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GHG Endline Study

for:

Low Carbon Rice: Reducing Climate Impact of Rice Millers in Indonesia

SWITCH-Asia

Version: 1.1

Contents

Project Overview

Project Title

SWITCH-Asia Low Carbon Rice: Reducing Climate Impact of Rice Millers in Indonesia

Project Location

Five districts in East and Central Java Province, Indonesia

1. Madiun
2. Sragen
3. Ngawi
4. Klaten
5. Boyolali

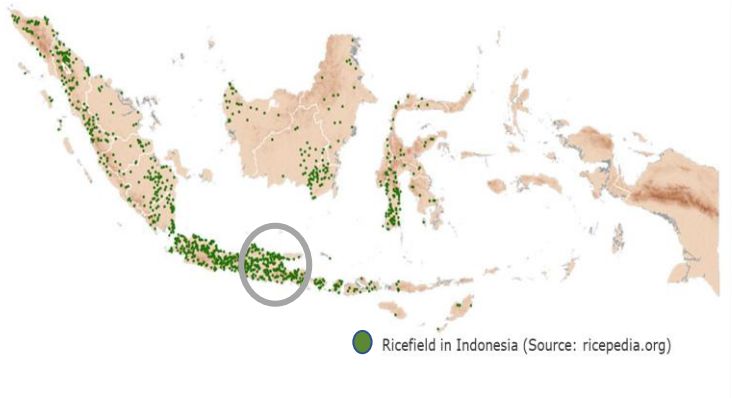

Figure 1: Location of districts in Indonesia

The mills in each district are summarized below in Table 1:

No	Rice Miller Owner	Address	Rice Mill
Madiun			
1	Yoyok K	Bongso Potro, Saradan	UD Karya Mandiri
2	Gunawan	Klumutan, Saradan	UD Sri Langgeng
3	Muh Maaruf	Lebak Ayu, Sawahan	UD Nawawi
4	Koko Supriyanti	Metesih, Jiwan	UD Aneka Usaha
5	Suparman	Kresek, Wungu	UD Berkang Abadi
6	Sugiyono	Palur, Kebon Sari	UD Sempulur
7	Budi Winarto	Lembah, Delopo	UD Sinar Gani
Ngawi			
1	Kasdi	Ngale, Oraon	Kasdi
2	Sumarno Ang	Karangsari, Ngawi	UD Dewi Sri
3	Jarmi Purwadi	Kartoharjo, Ngawi	Jami Purwadi

No	Rice Miller Owner	Address	Rice Mill
4	Madirun		Madirun
5	Mujillah	Banjansari, Padas	Elissa Putri
6	Suyanto Wawan	Geneng, Geneng	UD Sri Mullur
7	Siswoyo	Guyung, Gerih	Sri Mulyo
Sragen			
1	Umar Arifudin	Craken Krebet, Masaran	Azzam Putra PT. Hadi Mulya Utama
2	Aslabar	Mlale, Jenar	Aslabar
3	Sriyati	Mlale, Jenar	Sri Rezeki
4	Puji Hastutik	Gabus, Ngrampal	Sabar Makmur
5	Nori Muhadi	Kedungupit, Sragen	Putra Pangestu
6	iin Dwi Astuti	Mojokerto, Kedawung	UD Candi Agung
7	Parmin Japar	Gabukan, Tanon	UD Lumbung padi
8	Nur Laela Permatasari	Jetak Pabrik, Sidoharjo	UD Sumber Agung
Klaten			
1	Ita Rahmawati	Ngunut, Tulung	UD Syaiful
2	Wibisono	Bero, Trcuk	UD Dadi Mulyo
3	Hanani	Kalangan, Pedan	Sarwo Makmur
4	Haryono	Karanglo, Kebonarum	UD Adi Putro
5	M Hafid Zulkarnain	Senden, Ngawen	Haidar Propatani
6	Agus Riyanto	Sorogaten, Tulung	UD Abdhol Riyanto
7	Mardini	Pandeyan, Jatinom	UD Najwa
8	Sujimin	Munggung, Karangdowo	UD Ngudi Makmur
Boyolali			
1	Retno Mardiasih	Tambak, Mojosongo	UD Tani Makmur
2	Leni Deritanti	Tambak, Mojosongo	Rumah Beras Ciansah
3	Nyndia Sulistyo	Tanjung Sari, Banyudono	UD Nyndia Karya
4	Khayatun	Tawangsari, Teras	UD Sumber Arum
5	Murbowo	Jenengan, Sawit	Koperasi APOB
6	Muhadi	Dlingo, Mojosongo	Pangudi Bogo
7	Tulus Budiono	Bangak, Banyudono	Kondang Untung

Table 1: Rice mills in each district

In the second year of the project, the implementation strategy was refined to provide consistent technical assistance to all participating rice mills while delivering customized interventions aimed at improving business operations and accelerating the adoption of low-emission processing practices. This differentiated approach was necessary because rice mills vary significantly in terms of financial capacity, operational independence, and readiness to implement emission reduction measures. Tailoring support ensured that

each mill could progress effectively toward project objectives based on its specific context.

Two key categories of rice mills were defined: **(1) Leading (Unggulan) rice mills** and **(2) Aspiring (harapan) rice mills**. *Leading rice mills* are characterized by stronger financial capacity and operational independence, enabling a higher level of commitment to emission reduction initiatives. Initially, the sampling framework included two mills per district, totaling ten mills across five districts. In the second year, this was expanded to eight mills per district, resulting in a total of forty mills across the same five districts.

It is important to note that several mills were excluded from the final dataset due to operational constraints, including cessation of activities, inaccessibility, or lack of production during the data collection period. The mills excluded were **CV Songgo Langit**, **Margo Lestari**, and **UD Padi Murni**.

Project Description

The project aims to quantify greenhouse gas (GHG) emissions from the primary target group of rice millers operating within five districts across East Java and Central Java.

The project began with a baseline study conducted in December 2022. The baseline data was collected from the sampled rice millers. The study will end with an endline study after the study period at the end of 2024. However, due to the addition of one year, data collection will be carried out again in 2025.

Project Proponents

The project is funded by the SWITCH-Asia programme, through the European Commission. This programme aims to support sustainable development, contribute to economic prosperity and poverty reduction in Asia and Central Asia, and contribute to a transition towards a low-carbon, resource-efficient and circular economy.

Preferred by Nature is the lead recipient and project co-implementer. Preferred by Nature is a non-profit organisation working to support better land management and business practices that benefit people, nature and the climate in 100+ countries.

KRKP (Koalisi Rakyat untuk Kedaulatan Pangan; People's Coalition for Food Sovereignty) is a project co-implementer and is an experienced coalition that has worked on projects related to rice issues, especially in efforts to encourage policy changes. KRKP has the capacity related to lobbying and advocacy, project management, mapping and engagement of stakeholders, and campaigns. KRKP's network and members are located in each of the five districts.

Perpadi (Perkumpulan Penggilingan Padi dan Pengusaha Beras Indonesia) ; Indonesian Rice Millers and Traders Association) is a project co-implementer and is an integrated association of rice milling and trading-type companies, with national scope of operation. It has the capacity to mobilise rice milling communities and rice traders and direct their participation in developing and expanding agricultural industrialization to create the best of business comparative studies to different countries and technical assistance to improve rice milling efficiency and management of business.

Project Methods and Plan

Guidance

The study entails a baseline inventory of greenhouse gas emissions from the rice millers. The quantification process follows guidance as detailed by the Greenhouse Gas Protocol, the GHG Protocol Corporate Accounting and Reporting Standard, and more specifically the GHG Protocol for Project Accounting.

The GHGP divides emissions into three types:

Scope 1: Direct GHG emissions from sources that are owned or controlled by millers such as combustion for process equipment.

Scope 2: Indirect GHG emissions from purchased energy, such as electricity.

Scope 3: Indirect GHG emissions either upstream or downstream as a consequence of the millers' activities.

Emission factors will be sourced as appropriate throughout the study, relevant to project location and scope.

Project Boundaries

The project includes small rice mills in the five districts. System boundaries are established through financial and operational control parameters. Therefore, all miller activities are included for which they pay fuel or own, and all other emissions included for which they have operational control. The study follows a cradle-to-gate approach, which includes all emissions from sourcing of rice to the miller's exit gate. This is to exclude any activities performed after those at the mill, such as transport to customers or packaging or processing not done at the mill.

GHG Sources

A GHG source is any process that releases GHG emissions into the atmosphere.

The five sources as listed in the GHG Protocol for Project Accounting will be followed:

I. Combustion emissions from grid-connected electricity
II. Combustion emission from on-site generation of energy
III. Industrial process emissions
IV. Fugitive emissions
V. Waste emissions

Specific to the rice sector, and contextualized to the scope and focus of the study these GHG sources can be categorized into their Scope 1, 2 and 3 categories as shown in Table 2 below:

Emission Categories	Stages
Scope 1	
Combustion of fuels for process (owned vehicles, motors, wood pellets)	Milling – Threshing, Drying, Husker, Blower, Separator, Polisher, Transport of Co-products
Scope 2	
Purchased electricity (pumps, motors, lighting)	Milling – Threshing, Weighing, Drying, Packaging
Scope 3	
Employee commuting	Milling
Emissions from by-products (if destroyed)	Milling - Separator
Purchased goods and services (plastic packaging)	Milling – Packaging

Table 2: Emission categories by scope

Data

Calculations were made using the end 2024 to 2025 data, collected at the end of 2025 .

Reduction Targets

After the baseline study, and after an implementation phase of two years, an endline study will be conducted. The target is to achieve 15% reduction in absolute greenhouse gas emissions over the course of the study by 2024 through reduction interventions.

The GHG Reduction will be communicated in t CO_2eq where the reduction is calculated as GHG Reduction = Σ [Baseline Emissions – Project Activity Emission Reductions].

Collection Process

The sample of rice producers will be chosen with five mills sampled in the five districts. This stratified sampling ensures each district is represented, while allowing for random sampling from the farms and mills to ensure generalizability. It follows the sampling method applied internally of 0.8* √n where n is the population being studied.

An initial data screening checklist was developed (see Appendix A) to help the different stakeholders assemble the relevant data and enter some initial figures. This then informed inputs to a detailed excel calculator, to gather the Scope 1, 2 and 3 relevant emissions data. The entire process is supported by the team's technical specialists to help the millers as they need guidance. Finally, a on-site visit to the millers will cross-check gathered data with interviews so data can be verified and validated.

All records will be stored on the project team's SharePoint folders and not made public.

Quality Control

To ensure high quality of the collected data, the project will follow the five main principles of the GHG Protocol for Project Accounting.

Relevance: ensuring data that is collected, emissions factors applied, and methods are relevant to the project scope, intended outcomes and study scope.

Completeness: all baseline and endline data is collected based on study scope and system boundaries as described.

Consistent: methods, estimations, assumptions, and data are consistent allowing for generalizable and comparative outcomes.

Transparent: ensuring that data, analysis, and calculations are clearly documented for review.

Accuracy: strive for as accurate as possible data and estimations as practical and support farmers and millers with knowledge and guidance to share accurate data

Conservativeness: when estimations or uncertainty is introduced, use conservative values to overestimate rather than underestimate carbon footprint.

Roles and Responsibilities

Project Team

Contact Person	Responsibility
Angga Maulana Yusuf amaulana@preferredbynature.org	Project Manager and Lead, Preferred by Nature
Sucipto Kusumo Saputro ssaputro@preferredbynature.org	Project Secretary, Agriculture Specialist and Technical Expert, Preferred by Nature
László Szoboszlai lszoboszlai@preferredbynature.org	Carbon Footprint Specialist, Preferred by Nature

Table 3: Project member

Calculated GHG

Total Annual Emissions by Mill

Each mill's operations data was collected for the end 2024 to 2025 through on-site interviews. The data was summarized into Scope 1, 2 and 3 categories. There ended up being no burning of co-products, and instead all are sold to others past the gate, resulting in no emissions within scope from the co-products.

The following Table 4 summarizes the total GHG's emissions by each mill:

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Table 4: Total GHG emissions by mill

			Scope 1				Scope 2	Scope 3		
No	Participant	Operating time (days in a year)	Diesel (kgCO2e)	Wood Pellets (kgCO2e)	Transport of Co Product (kgCO2e)	Oil (kgCO2e)	Electricity (kgCO2e)	Employee Commuting (kgCO2e)	Plastic Packaging	Total Annual Emissions (kgCO2e)
	Madiun									
1	UD Karya Mandiri	288	-	8.557		-	14.057	103	25.215	**47.933**
2	UD Sri Langgeng	288	13.492	23.039		-	47.121	62	19.768	**103.482**
3	UD Nawawi	288	-	16.456		-	37.487	113	14.874	**68.931**
4	UD Aneka Usaha	240	11.243	-		264	63	578	2.718	**14.865**
5	UD Berkang Abadi	288	37.777	-		66	1.877	413	3.879	**44.011**
6	UD Sempulur	120	-	5.485		-	5.411	-	1.081	**11.978**
7	UD Sinar Gani	96	2.998	2.633		33	391	28	385	**6.468**
	Ngawi									
1	UD Sri Wahyuni	288	19.833	-		198	1.084	330	3.294	**24.739**
2	UD Dewi Sri	144	-	7.899			6.092	96	349	**14.436**
3	Jami Purwadi	75	3.513	-		110	386	-	553	**4.563**
4	Madirun	288	-	-			32.057	99	4.697	**36.853**
5	Elissa Putri	132	-	6.034		-	4.699	-	3.891	**14.625**
6	UD Sri Mullur	240	10.494	-		330	1.084	136	3.538	**15.582**
7	Sri Mulyo	96	2.998	1.317			6.025	31	308	**10.678**
	Sragen									
1	Azzam Putra	288	-	23.039		-	93.989	445	389.376	**506.849**
2	Aslabar	168	-	11.520		-	12.652	1.769	32.759	**58.699**
3	Sri Rezeki	240	-	16.456		-	53.704	2.320	135.203	**207.683**
4	Sabar Makmur	168	-	9.600		-	26.941	301	69.937	**106.779**
5	Putra Pangestu	200	-	9.142		-	46.392	1.263	66.664	**123.462**
6	UD Candi Agung	144	-	8.228		-	16.870	62	87.045	**112.204**
7	UD Lumbung padi	200	-	13.714		-	10.604	516	15.605	**40.439**
8	UD Sumber Agung	168	11.543	11.520		40	481	53	9.513	**33.149**
	Klaten									
1	UD Syaiful	200	-	-		-	15.062	1.691	2.175	**18.929**
2	UD Dadi Mulyo	136	-	3.108		-	6.326	-	2.870	**12.305**
3	Sarwo Makmur	144	-	-		-	6.326	103	917	**7.346**
4	UD Adi Putro	136	-	-		-	8.435	138	2.749	**11.321**
5	Haidar Propatani	120	-	-		-	6.507	-	1.236	**7.743**
6	UD Abdhol Riyanto	288	-	-		-	36.150	722	3.752	**40.623**
7	UD Najwa	288	-	13.165		-	36.150	1.392	1.816	**52.523**
8	UD Ngudi Makmur	288	-	19.748		-	43.380	1.083	8.788	**72.998**
	Boyolali									
1	UD Tani Makmur	240	-	-		-	21.690	1.667	2.395	**25.752**
2	Rumah Beras Ciansah	240	-	-		-	13.014	206	1.303	**14.523**
3	UD Nyndia Karya	192	7.795	3.511		41	1.503	413	5.242	**18.504**
4	UD Sumber Arum	192	8.994	3.511		33	590	309	947	**14.385**
5	Koperasi APOB	192	5.996	-		55	1.205	271	961	**8.488**
6	Pangudi Bogo	200	-	-		-	8.947	-	1.573	**10.520**
7	Kondang Untung	288	17.989	-	497	198	1.807	1.083	3.154	**24.729**
Average of Mills		205	4.180	5.883	497	40	16.934	481	25.149	52.678

Table 5: Total GHG emissions by mil

The average of mills figure is only based on data included in the scope of this study and does not seek to present an average emissions per small-medium rice mill figure that can be generalized to other mills outside of the scope of this study. It is meant to be used to compare the results of each individual mill to the average of the study. All results are in kg of CO2e annually.

There has been a clear decline in diesel use, and currently the largest emissions come from packaging of the emissions as also shown in Figure 2 below:

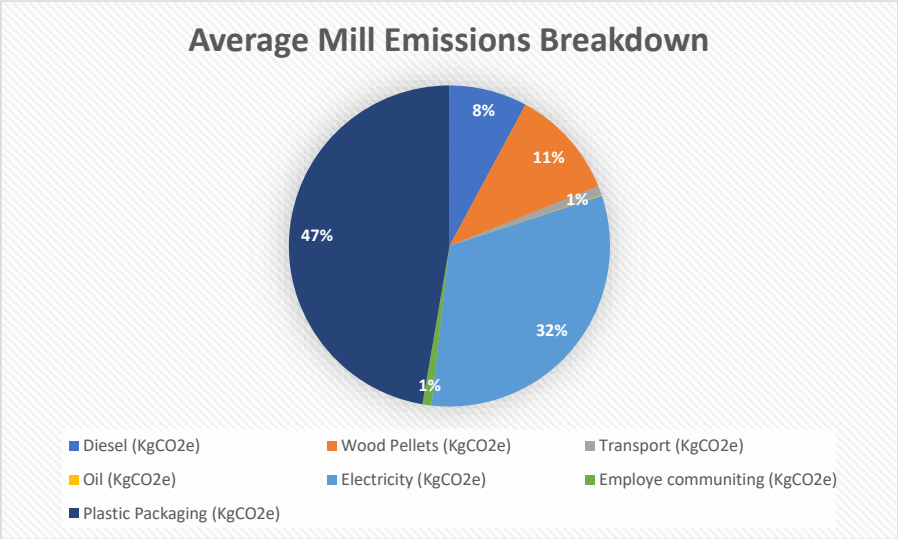

Figure 2: Average mill emissions breakdown

As different mills had differing days of operation, these annual results are not immediately comparable, and thus in the next sections the results will be summarized in terms of emissions by days of operation and emissions by a product intensity unit.

Production Process Map

The process map below shows the different steps in the rice milling operations at the various mills surveyed as part of the study:

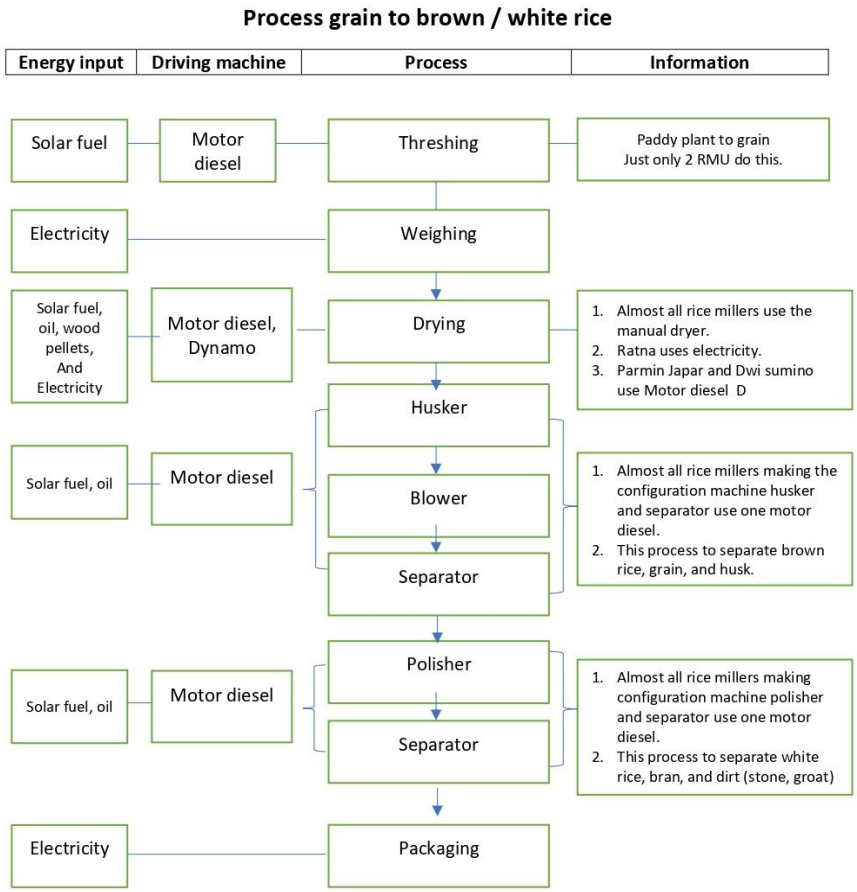

Figure 3: Production process map

It is notable that in the final study, there were 13 factories that used diesel engines for their production processes. Drying was done manually by 13 factories. And 64% of factories already used electricity. Electricity was no longer used for low-intensity work such as weighing, packaging, and factory lighting, but also for machinery.

Emissions by Functional Unit of Product and Day of Operation

The following Table 5 shows the emissions per kg of rice produced (kgCO2e/kg of total rice) combining the amount of brown and white rice at the various mills. Therefore, the functional unit in this study is 1 kg of rice processed at the mill. As the co-products (husk, bran, groat) are not destroyed but instead sold to others past the 'gate' they do not generate any emissions and are not part of the functional unit.

No	Participant	Operating time (days in a year)	White Rice (Kg/year)	Brown Rice (Kg/year)	Total Rice (Kg/year)	Emissions per kg of Rice (kgCO2e/year)
	Madiun					
1	UD Karya Mandiri	288	4.452.745		4.452.745	**0,011**
2	UD Sri Langgeng	288	5.759.994		5.759.994	**0,018**
3	UD Nawawi	288	3.562.235		3.562.235	**0,019**
4	UD Aneka Usaha	240	480.000	-	480.000	**0,031**
5	UD Berkang Abadi	288	883.865		883.865	**0,050**
6	UD Sempulur	120	315.034		315.034	**0,038**
7	UD Sinar Gani	96	75.379		75.379	**0,086**
	Ngawi					
1	UD Sri Wahyuni	288	518.400	345.600	864.000	**0,029**
2	UD Dewi Sri	144	45.995		45.995	**0,314**
3	Jami Purwadi	75	112.500		112.500	**0,041**
4	Madirun	288		910.080	910.080	**0,040**
5	Elissa Putri	132		1.133.801	1.133.801	**0,013**
6	UD Sri Mullur	240		599.976	599.976	**0,026**
7	Sri Mulyo	96	57.595		57.595	**0,185**
	Sragen					
1	Azzam Putra	288	3.744.000		3.744.000	**0,135**
2	Aslabar	168		1.007.960	1.007.960	**0,058**
3	Sri Rezeki	240		3.120.062	3.120.062	**0,067**
4	Sabar Makmur	168		1.679.933	1.679.933	**0,064**
5	Putra Pangestu	200		2.051.200	2.051.200	**0,060**
6	UD Candi Agung	144		2.159.914	2.159.914	**0,052**
7	UD Lumbung padi	200		480.168	480.168	**0,084**
8	UD Sumber Agung	168	-	1.679.933	1.679.933	**0,020**
	Klaten					
1	UD Syaiful	200	379.960		379.960	**0,050**
2	UD Dadi Mulyo	136	583.440		583.440	**0,021**
3	Sarwo Makmur	144	187.200		187.200	**0,039**
4	UD Adi Putro	136	510.272		510.272	**0,022**
5	Haidar Propatani	120	360.031		360.031	**0,022**
6	UD Abdhol Riyanto	288	974.938		974.938	**0,042**
7	UD Najwa	288	771.077		771.077	**0,068**
8	UD Ngudi Makmur	288	926.640	1.890.000	2.816.640	**0,026**
	Boyolali					
1	UD Tani Makmur	240	479.856		479.856	**0,054**
2	Rumah Beras Ciansah	240	312.000		312.000	**0,047**
3	UD Nyndia Karya	192		201.600	201.600	**0,092**
4	UD Sumber Arum	192	186.036	74.304	260.340	**0,055**
5	Koperasi APOB	192	232.606		232.606	**0,036**
6	Pangudi Bogo	200	458.380		458.380	**0,023**
7	Kondang Untung	288		285.120	285.120	**0,087**

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Average of Mills	205	1.014.238	1.101.228	1.188.914	0,057

Table 6: Emissions per kg of rice produced by mill

As shown in Table 5, the greenhouse gas emissions from rice mills ranged between 0.011 and 0.314 kilograms of CO_2 equivalent ($kgCO_2e$) for every kilogram of rice processed per year. On average, this amounts to 0.057 $kgCO_2e$ per kilogram of rice. When compared to the previous year (2024), which recorded an average of 0.072 $kgCO_2e$ per kilogram, this represents a reduction of approximately 20.8%.

To make the results of the mills comparable, the total annual emissions were also divided by the days each mill operates in a year. Therefore, here the unit is emissions per day of operation or kgCO2e/day in 2024 to 2025. The results are shown in Table 6 below:

No	Participant	Operating time (days in a year)	Emissions (kgCO2e)	Emissions per day of operation (kgCO2e)
	Madiun			
1	UD Karya Mandiri	288	47.933	**166**
2	UD Sri Langgeng	288	103.482	**359**
3	UD Nawawi	288	68.931	**239**
4	UD Aneka Usaha	240	14.865	**62**
5	UD Berkang Abadi	288	44.011	**153**
6	UD Sempulur	120	11.978	**100**
7	UD Sinar Gani	96	6.468	**67**
	Ngawi			
1	UD Sri Wahyuni	288	24.739	**86**
2	UD Dewi Sri	144	14.436	**100**
3	Jami Purwadi	75	4.563	**61**
4	Madirun	288	36.853	**128**
5	Elissa Putri	132	14.625	**111**
6	UD Sri Mullur	240	15.582	**65**
7	Sri Mulyo	96	10.678	**111**
	Sragen			
1	Azzam Putra	288	506.849	**1.760**
2	Aslabar	168	58.699	**349**
3	Sri Rezeki	240	207.683	**865**
4	Sabar Makmur	168	106.779	**636**
5	Putra Pangestu	200	123.462	**617**
6	UD Candi Agung	144	112.204	**779**
7	UD Lumbung padi	200	40.439	**202**
8	UD Sumber Agung	168	33.149	**197**
	Klaten			
1	UD Syaiful	200	18.929	**95**
2	UD Dadi Mulyo	136	12.305	**90**
3	Sarwo Makmur	144	7.346	**51**
4	UD Adi Putro	136	11.321	**83**
5	Haidar Propatani	120	7.743	**65**

No	Participant	Operating time (days in a year)	Emissions (kgCO2e)	Emissions per day of operation (kgCO2e)
6	UD Abdhol Riyanto	288	40.623	**141**
7	UD Najwa	288	52.523	**182**
8	UD Ngudi Makmur	288	72.998	**253**
	Boyolali			
1	UD Tani Makmur	240	25.752	**107**
2	Rumah Beras Ciansah	240	14.523	**61**
3	UD Nyndia Karya	192	18.504	**96**
4	UD Sumber Arum	192	14.385	**75**
5	Koperasi APOB	192	8.488	**44**
6	Pangudi Bogo	200	10.520	**53**
7	Kondang Untung	288	24.729	**86**
	Average of Mills	205	52.678	235

Table 7: Emissions per day of operation by mill

The results here do not show any significant outliers. The average comes to 235 kgCO2e/day of operation at the mills.

In order to make the three units of measurement (total annual emissions, emissions per kg of rice, emissions per day of operation) comparable, the following Table 7 ranks each mill in the respective measured unit.

No	Participant	Total Annual Emissions (kgCO2e)	Rank	Emissions per kg of Rice (kgCO2e/year)	Rank	Emissions per day of operation (kgCO2e)	Rank	Overall Score	Overall Rank
	Madiun								
1	UD Karya Mandiri	47.933	27	0,011	1	166	25	53	16
2	UD Sri Langgeng	103.482	32	0,018	3	359	32	67	24
3	UD Nawawi	68.931	30	0,019	4	239	29	63	20
4	UD Aneka Usaha	14.865	15	0,031	13	62	6	34	8
5	UD Berkang Abadi	44.011	26	0,050	21	153	24	71	28
7	UD Sempulur	11.978	9	0,038	15	100	17	41	12
8	UD Sinar Gani	6.468	2	0,086	32	67	9	43	13
	Sragen								
1	UD Sri Wahyuni	24.739	20	0,029	12	86	13	45	14
2	UD Dewi Sri	14.436	12	0,314	37	100	18	67	24
3	Jami Purwadi	4.563	1	0,041	18	61	5	24	5
4	Madirun	36.853	23	0,040	17	128	22	62	19
5	Elissa Putri	14.625	14	0,013	2	111	20	36	10
6	UD Sri Mullur	15.582	16	0,026	11	65	8	35	9
8	Sri Mulyo	10.678	7	0,185	36	111	21	64	21

No	Participant	Total Annual Emissions (kgCO2e)	Rank	Emissions per kg of Rice (kgCO2e/year)	Rank	Emissions per day of operation (kgCO2e)	Rank	Overall Score	Overall Rank
	Ngawi								
1	Azzam Putra	506.849	37	0,135	35	1.760	37	109	37
2	Aslabar	58.699	29	0,058	26	349	31	86	32
3	Sri Rezeki	207.683	36	0,067	29	865	36	101	36
4	Sabar Makmur	106.779	33	0,064	28	636	34	95	34
5	Putra Pangestu	123.462	35	0,060	27	617	33	95	34
6	UD Candi Agung	112.204	34	0,052	23	779	35	92	33
7	UD Lumbung padi	40.439	24	0,084	31	202	28	83	30
8	UD Sumber Agung	33.149	22	0,020	5	197	27	54	17
	Klaten								
1	UD Syaiful	18.929	18	0,050	22	95	15	55	18
2	UD Dadi Mulyo	12.305	10	0,021	6	90	14	30	7
3	Sarwo Makmur	7.346	3	0,039	16	51	2	21	4
4	UD Adi Putro	11.321	8	0,022	8	83	11	27	6
5	Haidar Propatani	7.743	4	0,022	7	65	7	18	1
6	UD Abdhol Riyanto	40.623	25	0,042	19	141	23	67	24
7	UD Najwa	52.523	28	0,068	30	182	26	84	
8	UD Ngudi Makmur	72.998	31	0,026	10	253	30	71	28
	Boyolali								
1	UD Tani Makmur	25.752	21	0,054	24	107	19	64	21
2	Rumah Beras Ciansah	14.523	13	0,047	20	61	4	37	11
3	UD Nyndia Karya	18.504	17	0,092	34	96	16	67	24
4	UD Sumber Arum	14.385	11	0,055	25	75	10	46	15
5	Koperasi APOB	8.488	5	0,036	14	44	1	20	3
6	Pangudi Bogo	10.520	6	0,023	9	53	3	18	1
8	Kondang Untung	24.729	19	0,087	33	86	12	64	21

Table 8: Mills ranked by indicators.

In the table 7 above, mills are ranked 1 to 40 based on the three measured units. Ranks from 1-10 are in green box, 11 -20 in yellow box, 21-30 in red box, and 31 – 40 in orange box. Finally, their three measurements are summed up for an overall score, and then ranked overall based on the three measurements. The most carbon efficient mill in this case is the Pangudi Bogo mill in Boyolali and Haidar Propatani mill in Klaten, These rankings may be useful when evaluating the processes at each mill to process the rice, and in particular how effectively the mill is operating.

Commented [AY7]: To help the reader understand the information, consider to also present the ranks using chart/graphic and add analysis/explation why Pangudi Bogo and haidar have most efficient mill. Cc @Sucipto Kusumo Saputro @Siti Jamilah

Challenges with Validation and Verification

The original study plan included collecting data from the mills through the submission of invoices, purchase order, receipts or data collection checklists. Upon the start of the study, it became apparent that the documentation management systems in place at the mills were rudimentary. This was because small rice mills were still family-owned and not professionally managed. All activities were carried out by the owners, making record-keeping difficult. Therefore, no formal records were presented or submitted for review.

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Instead, all data was collected by on-site visits, through interviews with mill managers and surveys of the sites. The checklists were therefore populated by Preferred by Nature staff who had interviewed the stakeholders at the mills. This meant that the results could not be verified through the audit of recorded data. It is for this reason, one finding of this study is that mill managers should work to improve on their document and record management systems. By having more detailed records, the data quality can improve. Improved measurement may lead to improved management of processes and better comparison of intervention measures to a baseline scenario.

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Concluding Insights and Future Pathways for Sector-Wide Emission Reductions

The completion of the GHG endline study confirms that this project has delivered measurable environmental outcomes within Indonesia's rice milling sector. Across 40 participating mills, greenhouse gas emissions averaged 0.057 kgCO2e/kg of rice processed, representing a 20.8% reduction compared to the 2023 baseline of 0.072 kgCO2e/kg. This improvement demonstrates that systematic interventions in milling operations—centered on diesel efficiency, equipment maintenance, and process optimization—translate into tangible emissions reductions.

The project has successfully positioned rice millers as independent stewards of low-emission operations. The technical systems, monitoring protocols, and market-based incentive structures introduced during the project period have been operationalized within participating mills' standard business functions. This institutionalization—moving from donor-dependent pilot to self-sustaining practice—represents the project's most significant sustainability achievement.

Industry stakeholders have demonstrated ownership of the emissions reduction agenda. Millers have voluntarily integrated carbon efficiency into competitive positioning, recognizing that low-emission certification increasingly influences buyer procurement decisions and market access. This market-driven adoption dynamic indicates that emissions reductions will persist beyond formal project conclusion.

While individual mill performance has improved significantly, sector-wide transformation toward sustainable rice milling requires coordinated action across fragmented value chain actors. The project's closing creates critical inflection point where pilot-stage achievements must transition into systemic change. Sustained progress depends on three interdependent components:

1. Mill-level actions must advance beyond project beneficiaries to reach non-participating mills, particularly in Red and Orange performance tiers. Knowledge-sharing platforms linking high-performing mills with lower-performing counterparts offer cost-effective scaling mechanisms. Industry associations should formalize peer-mentoring protocols and technical exchange programs.
2. Policy integration must anchor emissions reduction within national and regional agricultural development frameworks. Integration of milling sector emissions standards into government rice procurement specifications, export quality requirements, and agricultural extension services will convert project-level innovation into market-mandated practice.
3. Stakeholder collaboration among millers, policymakers, financial institutions, and international partners must extend beyond project timeframes. Multi-stakeholder platforms for technical standard-setting, financing mechanism development, and market linkage creation will determine whether endline achievements scale toward sector-wide transformation.

This project generates robust evidence for replication across comparable agricultural processing sectors. The demonstrated reduction of 20.8% over one year—achieved through focused technical support without requiring capital-intensive equipment

replacement—indicates that emissions intensity improvements are accessible even for resource-constrained operators in developing country contexts.

The wide performance distribution across mills reveals that sector heterogeneity, rather than technical impossibility, explains emissions variation. Targeted technical assistance addressing mill-specific operational constraints proves more effective than generic interventions, suggesting that replication efforts should prioritize diagnostic capacity building and customized solution design.

Conclusion

The successful completion of this GHG endline study affirms that low-emission rice milling represents both an environmental necessity and economic opportunity for Indonesia's rice sector. Project outcomes demonstrate technical feasibility, operational viability, and market receptivity to sustainability improvements. The transition from project-dependent implementation to independent mill stewardship reflects genuine institutional anchoring of emissions reduction practices.

However, full realization of the sector's emissions reduction potential requires coordinated commitment from multiple stakeholders beyond project boundaries. The endline findings provide evidence base and performance benchmarks upon which stakeholders can construct scaled, systemic responses to milling sector decarbonization.

This project's legacy will ultimately depend not on its direct achievements, but on whether participating mills and sector-wide partners convert the knowledge, systems, and market signals generated during project implementation into sustained, independent action toward a genuinely low-emission rice milling sector serving Indonesia's food security and climate commitments.

Appendix A: Checklist for Initial Data Collection

Preferred by Nature
Carbon Footprint Checklist

For Rice Millers in Central and Eastern Java

Instruction: This checklist serves to help collect the basic information of milling practices to allow for accurate data collection. The checklist is then meant to serve as a pre-assessment tool for a more detailed data collection phase. A data collection calculator Excel file sent separately will allow each entity to enter their relevant details to calculate their Scope 1, 2 and 3 carbon emissions.

Carbon Footprint Checklist	
Husk Management	How is the by-product husk managed (burned, sent to industry, etc)?
	Are there other by-product management practices on-site?
	What records of this management are available and how are they stored?

Milling	Please describe the steps of the milling process, and indicate where energy (fuel, steam, electricity, etc.) is used: Process; Energy Input ; ; ; ; ; ; ; ; Please see the example below:

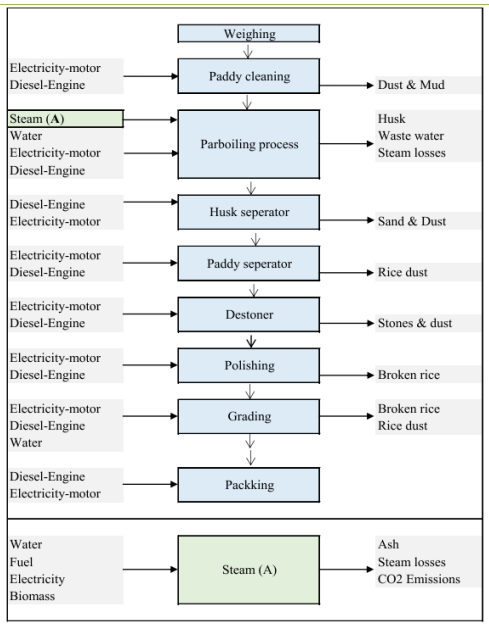

Figure 2: Process flow diagram of rice mills

Source: Sivappirakasam, K., & Kulatunga, A. (2018). Life cycle assessment of rice processing.

What records of fuel consumption are available and how are they stored?
How much fuel (e.g., diesel) were used in 2021:
Are there any other fuel/energy sources on site (petrol, bioethanol, propane, solar panels, etc)?
What records of this consumption are available and how are they stored?
Is there any grid-supplied electricity being used?
If yes, how many kWh used in 2021?

	What is the grain loss rate at milling? (e.g., between 28-37%)
	What is the moisture content of the rice when it is bought?
	Is rice husk torrefaction being done at the mill? If yes, please indicate energy input.
	How is any waste handled (co-products)? Landfilled? Biomass burned? Any other uses of biomass?

Appendix B: Excel Sheet with Data Calculations

Attached Excel File with Calculations

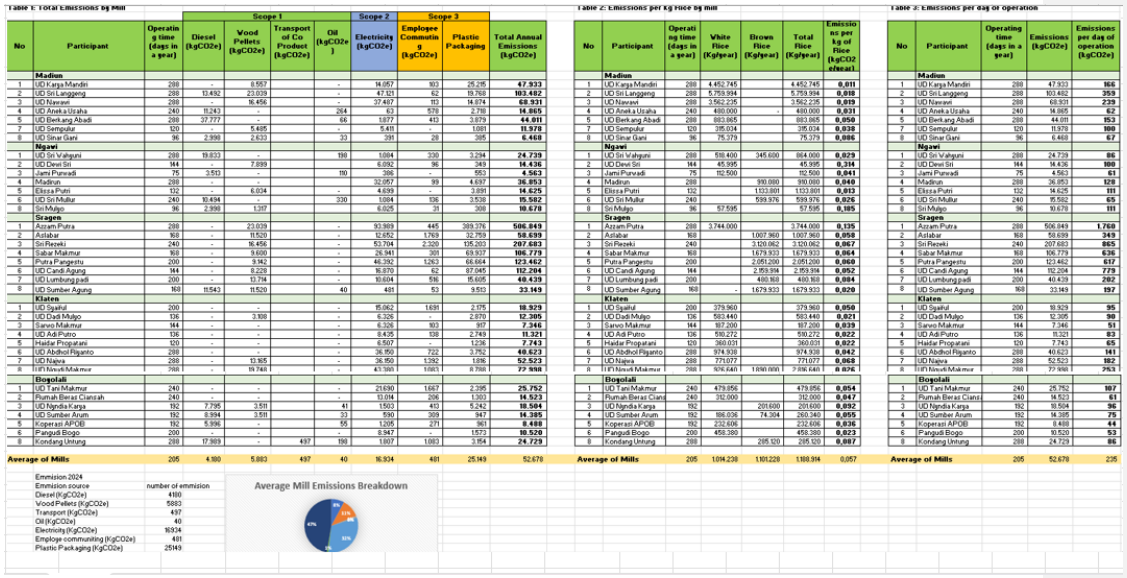

Table 1: Total Emissions by Mill

No	Participant	Operating time (days in a year)	Scope 1				Scope 2	Scope 3		Total Annual Emissions (kgCO2e)
			Diesel (kgCO2e)	Wood Pellets (kgCO2e)	Transport of Co Product (kgCO2e)	Oil (kgCO2e)	Electricity (kgCO2e)	Employee Commuting (kgCO2e)	Plastic Packaging	
	Madiun									
1	UD Karya Mandiri	288	-	8.557		-	14.057	103	25.295	**47.933**
2	UD Sri Langgeng	288	13.492	23.039		-	47.121	62	19.768	**103.482**
3	UD Nawarel	288	-	16.456		-	37.407	113	14.874	**68.931**
4	UD Aneka Usaha	240	11.243	-		264	63	578	2.718	**14.865**
5	UD Berkang Abadi	288	37.777	-		66	1.077	413	3.079	**44.011**
7	UD Sempulur	120	-	5.485		-	5.481	-	1.991	**11.979**
8	UD Sinar Gani	96	2.998	2.633		33	291	28	385	**6.468**
	Ngawi									
1	UD Sri Wahyuni	288	19.833	-		198	1.094	330	3.294	**24.739**
2	UD Devi Sri	144	-	7.899			6.092	96	349	**14.436**
3	Jami Purwadi	75	3.513	-		110	286	-	653	**4.563**
4	Madirun	288	-	-			32.057	99	4.697	**36.853**
5	Elissa Putri	132	-	6.024		-	4.699	-	3.891	**14.625**
6	UD Sri Mulyo	240	10.494	-		330	1.094	136	3.538	**15.592**
8	Sri Mulyo	96	2.998	1.317			6.025	31	308	**10.678**
	Sragen									
1	Azzam Putra	288	-	23.039		-	93.989	445	389.376	**506.849**
2	Aslabar	168	-	11.520		-	12.652	1.769	32.759	**58.699**
3	Sri Rezeki	240	-	16.456		-	53.704	2.320	135.203	**207.683**
4	Sabar Makmur	168	-	9.600		-	26.941	305	69.937	**106.779**
5	Putra Pangestu	200	-	9.142		-	46.392	1.263	66.664	**123.462**
6	UD Candi Agung	144	-	8.229		-	16.070	62	87.945	**112.294**
7	UD Lumbung padi	200	-	13.714		-	10.604	516	15.605	**40.439**
8	UD Sumber Agung	168	11.543	11.520		40	481	53	9.553	**33.149**
	Klaten									
1	UD Syaiful	200	-	-		-	15.062	1.691	2.175	**18.929**
2	UD Dadi Mulyo	136	-	3.168		-	6.326	-	2.870	**12.365**
3	Sarwo Makmur	144	-	-		-	6.326	163	817	**7.346**
4	UD Adi Putro	136	-	-		-	8.435	138	2.749	**11.321**
5	Haidar Propatani	120	-	-		-	6.507	-	1.236	**7.743**
6	UD Abdhol Riyanto	288	-	-		-	36.150	722	3.752	**40.623**
7	UD Najwa	288	-	13.165		-	36.150	1.392	1.816	**52.523**
8	UD Nivuk Makmur	288	-	19.748		-	43.380	1.663	8.798	**73.988**
	Bogolali									
1	UD Tani Makmur	240	-	-		-	21.690	1.667	2.395	**25.752**
2	Rumah Berasi Cianiah	240	-	-		-	10.014	206	1.303	**14.523**
3	UD Ngindia Karya	192	7.795	3.511		41	1.503	413	5.242	**18.504**
4	UD Sumber Arum	192	8.994	3.511		33	590	309	947	**14.385**
5	Koperasi APOB	192	5.996	-		55	1.205	271	961	**8.488**
6	Pangudi Blogo	200	-	-		-	8.947	-	1.573	**10.520**
8	Kondang Untung	288	17.989	-	497	198	1.807	1.083	3.154	**24.729**
Average of Mills		205	4.180	5.883	497	40	16.934	481	25.149	52.678

Table 2: Emissions per Kg Rice by Mill

No	Participant	Operating time (days in a year)	White Rice (Kg/year)	Brown Rice (Kg/year)	Total Rice (Kg/year)	Emissions per kg of Rice (kgCO2e/year)
	Madiun					
1	UD Karya Mandiri	288	4.452.745		4.452.745	**0,011**
2	UD Sri Langgeng	288	5.759.994		5.759.994	**0,018**
3	UD Nawarel	288	3.562.235		3.562.235	**0,019**
4	UD Aneka Usaha	240	480.000		480.000	**0,031**
5	UD Berkang Abadi	288	883.865		883.865	**0,050**
7	UD Sempulur	120	395.034		395.034	**0,038**
8	UD Sinar Gani	96	75.379		75.379	**0,086**
	Ngawi					
1	UD Sri Wahyuni	288	518.400	345.600	864.000	**0,029**
2	UD Devi Sri	144	45.995		45.995	**0,314**
3	Jami Purwadi	75	152.500		152.500	**0,041**
4	Madirun	288		910.080	910.080	**0,040**
5	Elissa Putri	132		1.533.801	1.533.801	**0,013**
6	UD Sri Mulyo	240		599.976	599.976	**0,026**
8	Sri Mulyo	96	57.595		57.595	**0,185**
	Sragen					
1	Azzam Putra	288	3.744.000		3.744.000	**0,135**
2	Aslabar	168		1.007.360	1.007.360	**0,058**
3	Sri Rezeki	240		3.120.062	3.120.062	**0,067**
4	Sabar Makmur	168		1.679.933	1.679.933	**0,064**
5	Putra Pangestu	200		2.051.200	2.051.200	**0,060**
6	UD Candi Agung	144		2.859.994	2.859.994	**0,052**
7	UD Lumbung padi	200		400.168	400.168	**0,084**
8	UD Sumber Agung	168	-	1.679.933	1.679.933	**0,020**
	Klaten					
1	UD Syaiful	200	379.960		379.960	**0,050**
2	UD Dadi Mulyo	136	583.440		583.440	**0,021**
3	Sarwo Makmur	144	187.200		187.200	**0,039**
4	UD Adi Putro	136	510.272		510.272	**0,022**
5	Haidar Propatani	120	360.031		360.031	**0,022**
6	UD Abdhol Riyanto	288	974.938		974.938	**0,042**
7	UD Najwa	288	771.077		771.077	**0,068**
8	UD Nivuk Makmur	288	976.640	1.999.999	2.976.640	**0,026**
	Bogolali					
1	UD Tani Makmur	240	479.856		479.856	**0,054**
2	Rumah Berasi Cianiah	240	312.000		312.000	**0,047**
3	UD Ngindia Karya	192		201.600	201.600	**0,092**
4	UD Sumber Arum	192	186.036	74.304	260.340	**0,055**
5	Koperasi APOB	192	232.606		232.606	**0,036**
6	Pangudi Bogo	200	458.380		458.380	**0,023**
8	Kondang Untung	288		285.120	285.120	**0,087**
Average of Mills		205	1.014.230	1.101.228	1.188.914	0,057

Table 3: Emissions per day of operation

No	Participant	Operating time (days in a year)	Emissions (kgCO2e)	Emissions per day of operation (kgCO2e)
	Madiun			
1	UD Karya Mandiri	288	47.933	**166**
2	UD Sri Langgeng	288	103.482	**359**
3	UD Nawarel	288	68.931	**239**
4	UD Aneka Usaha	240	14.865	**62**
5	UD Berkang Abadi	288	44.011	**153**
7	UD Sempulur	120	11.979	**100**
8	UD Sinar Gani	96	6.468	**67**
	Ngawi			
1	UD Sri Wahyuni	288	24.739	**86**
2	UD Devi Sri	144	14.436	**100**
3	Jami Purwadi	75	4.563	**61**
4	Madirun	288	36.853	**128**
5	Elissa Putri	132	14.625	**111**
6	UD Sri Mulyo	240	15.592	**65**
8	Sri Mulyo	96	10.678	**111**
	Sragen			
1	Azzam Putra	288	506.849	**1.760**
2	Aslabar	168	58.699	**349**
3	Sri Rezeki	240	207.683	**865**
4	Sabar Makmur	168	106.779	**636**
5	Putra Pangestu	200	123.462	**617**
6	UD Candi Agung	144	112.294	**779**
7	UD Lumbung padi	200	40.439	**202**
8	UD Sumber Agung	168	33.149	**197**
	Klaten			
1	UD Syaiful	200	18.929	**95**
2	UD Dadi Mulyo	136	12.305	**90**
3	Sarwo Makmur	144	7.346	**51**
4	UD Adi Putro	136	11.321	**83**
5	Haidar Propatani	120	7.743	**65**
6	UD Abdhol Riyanto	288	40.623	**141**
7	UD Najwa	288	52.523	**182**
8	UD Nivuk Makmur	288	77.988	**263**
	Bogolali			
1	UD Tani Makmur	240	25.752	**107**
2	Rumah Berasi Cianiah	240	14.523	**61**
3	UD Ngindia Karya	192	18.504	**96**
4	UD Sumber Arum	192	14.385	**75**
5	Koperasi APOB	192	8.488	**44**
6	Pangudi Bogo	200	10.520	**53**
8	Kondang Untung	288	24.729	**86**
Average of Mills		205	52.678	235

Emmision 2024	
Emmision source	number of emmision
Diesel (KgCO2e)	4180
Wood Pellets (KgCO2e)	5883
Transport (KgCO2e)	497
Oil (KgCO2e)	40
Electricity (KgCO2e)	16934
Employe communiting (KgCO2e)	481
Plastic Packaging (KgCO2e)	25149