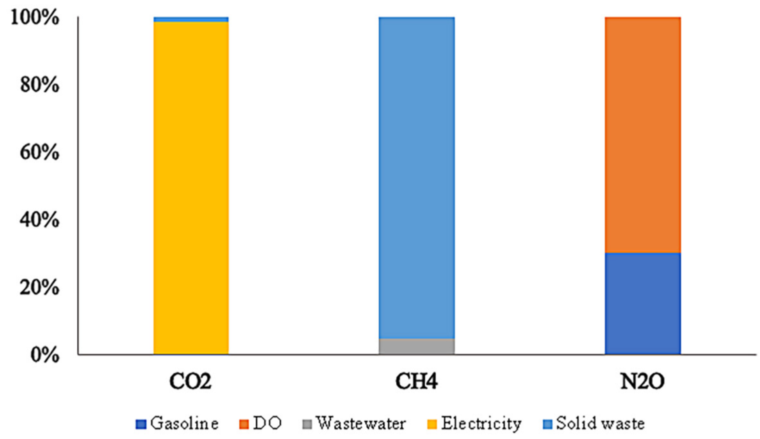

Figure 2. Proportion of greenhouse gases in emissions sources at the facility

The results show that the facility has an energy consumption of 1,499.61 tons of oil equivalent (TOE) (converted from electricity consumption and energy consumption). According to the provisions of point a, Clause 1, Article 6 of Decree 06/2022/ND-CP of the Government, establishments are subject to conducting GHG inventory because they have a total annual energy consumption of 1,000 TOE or more.

Solutions to reduce greenhouse gas emissions at the facility

On the basis of the estimation of GHG load at the facility, the authors propose the measures to reduce GHG emissions based on cost-benefit calculations; Feasibility in implementation; harmony and co-benefits with climate change adaptation and socio-economic development; and in accordance with the national and industry development plan for the period 2021–2030 towards the goals of the National Strategy on Climate Change for the period up to 2050. Seafood processing at the facility uses lots of water and energy (electricity), so the cleaner production opportunities proposed by the authors mainly focus on saving water while reducing the pollution load in wastewater streams and decreasing electricity consumption. Solar power is a form of clean energy, so the facility can take advantage of the roof areas to install solar power. This is highly possible, since the An Giang province has a fairly high total number of sunshine hours in the year, specifically from 2019–2021 the number of sunshine hours ranges from 2,500–2,600 hours of sunshine/year (An Giang Province Statistical Yearbook, 2022). With such favorable conditions, installing rooftop solar power would achieve good performance. However, achieving the best performance for rooftop solar power installation depends on many factors, such as: photovoltaic cell quality, production technology, installation direction and installation tilt, installation space, weather conditions, maintenance regime, etc. Therefore, when installing rooftop solar panels, the above factors need to be carefully calculated to achieve the best results. Installing rooftop solar power is one of the effective and energy-saving measures and is also a measure to reduce the GHG emissions at the facility.

CONCLUSIONS

The study at seafood processing facility showed that sources of the GHG emissions at the facility include direct sources (gasoline, DO, wastewater treatment, chemicals) and indirect sources (electricity and waste). The facility emits a large amount of GHG into the air (19,144.14 tons CO_2eq). The main source of the GHG emissions at the facility is mainly indirect emissions from waste (60.37% of total CO_2eq) and electricity (36.55% of total CO_2eq) and the remaining is from direct sources (gasoline, DO and wastewater treatment). Currently, the production facility is not operating at full design capacity, the average number of non-consecutive production days is 3–4 days/week, so GHG emissions depend on the number of production days of the facility and the volume of production. In addition, large amount of domestic solid waste also indirectly causes GHG emissions. The research results are the basis for providing important data for making decisions on mitigating the GHG emissions at the facility and are also the basis for setting mitigation goals.

REFERENCES

1. Arioli, M.S., Marcio de Almeida, D.A., Amaral, F.G., Cybis, H.B.B. 2020. The evolution of city-scale GHG emissions inventory methods: A systematic review. Environmental Impact Assessment Review, 80, 106316.
2. Diep, N.T.H., Diem, P.K., Thao, P.T.B., Giao, N.T., Nhunh, D.T.C., Linh, H.N., Nghia, N.M. 2022. Assessment greenhouse gas emissions on household in Can Tho city. Vietnam Journal of Science, Technology and Engineering, 64(4), 54-60.
3. Gokoglu, N., Yerlikaya, P.O. 2015. Seafood Chilling, Refrigeration and Freezing: Science and Technology.
4. GOV (Government of the Socialist Republic of Viet Nam) 2022. Decree No. 06/2022/ND-CP dated January 7, 2022 Decree Regulations on mitigation of greenhouse gas emissions and protection of the ozone layer. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Nghi-dinh-06-2022-ND-CP-giam-nhe-phat-thai-khi-nha-kinh-va-bao-ve-tang-o-don-500104.aspx
5. GOV (Government of the Socialist Republic of Viet Nam) 2022. Decree No. 08/2022/ND-CP elaboration of several dated January 10, 2022 Decree detailing a number of articles of the Law on Environmental Protection. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Nghi-dinh-08-2022-ND-CP-huong-dan-Luat-Bao-ve-moi-truong-479457.aspx
6. Hardy J.T. 2003. Climate change: causes, effects, and solutions. John Wiley & Sons.
7. Huan, C.S., Thinh, M.V., Ha, C.V., Loan, B.T.Phuong, Hang, V.T., Hieu, D.Q., Trang, D.T.M., Trang, B.T.T. 2020. Study on Greenhouse Gas Emission of Rice Soils in Thai Binh Province. Vietnam Journal of Agricultural Science, 18(2), 113-122.
8. IPCC 1995. IPCC Second Assessment Climate Change 1995. Intergovernmental Panel on Climate Change. IPCC CONTENTS
9. IPCC 2001. Climate change 2001 The Scientific Bais. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. TAR-*A (ipcc.ch)
10. IPCC 2007. Cliamte Change 2007 Synthesis Report. A Report of the Intergovernmental Panel on Climate Change ar4_syr_full_report.pdf (ipcc.ch)
11. IPCC 2015. Cliamte Change 2014 Synthesis Report. Intergovernmental Panel on Climate Change. AR5 Synthesis Report - Climate Change 2014 (ipcc.ch)
12. IPCC 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Task Force on National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html.
13. Kongboon, R., Gheewala, S.H., Sampattagul, S. 2022. Greenhouse gas emissions inventory data acquisition and analytics for low carbon cities. Journal of Cleaner Production, 343, 130711.
14. Mai, C.T.T., Trung, D.T., Tuyet, N.T.A. 2021. Energy consumption and CO_2 emissions in the construction materials manufacturing industry in the period 1996-2018: input–output analysis. Journal of Materials and Construction - Institute of Construction Materials, (1), 46-51.
15. MONRE (Ministry of Natural Resources and Environment) 2022a. Circular No. 01/2022/TT-BTNMT Detailed regulations on implementation of the Law on Environmental Protection on response to climate change.
16. MONRE (Ministry of Natural Resources and Environment) 2022b. Official Dispatch No. 1278/BĐKH-TTBVTOD on Aannouncing the results of calculating the emission coefficient of Vietnam's power grid in 2021.
17. MONRE (Ministry of Natural Resources and Environment) 2022c. Decision No. 2626/QD-BTNMT on announcing the list of emission factors for greenhouse gas inventory.
18. Ngan, N.V.C., Nguyen Vo Chau NganThuan, P.T., Trung. C.B., Phan Thanh Thuan & Chau Bao Trung. 2023. Effect of temperature on the performance of anaerobic treatment of seafood processing wastewater. CTU Journal of Science, 59(3A), 32-40. Can Tho University Scientific Magazine, 59(3A), 32-40.
19. Phuoc, N.T.K., Liem, L.T.T. 2023. Greenhouse gasses emission tradeoffs to achieve financial efficiency value from chili and green mustard cultivation in Hon Dat District, Kien Giang Province, Vietnam. CTU Journal of Science, 59(Special issue on Environment and Climate change), 42-53.
20. Prime Minister 2022a. Decision No. 896/QD-TTg deciding on Approving the National Strategy on Climate Change for the period up to 2050.
21. Prime Minister 2022b. Decision No. 858/QD-TTg deciding on approving the strategy for developing agricultural mechanization and agro-forestry-fishery processing until 2030.
22. Prime Minister 2022c. Decision No. 01/2022/QD-TTg Decision Promulgating a list of fields and establishments emitting greenhouse gases that must conduct a greenhouse gas inventory.
23. Shrestha, R. M., Kim, O., N. T., Shrestha, R. P., Rupakheti, M., Rajbhandari, S., Permadi, D.A., Kanabkaew, T., & Iyngararasan, M. 2013. Atmospheric Brown Clouds (ABC) Emission Inventory Manual, United Nations Environment Programme, Nairobi, Kenya.

24. The National Assembly 2014. Law No. 55/2014/QH13 Law on Environmental Protection – Vietnam. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Luat-bao-ve-moi-truong-2014-238636.aspx
25. The National Assembly 2020. Law No. 72/2020/QH14 Law on Environmental Protection– Vietnam. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Luat-so-72-2020-QH14-Bao-ve-moi-truong-2020-431147.aspx
26. Thuan, N.T.T., Anh, C.T., Huy, Le Quang, Dung, N.T.B. 2017. Assessment of greenhouse gas emissions from the pig production in Lam Dong. Science & Technology Developmet, 20, 5-13.
27. Tseng, M-L., Tran, T.P.T., Ha, H.M., Bui, T.D., Lim, M.K. 2022. Causality of circular business strategy under uncertainty: A zero-waste practices approach in seafood processing industry in Vietnam. Resources, Conservation and Recycling, 181, 106263.
28. Venugopal, V., Sasidharan, A. 2021. Seafood industry effluents: Environmental hazards, treatment and resource recovery. Journal of Environmental Chemical Engineering, 9(2), 104758.