



RECP MANUAL

RICE MILL SECTOR

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COMPILED BY:

PERMOD KUMAR GUPTA

Chief Technical Advisor, UNIDO

 Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation



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The National Resource Efficient and Cleaner Production (RECP) programme of Indonesia aims to bolster the competitiveness and profitability of small and medium enterprises (SMEs) in Indonesia. The RECP programme focuses on key sectors that drive economic development and job creation around Indonesia and which are significant in terms of consumption of materials, energy and water and potential environmental impacts. Small and micro rice milling enterprises were selected for RECP implementation as they provide jobs and income and deliver goods and services that improve the lives of consumers and of communities. Adding value to agriculture and other rural industries is at the heart of the work of UNIDO in agribusiness. By strengthening the link between agriculture, industry and markets, the Organization creates stronger value chains and helps in upgrading technology and useful product from waste/by-product that will sustain long-term industrial and economic growth.

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DISCLAIMER

This manual is compiled and collated without formal United Nations editing. The brief RECP case studies are extracted from global CP/RECP programmes, Central Pollution Control Board (CPCB) India, Bureau of Energy Efficiency (BEE) and National Productivity Council publications and most of them are available on the respective websites. The statistical data, opinions and results presented in the text are the responsibility of the authors of the manual and should not be assumed to carry the endorsement of UNIDO, SECO or the Government of Indonesia (GOI). Although great care has been taken to maintain the accuracy of the information herein, neither UNIDO nor SECO assume any responsibility for any consequences that may arise from the use of the manual. Experiences shared in this document may be freely quoted or represented but acknowledgment will be appreciated.



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LIST OF ABBREVIATION

BEE	=	Bureau of Energy Efficiency
BRY	=	Brown rice yield
CH₄	=	Methane gas
CP	=	Cleaner Production
CEO	=	Chief Executive Officer
CNG	=	Compressed natural gas
CO₂	=	carbon Dioxide
CPCB	=	Central Pollution Control Board
DO	=	Diesel oil
DPR	=	Detailed project reports
EEM	=	Energy efficiency motors
FBG	=	Fine biomass gasification
FI	=	Financial institutions
GHG	=	Green House Gas
GOI	=	Government of Indonesia
H₂	=	Hydrogen
HBRY	=	Head brown rice yield
HRY	=	Head rice yield
IFC	=	International Finance Corporation
kWhr	=	Kilowatt hour
LHF	=	Low hanging fruits
LRP	=	Local resource person
LSP	=	Local service provider
MMT	=	Million metric tons
MPW	=	Ministry of Public Works
MRY	=	Milled recovery yield
MW	=	Megawatt
MWe	=	Megawatt equivalent
MY	=	Model year
NGO	=	Non-Governmental Organization



OPC	=	Ordinary Portland cement
PF	=	Power factor
PLN	=	Perusahaan Listrik Negara (<i>Indonesian National Electricity Company</i>)
PMC	=	Project Management Committee
PPA	=	Power Purchase Agreement
PPC	=	Portland Pozzolana Cement
RECP	=	Resource Efficient and Cleaner Production
RH	=	Rice husk
RHA	=	Rice husk ash
SEC	=	Specific Energy Consumption
SECO	=	State Secretariate for Economic Affairs
SiC	=	Silica carbide
SiO₂	=	Silica dioxide
SME	=	Small and medium enterprise
TPH	=	Ton per hour
UNEP	=	United Nations Environment Programme
UNIDO	=	United Nations Industrial Development Organization
VFD	=	Variable frequency drives
WB	=	Wet based
WMC	=	Waste Minimization Circle
WWTP	=	Wastewater treatment plant



1.0. PREAMBLE

Indonesia is an archipelagic country in South-East Asia, extending 5,120 km from east to west and 1,760 km from north to south. It encompasses an estimated 17,508 islands, only 6,000 of which are inhabited. There are five main islands: Sumatra, Java, Kalimantan, Sulawesi and Papua. The total area is 9.8 million km² and the sea constitutes about 81 per cent of this. Lying along the equator, Indonesia experiences two seasons – a rainy season and a dry season – with no extremes of summer or winter.

Small industries and service businesses form an important part of the socio-economic fabric of both urban and rural areas in Indonesia. Small enterprises provide jobs and incomes and deliver goods and services that improve the lives of consumers and communities. Industrialization is vital for economic development and has helped bring millions out of poverty in recent decades. But as more countries industrialize, growing consumption, rapid urbanization and unsustainable use of natural resources is exacerbating climate change and polluting the ecosystems on which we depend. In medium and large enterprises and corporates, business operations consume materials, water and energy, and release waste, wastewater and air emissions, causing an adverse impact on the environment. While the impact from small industries is not large, the collective impact of these industries is significant at the local, regional and national level.

Adding value to agriculture and other rural industries is at the heart of the work of UNIDO in agribusiness. By strengthening the link between agriculture, industry and markets, the Organization creates stronger value chains and helps build infrastructure that will sustain long-term industrial and economic growth (UNIDO 2017). Urbanization, climate change and environmental degradation are also adding to political and social tensions, while fast-paced technological change presents both opportunities and challenges.

Resource Efficient and Cleaner Production (RECP) project Indonesia assists governments, institutions and industry to best adapt their production methods, move towards resource efficient cleaner production systems and develop sustainable, resource efficient solutions. Efficient utilization of resources – raw material, energy, water and auxiliaries – becomes crucial for the survival of businesses, which generally operate on low profit margins and are mostly family-owned traditional units. Moreover, production processes are mostly based on obsolete technology, or even improved technology which has become inefficient over time. The inefficient utilization and excessive use of resources also contributes to exceeding levels of material and energy intensities and environmental footprints.

By focusing on using materials, water and energy more efficiently and eliminating the causes of wastes, enterprises can improve productivity and save money. This practice is known as Resource Efficient and Cleaner Production (RECP). Rooted in the manufacturing and processing industries, over the past two decades pilot projects in Indonesia and elsewhere in South-East Asia have proven that RECP concepts and practices can also be beneficially applied in a range of small industry sectors.

2.0. RESOURCE EFFICIENT CLEANER PRODUCTION (RECP)

RECP is aimed at preventing waste and pollution at source whilst also increasing efficiency in the use of natural resources. It starts with making more efficient use of all materials, including chemicals and packaging, and of energy and water, from all sources. This in turn minimizes the amount of waste, wastewater and air emissions, which in turn improves health, safety and well-being for employees, consumers and communities. Indeed, a virtuous cycle is established whereby increased resource efficiency consecutively minimizes wastes and improves community well-being, which in turn fosters productivity. Business benefits are achieved from spending less on procuring energy, materials and water, and by earning more from selling more and better quality products and services.

The Resource Efficient and Cleaner Production (RECP) programme has long been a central element in the work of UNIDO on the environment. This flagship initiative, run jointly with the United Nations Environment Programme (UNEP) and funded principally by Switzerland, delivers services to improve resource productivity and environmental performance in 63 developing countries and economies in transition, targeting governments, civil society and businesses, with a particular focus on SMEs. The programme applies preventive environmental strategies to processes, products and services to increase efficiency and reduce risks to communities and the environment.

2.1. Small rice mill industry in Indonesia

Rice is an important food source globally and the second most important crop in the world. It is the staple food for the world's most densely populated region and for hundreds of millions of people in Asia, Africa and Latin America. Indonesia is reported to process approximately 79 million tons of paddies per year and provide staple food grain and other valuable by-products required by the local population. Indonesia has approximately 170,000 small rice milling units which make up 94 per cent of the total rice milling units in the country. However, rice sector development is hindered by quality issues, a lack of technical skills, fragmented and underdeveloped production due to obsolete technology, suboptimal usage of by-product.

2.1.1. Industry background and market opportunities

Unique features/issues of the sector

Rice is one of the most important agricultural products in Indonesia and the sector has been fully supported by infrastructure, including research and development as well as government regulations in pricing. The sector's vulnerability to climate change requires adaptation strategies for irrigation, biotechnology and the selection of alternative crops.

Although Indonesia is the third largest country regarding global rice production, it is still a net rice importer probably due to non-optimal production techniques in combination with large per capita rice consumption. In fact, Indonesia has the largest per capita rice consumption in the world, with Indonesians consuming around 140 kg of rice per person per year. In principle, the current national production of rice should be sufficient to feed the country if the recovery of rice from paddies is satisfactory and import policies are revised based on national demand and production.

The expansion in paddy area has been accompanied by an even higher growth in rice yield. The average national rice yield is now higher than the global average. In Indonesia, the average rice yield is 4.69 tons per hectare, compared to the global average of 4.15 tons per hectare and the average for Asia, which is 4.21 tons per hectare. However, inefficient milling technologies and polluting production processes mean that the sector does not meet the accepted quality standards and an economical by product utilization due to their small size.



On the other hand, as discussed in previous section, so far Indonesia is also one of the rice importers whereas in principle it could very well enjoy a huge rice surplus and thus enter the growing export market. The export price of rice could be an incentive; although currently it shows a decreasing trend, it is expected to increase in the long-term.

2.1.2. Rice production in Indonesia

According to the Indonesian Ministry of Public Works (MPW), approximately 84 per cent of Indonesian rice area was irrigated, while the remaining 16 per cent was rain fed. Increasing use of high yielding rice varieties, such as Ciherang, Inpari13, Sintanur, and Mekongga by farmers both on and outside of Java is improving yields. Therefore, post forecasts for the model year (MY) 2017/18 show Indonesian rice production reaching 79.2MMT of paddy and 37.4MMT of milled rice equivalent.

Growth pattern of paddy production

Indonesian national production of paddy rose to 79 million tons in 2016 from 74 million tons in 2015, and from 70 million tons in 2014. Therefore, with this growth rate, Indonesia will not need to import rice and it could even become a net exporter of rice by improving its productivity. The country will continue to increase agricultural production through various means, including agricultural mechanization. Through measures such as the provision of agricultural machinery assistance to farmers, the Ministry encourages mechanization of agriculture to further improve productivity.

Small holder farmers account for around 90 per cent of Indonesia's rice production, each holding an average land area of less than 0.8 hectares. The average growth rate in production is reported to be 3.5 per cent annually, as presented in following table.

Table 1: Rice production trend in Indonesia

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rice Production ¹	60.3	64.4	66.4	65.4	69.1	71.3	70.9	75.4	79.2

¹ figures are in millions of tons of paddy

Source: Food and Agriculture Organization of the United Nations and Indonesian Ministry of Agriculture

2.1.3. Major rice paddy producer in Indonesia

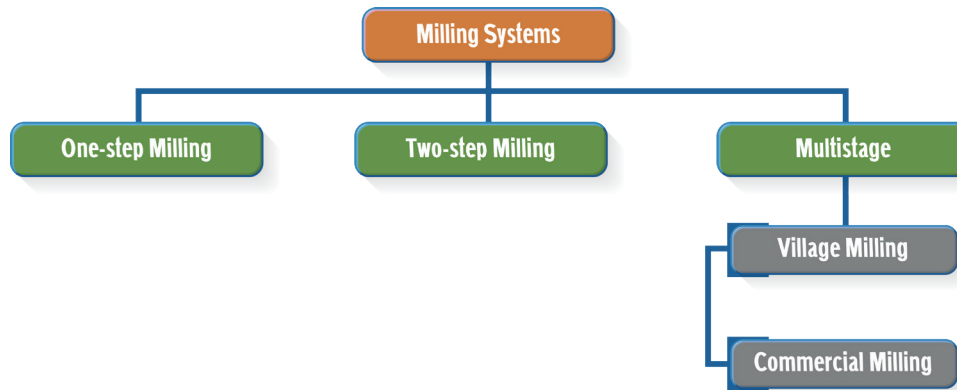
Indonesian provinces where the major rice paddy is produced are:

1. East Java
2. West Java
3. Central Java
4. South Sulawesi
5. South Sumatra

The provinces in the major island of Java, particularly East Java, West Java, and Central Java, accounted for 48.56 per cent of the total paddy production. Indonesia has also registered one of the highest growths in paddy production at 3.43 per cent per year from 1961-2017, as against the world average of 2.43 per cent.

3.0. RICE MILLING PRODUCTION PROCESS

The objective of a rice milling system is to remove the husk and the bran layers from paddy rice to produce whole white rice kernels that are sufficiently milled, free of impurities and contain a minimum number of broken kernels. The milling yield and quality of rice is dependent on the quality of the paddy, the milling equipment used and the skill of the mill operator.



Two types of processing are in practice. One is raw rice processing (rice shellers) and the other is parboiled rice processing (not common in Indonesia so far). Raw rice or white rice is obtained from untreated paddy, while parboiled rice is obtained by milling the pretreated paddy. Pretreatment is given to the paddy to improve the nutritional and cooking qualities of rice.

Milling systems:

Rice milling is done from one-step milling to multistage milling and will be discussed briefly here.

Milling, an important processing step of paddy (rough rice), is usually carried out to produce white and polished grain. A typical rice milling system is a multi-stage process involving a number of different processing steps, such as:

1. Pre-cleaning of paddy
2. De-husking or de-hulling
3. Paddy separation
4. Whitening or polishing
5. Grading and separation of white rice
6. Mixing of rice as per market demand
7. Weighing of rice

It is important to determine the appropriate paddy de-husking percentage in the sheller for various rice varieties to improve milling quality of rice during de-husking and whitening operations.

The milling out turn of paddy depends on several factors as;

- Variety of paddy
- Percentage of matured grains
- Moisture content in paddy
- Drying methods used
- Milling techniques (Rajkumar et al., 2004)



The most important parameters during milling are head rice yield (HRY) and kernel whiteness. These two parameters are used to define milled rice by their economic and quality context. The transaction price of rice has been strongly correlated to the size and shape, whiteness and cleanliness of the rice. Therefore, among the parameters affecting rice milling quality, the optimization of the sheller and whitener machines is necessary to maximize HRY and desired kernel whiteness.

Milling recovery from village mills is very low (53 per cent recovery on average, with the remaining 47 per cent produced as meal, bran, or husk), with milled rice having a high degree of broken grains. The by-products of milling are used in pig, fish and poultry production and, depending on the locality, payment is made through the retention of the by-products by the miller. Therefore, there is perceived negative incentive for the miller to improve milling recovery, as it would reduce the miller's revenue. Furthermore, the amount of whole kernels in milled rice is of little importance to rural families that are serviced by the mill.

3.1. Terminology used in milling

To understand the different objectives of rice milling, it is important to understand the generic terminology used in the sector:

- * **Rough rice:** Also called paddy rice as it comes from the field. Rice kernels are still encased in their inedible, protective hull.
- * **Brown rice, husked rice or cargo rice:** The least processed form of rice. It has the outer hull removed, but still retains the bran layers which are edible but of a chewier texture than white rice. Cooking time of brown rice is longer than milled rice.
- * **Milled rice:** Also called white rice, or rice after milling which includes removing all or part of the bran and germ from the rough rice.
- * **Milling recovery yield (MRY):** Total milled rice obtained out of paddy; expressed as weight percentage of milled rice (including broken) from paddy. The maximum milling recovery is 69 to 70 per cent depending on rice variety, but because of grain imperfections and the presence of unfilled grains, achieved in milling recovery is less than 65 per cent. Some village type rice mills have 55 per cent or lower milling recovery.
- * **Head brown rice yield (HBRY):** This is more or less same as milled recovery yield (MRY).
- * **Milling degree:** A measure of the amount of bran removed from the brown rice.
- * **Head rice:** Milled rice with a length greater or equal to three quarters of the average length of the whole kernel. It is often expressed on a percentage paddy or rough rice basis (on 14 per cent moisture content basis).
- * **Head rice yield/recovery (HRY):** Weight percentage of head rice (excluding broken) obtained from a sample of paddy. Under controlled conditions, head rice recovery can be as high as 84 per cent of the total milled rice or 58 per cent of the paddy weight.

Commercial rice mills turn out 55 per cent head rice on average, whereas head rice recovery of village type rice mills is in the order of 30 per cent.

- * **Whole kernel:** A milled rice grain without any broken parts.
- * **Broken kernel:** Also called broken. Depending on the rice mill this can be only one fraction or it can contain several fractions of different sizes:
 - **Large broken kernel:** 50 to 75 per cent of the whole kernel size
 - **Medium broken kernel:** 25 to 50 per cent of the whole kernel size

- **Small broken kernel:** Less than 25 per cent of the kernel size, cannot pass through a sieve with 1.4mm diameter holes
- **Chips:** Fragments of a kernel which pass through a sieve with 1.4mm diameter holes
- * **Impurities:** Materials in the rice that are not part of the milled rice kernel. May include stones, husk, chaff, weed seeds, etc.

3.2. Chronology of rice milling history

The traditional way of processing rice by hand, pounding rice in a mortar with pestle, is no longer practiced by farmers. Currently, paddy processing and milling in the province have mostly been performed mechanically at the rice mills. This is because the traditional method is laborious, inefficient, and has limited capacity. Efficiency and productivity of the finished product can be increased by improving machinery usage for both harvesting and processing.

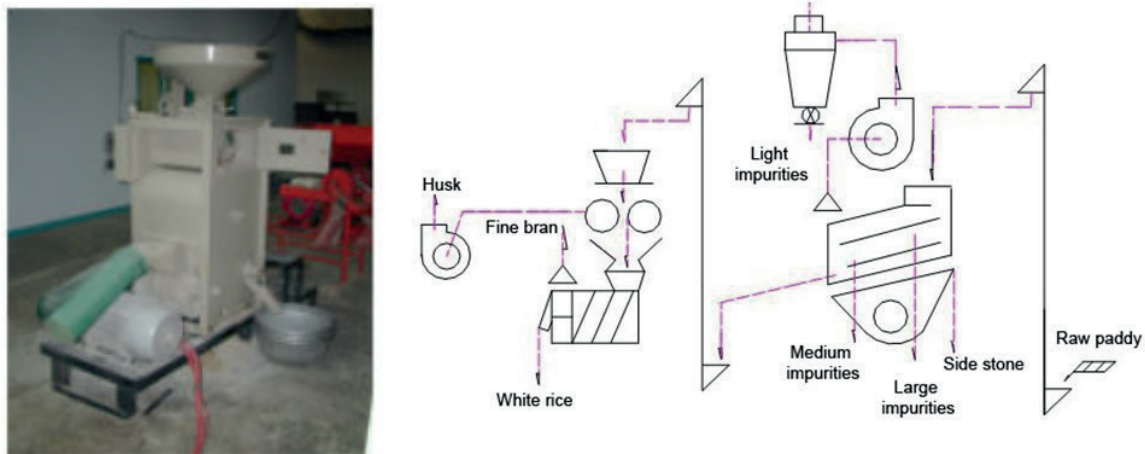


Figure 1: Example of machinery in rice milling unit

Distribution of small-scale rice mills in Indonesia is concentrated in an area of paddy growing regions, which cater to the demand for rice throughout the country. Since most farmers practice subsistence farming, and rice is milled according to consumption, these small-scale rice mills can be operated throughout the year. However, the quantity of milling changes in accordance with demand; for example, peak demand is during harvesting and before fasting month.

3.2.1. Mini rice mill plant

The mini rice mill plant consists of a paddy cleaner, de-stoner, paddy husker (rice huller), separator, rice miller (dry polisher), bucket elevator and blower. It can produce satisfactory quality white rice with a comparatively higher percentage of broken rice. It is considered to be a suitable and more practical means of milling for a small farmer or small scale rice producer.

3.2.2. 0.5-1.5TPH Compact small rice mill plant

Compact milling machinery is available to small millers. It is more efficient due to the following features:

- *Automatic operation from the paddy loading to finished white rice*
- *Higher milling yield and less broken rice*
- *High quality white rice, low temperature rise*
- *Compact structure, small space occupation*
- *Convenient installation and maintenance*
- *Low investment and high return*



Figure 2 : A compact rice milling unit of 1.5TPH capacity

3.3. Factors affecting the quality of rice

Separating the husk from the brown rice

Rice husk and broken rice are removed from the husked material at the winnowing section which is referred to as the aspirator. In the aspirator, the material is divided into a mixture of brown rice, unhusked whole grains, and rice husk. The husked material is taken out by the suction of the aspirator fan. After passing through the rubber roll husker, the brown rice and unhusked paddy grain will move to the next step: the paddy separator.

Performance of rubber roller de-huskers

In a properly adjusted rubber roll husker, husking efficiencies can be as high as 95 per cent, but generally husking efficiencies are often lower. Besides machine adjustments, uniformity of grain thickness will affect husking efficiency. If a mixture of varieties is fed into the husker, or paddy grain that did not mature uniformly in the field, husking efficiencies will be lower. Capacity of the rubber roll husker varies and depends on the size of the rubber rolls. As an example, a 10-inch wide by 10-inch diameter roller has a rated milling capacity of 2.5 tons per hour of paddy.

Advantages of rubber roller huskers

Replacing steel/disc rollers with rubber rollers results in the following advantages:

- *Reduced breakage of milled kernels*
- *High hulling efficiency*
- *By-products are free from sand and silicone*
- *Brown rice kernels are not scratched, higher quantity of bran compared to under runner disk husker*
- *Machine can incorporate a husk separator*
- *Compact in comparison to disc husker*
- *Low vibration*



Disadvantages of rubber roller huskers

- Capital cost of machine is very high
- High wear rate of rubber rolls results in increased operating costs
- Higher power consumption compared to disc huller
- Maintenance cost high as more spare parts to be replaced
- Requires skilled operator
- Life of machine is shorter than disc huller and steel huller



Figure 3: Rubber roller huskers

Appropriate rubber rolls spacing leads to increased husking percentage and reduced rice breakage in the sheller. Rice milling quality is significantly affected by whitener rotor speed and paddy moisture content.

3.4. General guidelines for optimum lifespan and performance of rubber rollers

- Paddy should be at approximately 14 per cent moisture content and having uniform moisture.
- Before starting the husker, check the alignment of the rubber rolls. Remove any grain present between the roll.
- Adjust the clearance to nearly 0.5 mm (or) the rolls should be just touching each other.
- After starting the machine check the hulling efficiency. If the efficiency is less than 90 per cent, decrease the clearance until the hulling efficiency is about 90 to 95 per cent.
- In operation the feed gate above the rollers must be fully opened so that the rollers will wear out uniformly.
- Check hulling efficiency at regular intervals as the rubber rolls wear.
- Before stopping the machine, close the feed gate completely and clear the rolls of paddy.
- The roller's axis must be in perfect line with that of hub and shaft.
- The roller surfaces must be aligned and must be kept at an equal distance whilst rotating.
- While changing the rolls, the bigger roll should always be mounted to the fast moving shaft.
- Spare rolls must be kept in a dark room and if possible should be packed well to protect them from light and sudden changes in temperature.
- The huller should be cleaned after every day of operation.
- The side baffle plates on each side of the rubber rolls should be checked each day to see that there is no leakage of paddy between the plate and the rubber roll surfaces.
- Whenever rubber rolls are replaced, it should be ensured that their end faces are in line.
- The cover plates of the cooling chamber inside the rubber roll housing should be removed once a week and cleaned thoroughly.



Note 1: *Reported performance of thermos-resistant, Hi Life Rubber Rollers is to change after 600 tons of paddy processing. Almost 8,000 nos. of 75 kg bags of paddy at a speed of 5 tons/hour in 24 hours running condition).*

Note 2: *The highest HRY value was reported to be obtained at the paddy de-husking rate of 80 per cent. At this de-husking rate, the desired kernel whiteness was achieved.*

4.0. HOW TO PRODUCE GOOD QUALITY MILLED RICE

There are generally three major requirements for producing good quality milled rice discussed here, but this is not an exhaustive list.

4.1. Quality of paddy

The starting quality of paddy is most critical and should be of good quality. Paddy should be at the right moisture content (around 14 per cent) and have a high purity before milling.

Characteristics of a good quality paddy

- *Uniformly mature kernels*
- *Uniform size and shape*
- *Free of fissures*
- *Free of empty or half-filled grains*
- *Free of contaminants such as stones and weed seeds*

Indicators for good quality milled rice

- *High milling rice recovery*
- *High head rice recovery*
- *No/minimum possible discoloration*

Effect of crop management on paddy quality

Many crop management factors have an impact on the quality of paddy though often they are beyond the control of rice millers.

- *A sound paddy kernel, one that is fully matured and not subjected to physiological stresses during its grain formation stage.*
- *Timely harvesting, threshing, drying, and proper storage of paddy before milling.*
- *Mixtures of chalky and immature kernels, mechanically stressed grain during harvesting threshing.*
- *Delays in drying, and moisture migration in storage can result in broken and discolored milled rice.*
- *Blending/mixing different varieties with different physico-chemical properties.*

Purity is related to the presence of material other than paddy and includes chaff, stones, weed seeds, soil, straw, stalks, etc. which can reduce milling recoveries and the quality of rice and increases the wear and tear on milling machinery.

4.2. State-of-the-art equipment for milling

It is not possible to produce good quality milled rice with poor milling equipment even if the paddy quality is optimal and the operator is skilled. It is strongly advised based on production size and time to replace equipment with more efficient alternatives. These alternatives can seem expensive but in the long term they work out to be cheaper when routine operational cost is considered. In addition to efficient process technologies, it is also important to service and maintain the mill properly. The rice mill should always be clean and well maintained.



Figure 4: A state-of-the-art rice mill

4.3. Operator skills

Small rice mill operators are often untrained apprentices who picked up skills on the job. To improve productivity and product quality, it is important to upgrade the skills of the operator, to ensure skilled operation.

In small mills, operators are seen continually adjusting valves, ducts and screens, which is an indication that the operators are not qualified and do not have the required skills. Generally in properly designed and operated mills there should be very few adjustments required to the machines once a steady state in the grain flow is attained. In addition, rice mills are often dusty and dirty, with the ducts and bearings worn out. Operators must be trained not only in operation, but also in mill maintenance, which is crucial to improve rice quality.

Losses estimated in rice milling that may be attributed to poor paddy quality, machine limitations, or operator inexperience, is anywhere from 3 to 10 per cent of potential yields.



5.0. RICE MILLING YIELDS

Milling yields are determined by several factors including paddy variety, crop history and type of milling equipment used.

Potential yields can be determined using optimum quality paddy dried to 13 - 14 per cent moisture content using laboratory milling equipment. Milling yields in the real world are often much lower. The table below lists some typical data for milling recovery and head rice recovery (both based on paddy weight) for various milling systems.

Table 2 Typical data for milling recovery and head rice recovery (both based on paddy weight) for various milling systems

Milling process	Milling recovery %	Head rice recovery %
Potential (laboratory)	68-72	50-58 ¹
Single stage village mill (Engleberg steel mill)	50-55	15-30
Compact rice mill (two stage single pass village mill)	>60	40-50
Multi stage, modern rice mill	65-70	45-55

Depending on variety

5.1. Quality problems in rice milling

There are numerous factors that determine the final quality of rice produced by the rice mill. These factors are mentioned as below:

- **Under-milled rice:** Under-milled rice is under-polished rice, or rice with bran streaks left in it which have short storage life because of the high oil content of the bran.
- **Broken grains:** Grain breakage is a result of fissuring, which occurs naturally in the field due to daily changes in temperature and relative humidity and also improper management of grain at all post-harvest operations. Improper drying techniques often lead to fissuring in grain, or re-wetting of stored paddy, and improper milling techniques.
- **Discoloration:** A general discoloration of the entire rice kernel occurs if wet paddy is left undried for extended periods. The wet grain will heat up, causing the grains to turn yellow or tan.
- **Chalkiness:** If the kernel is opaque rather than translucent, it is known as chalky which downgrades milled rice. Chalky grains are more brittle than non-chalky grains and can break more easily during milling.
- **Damaged kernels:** Damaged rice kernels are those which are fully or partially darkened as a result of insect, mold, water, or heat damage.
- **Impurities:** Impurities in milled rice are a sign of improperly cleaned paddy prior to milling or contamination of rice during milling.

5.2. Modern rice mills

To take care of the problems mentioned above, a modern, improved method of processing is employed. This method of milling encompasses cleaning, drying of paddy before storage and/or processing, de-husking, aspirating of husk, separating paddy and brown rice, polishing to remove bran and grading rice and broken and color sorting to remove colored and infested grains.

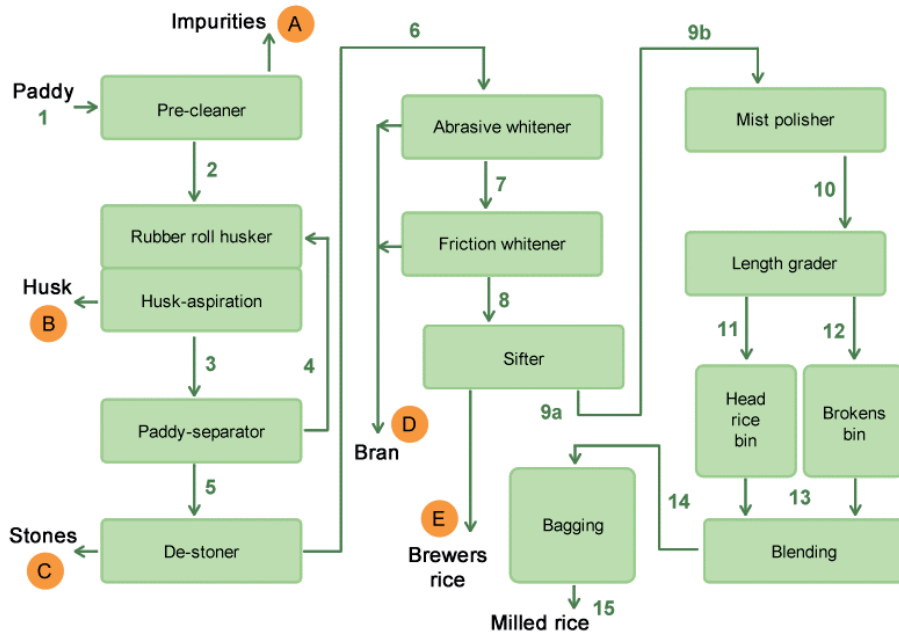


Figure 5: Modern rice mills scheme

6.0. WHY RECP IN RICE MILLS?

CONTEXT

In the present context of global competition and increasing pressure on natural resources and energy, every stakeholder is exploring the possibilities of improving the yield, from conserving raw materials to reducing resource consumption, such as energy. This manual discusses the yield/recovery of rice, by-products and their effective utilization, energy requirements for rice processing and environmental concerns and mitigation measures.

Small rice millers in Indonesia use a single diesel engine to turn one shaft with several belts that run all different shakers, transporters, mills and polishers. As per RECP audit assessment during 2016, an average of 20 liters of diesel is used to mill one ton of rice, equivalent to 65 kWhr per ton. For rice sellers (without parboiling), only 40 to 45 kWhr per ton is used in India and other rice growing/milling countries in the region.

RECP focus in the rice sector

RECP application in the rice sector is focused mainly:

1. During harvesting (Not under control of Rice Mills)

For the rice crop, the harvest time is often determined by the visual appearance, color, and moisture content of the grains. When the crop ripens, rice grains will be filled and tight, the grain color changes from green to olive-green to yellow and the moisture content drops between 18 per cent w.b. and 22 per cent w.b. [on weight-basis]. Grains should be firm but not crumbly when pressed between the teeth.

Threshing

Threshing is the physical process of separating the grains from the rice straw and the panicles. Harvested paddy should be threshed simultaneously on the day of harvest. Rice straws and panicles that are wet from overnight rains or morning dew must be field-dried before threshing. However, this is beyond control of millers.

2. Post harvesting

Drying

Drying is the process that reduces the moisture content of the rice paddy down to a safe level where rice can be properly milled and stored. Delay in the drying process, incomplete drying or ineffective drying will reduce the grain quality and result in post-harvest losses.

1. *Sun-dry the wet paddy by spreading the grains evenly on a plastic sheet or a canvas in a layer about 4 to 5cm deep. Turn over the paddy every 30 minutes using a garden rake and by using hand and foot, tenderly spreading the grains as they dry. Slow drying of the rice paddy will prevent cracking. By contrast, quick and fast drying will cause the grains to crack and will result in many broken grains when milled.*
2. *Ensure that the surface temperature of the rice paddy being dried does not rise above 36°C or is kept lower than 36°C. In stored grains, both in sacks or canvas bags with inadequate drying, the paddy temperature can suddenly rise above 36°C. This may mean there is a high moisture content and the rice paddy may germinate under such conditions.*
3. *Slow drying is preferable to avoid the cracking of rice grain, and if the temperature rises over 36°C, the percentage of breakage might increase.*
4. *Don't mix the paddy with 5 per cent different moisture content because it causes the production of fermentation and mold. Also, it is difficult to make the moisture of paddy even before milling.*



Cleaning

Cleaning is the process to remove rice straw chaff, foreign matter and immature/empty grains within paddy after threshing and drying. A high percentage of chaff, or foreign matter (including bits of soil, sand, small stones, metal debris, pieces of plastic or paper, twigs and branches, bits of wood, weed seed, other grains, chemical and poisonous matter) will increase the cost of wear-and-tear and spoilage to the mill operator's machine.

The importance of cleaning is as follows:

- To remove foreign matter, broken and immature grains.
- To increase milling efficiency.
- To decrease damage to the machine.
- To decrease running cost, due to less wear of consumable parts
- To keep the percentage of foreign matter, broken and immature grains less than 1 per cent, in order to increase mechanical efficiency and reduce energy consumption by more than 5 per cent.

To decrease post-harvest loss

- Prevent broken rice. With every 5 per cent of broken rice avoided, milling recovery of head rice increases by 10 per cent.
- Avoid immature grains. Immature grains decrease the milling recovery rate and the mechanical efficiency of the rice milling.
- Use a winnowing tray/ basket and mechanical cleaners.

3. Milling

Rice milling is the next key stage in the post-harvest chain. The good grain is milled through mechanical means to remove the outer skin, hull, and bran to reveal the white kernel and endosperm of the grain that is utilized as a food product for human consumption. By-products, such as germ and bran, can also be collected and utilized as valuable products.

During milling, in addition to product yield and quality as discussed in previous sections, energy conservation and by-product utilization are vital and are discussed below:

1. *To reduce electrical energy consumption, replace inefficient equipment like blowers, pumps, transmission systems, oversized and inefficient electrical motors, variable frequency drives, etc. Energy efficiency can be improved by 20 to 40 per cent by replacing inefficient blowers with efficient bran blowers; hullers and whiteners with new systems; and canvas and aluminum buckets with nylon and plastic buckets for elevators.*
2. *Gasification technology is widely used as an off-grid solution, especially in countries with high energy costs or mill having no access to grid electricity. This technology can reduce 70 per cent of DO consumption in dual fuel diesel engines and total DO consumption by replacing the dual fuel engine with a 100% gas fuel-based engine. Cleaner, fluidized-bed gasification technology preferred, as conventional downdraft gasifiers produce large amounts of tar.*
3. *To increase the economic potential of rice milling, the second by-product, bran, could be used to produce rice bran oil. The vegetable oil content of rice bran is 22 per cent, for which the retail price of refined bran oil is about \$3 to \$5 per liter due to its low/no cholesterol content. Rice bran is now often used as a low value feedstock for animals.*

6.1. Objectives of the RECP study

The combined pressures of industrial development due to increased product and services demand, urbanization and population growth are increasing demand for resources including energy. Improved access to clean energy and greater energy efficiency critical to the sustainable future envisaged in the 2030 Agenda and the Paris Agreement on climate change. However, access to clean energy in itself will not be enough. To ensure long-term sustainability, it is also crucial for clean energy to be directed into productive uses that help create jobs and boost income generation.

The objectives of RECP implementation in rice mills are as follows:

- * Develop tools and techniques to carry out an RECP audit of the rice mills
- * Technology audit to identify low yield and high percentage of broken rice
- * Energy audit to identify energy efficiency measures and to provide guidelines to optimize energy usage per unit of product
- * Identify techno-economically viable RECP measures and categorize them into:
 - *No cost RECP measures like control on purchase quality of paddy*
 - *Low cost RECP measures like good housekeeping and process parameters control*
 - *Medium cost RECP measures, such as paddy drying technology*
 - *High cost RECP measures related mostly to production technology and by-product valorization technologies*
- * Support in developing bankable Detailed Project Reports (DPRs) for cost involved RECP measures, e.g. production process upgradation and valorization of biomass
- * Link up financial institutions (FIs) to the micro/SMEs for implementation of RECP measures, although FIs have little or no interest in micro-sector
- * Capacity building of all local stakeholders in RECP in the rice milling region

6.2. Activities and expected outcomes of RECP implementation

Activity 1: Resource use and technology analysis

One of the critical tasks of this activity is a quick sectoral scoping to identify the major areas, such as current raw material to product ratio (generally known as yield of brown/milled/head rice in this sector), quality of product and by-products and economically viable usage of by-products, input resources used like energy, water and packaging materials. Another area is quick scan of technology used and its impact on resource usage, productivity and product quality. A guidance document on existing techno-economically viable efficient technologies relevant to size of production will be helpful and provides supplier address and contact details.

Activity 2: Capacity building of local service providers (LSPs) and SMEs

For the application of RECP, capacity building of users and various stakeholders is the first and most important activity. It is proposed that this should commence with an introductory workshop/RECP clinic to share the basics of RECP and its implementation mechanism.

It is necessary to create national/local capacities among services providers (including trainee experts) or technology providers in the micro-sector of rice milling that would help in the adoption of RECP measures. The trainees, experts and technology providers identified during Activity 1 will be trained in RECP basics, concept, techniques and methodology in a classroom, followed by on-the-job training while conducting an RECP audit.



After the RECP clinic and formal capacity building module, a kickoff/quick scan visit shall be conducted for selected units to identify obvious RECP measures and major issues of the small millers. A quick RECP scan with preliminary recommendations based on the experience of the expert/implementing agency will serve as a motivating tool to understand the benefits of RECP.

Activity 3: Implementation of RECP measures

The RECP programme and methodology are also designed to facilitate the implementation of identified and agreed techno-economically viable RECP measures in the micro-sector rice mill selected during and after the project. In addition to providing assistance in implementation of low-cost RECP options, micro-enterprises/units will also be supported through development of ready to use DPRs to facilitate decision-making, especially for cost involved options and also for bank financing. This document will share some simple examples of DPR especially for valorization of biomass from rice milling.

Activity 4: Facilitation of innovative financing mechanism

One of the objectives of this manual is to facilitate the implementation of RECP measures through innovative financing mechanisms without creating market distortion. Efforts are in progress to develop financial mechanisms tailored to micro-enterprises which generally have low credentials and often lack the collateral required by financial institutions. In many countries, the national government supports finance for the procurement of paddy, but finance for technology upgrades and resource-efficient technologies is often not in place.

7.0. FACILITATORS TO ASSIST RECP IMPLEMENTATION

Small- and micro-industries on their own may not be competent or have sufficient human resources to improve resource efficiency and reduce waste generation for several reasons, including industry priorities and understanding of the RECP concept. Several types of national/regional/local organizations can act as facilitators/local resource person (LRP) to help companies to identify and implement RECP measures. Facilitators could be from organizations such as sectoral industry associations, RECP associations, research institutes, consultants, RECP centers, NGOs, universities, chambers of commerce, etc.

With the help of facilitators, RECP-related national/sectoral programmes will improve resource efficiency and associated benefits in participating units, for example:

- *Help industry to reduce production/processing costs and mitigate risk of rising resource prices*
- *In-house capacity building to develop necessary skills to analyze data and RECP experience within an organization and as an individual*
- *Reduce fugitive emissions and noise pollution (major area in rice milling) from processing and related activities*
- *Contribute to the environment, through reduced wastes and greenhouse gas emissions (from energy conservation, usage of carbon neutral fuel for energy sources and avoiding methane generation from biodegradation of stored by-products like rice husk)*



8.0. HOW TO IMPLEMENT RECP IN YOUR MILL

To assess RECP potential and implement techno-economical RECP measures, these are the 3 logical steps to take:

1. Source inventory

Where excess resources are consumed and wastes & emissions generated?

2. Cause evaluation

Why high resources are used and wastes and emissions generated?

3. Option generation

How can resource consumption be optimized and waste causes be eliminated?

How to initiate RECP in your mill?

After the 3 logical steps discussed above, how do we initiate implementation and internalize RECP?

RECP is achieved by:

1. *Applying know-how*
2. *Improving technology*
3. *Changing attitudes*

RECP calls for:

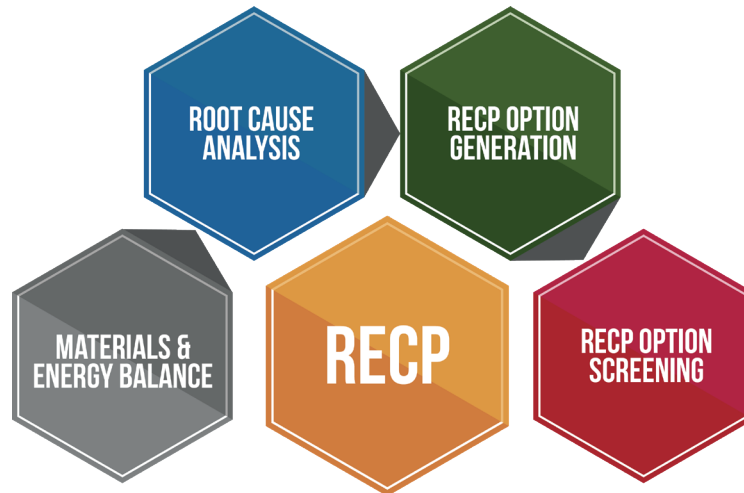
1. *Management commitment*
2. *Operators/shop floor employees' involvement*
3. *Organized approach (methodology)*

A user friendly methodology for the micro/informal sector has been developed because this kind of methodology:

- * *Tailors to small- and micro-companies in developing economies, which differ in many ways from core sector industries and multinational companies.*
- * *Focuses on product yield/recovery and energy usage and waste, which is less visible than waste, water and raw materials.*
- * *Explains in a simple/user friendly way how RECP is applied in practice with examples, because all companies are different.*
- * *Focuses on how to overcome barriers such as lack of priorities, time limitations with small/family owned units lacking recording and reporting.*
- * *Makes up for the lack of practical company examples in Indonesia.*

This methodology is based on:

- * The Resource Efficient Cleaner Production (RECP) strategy, that is the resource optimization & prevention of waste, systematic approach simplified for micro-sectors and aimed at continuous improvement.
- * Several CP/RECP existing audit methodologies exists, which are tailored for micro-industrial sectors.
- * Real practice experience from RECP/CP assessments carried out as part of the global National Cleaner Production Centers programme across 60 countries.



8.1. Methodology of RECP audit for micro-industries

The proposed RECP methodology for the micro/informal sector is divided into 10 tasks which are simple and user-friendly. Although micro-industries can also implement parts of RECP without following a methodology, this will not provide comprehensive options and may not be sustainable.

- * **Task 1:** *Establishment of small RECP team in participating units*
- * **Task 2:** *Collection and compilation of baseline data (production, consumption of raw materials, energy, water and waste generation) before RECP*
- * **Task 3:** *Estimation of RECP potential as per benchmark and/or based on experience of implementing agency*
- * **Task 4:** *Identify RECP audit focus (generally entire unit is audit focused in micro-sector unless focus is specifically on by-product utilization)*
- * **Task 5:** *Material (yield) and energy balances (primary) for selected focus areas*
- * **Task 6:** *Cause analysis for possible lower yield, high resource consumption and waste generation*
- * **Task 7:** *Identify RECP options to apply RECP techniques*
- * **Task 8:** *Select option for implementation based on feasibility analysis and available resource*
- * **Task 9:** *Start implementing RECP solution from Step 8 and solicit external assistance from project*
- * **Task 10:** *Record and report implementation results including untold experiences*

Task 1: Establish RECP teams in participating units

After the RECP clinic/awareness workshop, the company RECP team will be established and hold a half-day first meeting to agree on each member's roles, as well as how and when to carry out the pre-assessment. In addition, the team should inform staff about the pre-assessment and composition of team proposed as follows:





- *Decision-making power for implementation of agreed on RECP options*
- *Knowledge of production processes, resource usage and cost related to resources*
- *Some knowledge/idea of the environmental impact of their activities*
- *Access to resource consumption, purchase/sale data*

Preferred positions/responsibilities

- *Owner/CEO of company (in micro-sector most decision-making powers are with the owners)*
- *Those responsible for purchase and sale record*
- *Those responsible for maintenance*

Task 2: Collection and compilation of baseline data (production, consumption of raw materials, energy, water and waste generation) before RECP

This information is generally obtained from existing documentation (purchase and sale records), interaction with staff, a walkthrough of the plant and if necessary simple monitoring on the spot.

Information collected should include:

- *General information on unit operations*
- *General production flow chart (simple block diagram with inputs and outputs)*
- *Production data for the past year or the past month (representative)*
- *Production and resource consumption data and costs for the past year or past month*
- *Inventory and specification of major equipment*
- *Overview of information collected for each process step/department*
- *Possible waste generation quantity/quality*

Task 3: Estimation of RECP potential as per sectoral benchmark and/or based on experience of implementing agency

Production and resource consumption data should also include:

- *Resource used (raw material, recovery/yield, important auxiliaries including water)*
- *Costs/rates/unit and total input and sale cost per year*
- *Energy (all sources) consumption and costs*
- *Fuel mix (diesel, coal, CNG, etc. both for processing and paddy drying)*
- *Electricity bills from utility companies if purchased or alternative fuel consumption record*
- *Captive power generation if any*

Task 4: Identify RECP audit focus

In industries in general, and particularly in the micro-sector, the whole unit is considered as the focus for audit. In small conventional rice mills, by-product utilization is techno-economically viable individually and/or collectively. This can be coordinated with a cluster of units located within manageable distances for ease of transportation of the by-product.



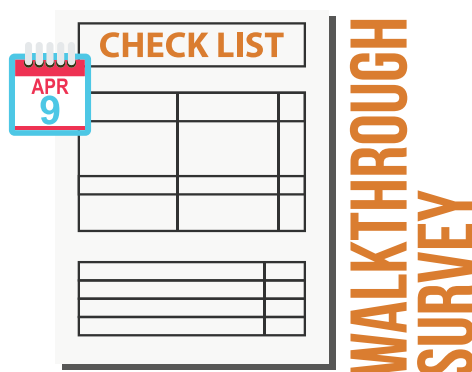
For selecting the audit focus for RECP implementation, the following is advised:

- *Select timings requiring the minimum possible down time of production*
- *In seasonal production units, conduct RECP while the unit is in operation*
- *Ensure minimal resources are required and implementation is easy, with quick results to motivate the stakeholders*

Walkthrough survey by RECP team with external members

Purpose of walkthrough audit

- *Better understanding of process/production for all team members*
- *In-depth observations of the production process steps*
- *Familiarity with resource consumption/waste generation areas*
- *Receive feedback from production/shop-floor staff about generic problems/concerns*
- *Familiarity with basic log/control sheets for process control*
- *Recording of obvious visible losses of energy and materials*
- *Obtain information about quantities and costs of waste/low value by-products wherever applicable*



The team should prepare a focus area flow chart for each of the selected focus areas as follows:

- *List the different steps of the process and draw a box around each step*
- *List the most important inputs (resources) for each step on the left, such as raw material, energy, water and auxiliaries*
- *List the most important outputs for each step on the right, such as by-products/solid wastes, waste heat, emissions, noise and wastewater*
- *List the intermediate and final products between the steps, such as brown rice, polished rice*
- *Add any information on units of measurement for inputs and outputs and quantities and costs that is already available*

Task 5: Material (percentage yield of main product and by-products) and energy balances (primary) for total unit.

What goes into a process must come out somewhere else? Based on the process flow chart and quantified inputs and outputs prepared in the previous tasks, it is important to work out the “balance” of the inputs and outputs. Any inputs that do not come out as useful outputs (e.g. rice head, broken/pin rice) are considered “losses”.



- Try to “balance” inputs (procured paddy not dried) and outputs including by-products and wastes if any (what goes into a process must come out!).
- Only primary balances from data on purchase and sale from records and reports is sufficient for micro-sectors. Only in the case of biomass valorization and oil recovery feasibility from rice bran does secondary data need to be arranged.
- Identify and establish percentage yield, “losses” – energy (waste heat, inefficient usage), products including quality loss, materials including by-products
- Calculate costs of low yield and losses



Be practical. This looks like a difficult task, but it is easy so long as the primary data is reliable and representative. To start RECP primary data is good enough and secondary data is

Task 6: Cause analysis for possible lower yield, high resource consumption and waste generation

Cause analysis is the most creative phase of the RECP programme and methodology. It is a brainstorming session of the RECP team, owners, and other sectoral and/or RECP experts.

After the successful completion of Task 4 and Task 5, RECP cause analysis becomes easy. Remember to keep in mind all eight techniques of RECP and to look into the causes related to each of the RECP techniques.

Ask the questions: Why is the yield lower than the benchmark? Why is the percentage of broken product higher than normal? Why is the quality of product affected (such as in mold and fungus infestations)? Why is specific resource consumption high (material, energy, water and auxiliaries), leading to losses? Keep asking until you have found the “root cause.”

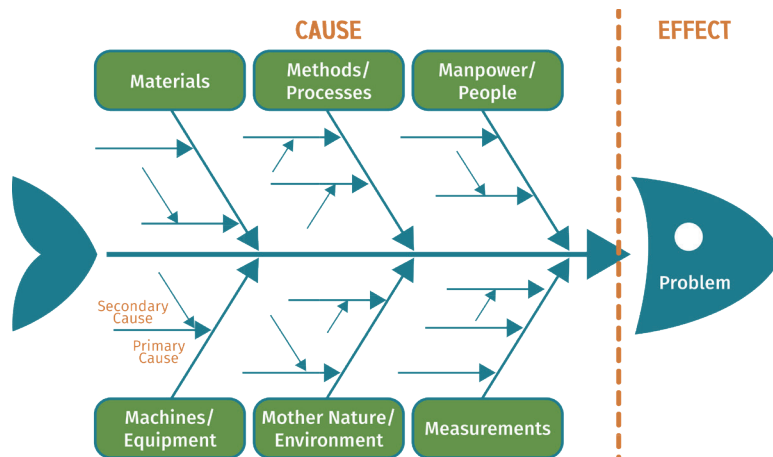


CAUSE ANALYSIS

Look for different causes:

- Human resources (awareness and technical capabilities)
- Existing practices (conventional)
- Machine/technologies
- Material/process parameters

For cause analysis, we can use the fish bone diagram to establish the primary, secondary and tertiary causes.



Material losses with an energy-related cause

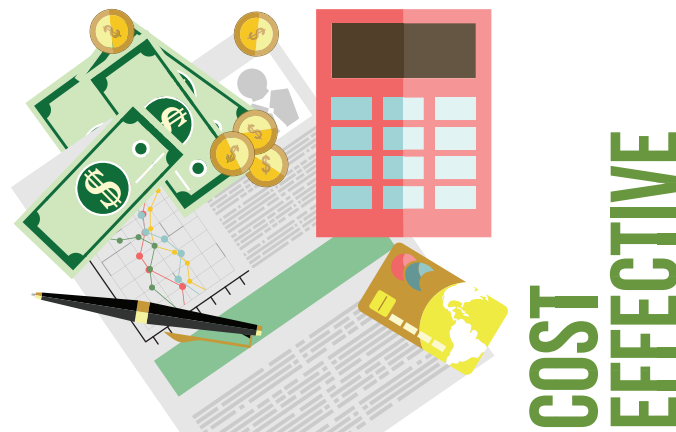
- Loss of paddy quantity and quality due to open solar drying (no paddy drying equipment), vulnerable to weather and infestation
- Low yield of head rice due to under/over drying of paddy having uneven moisture due to improper drying temperature control
- Excess broken percentage of rice due to fluctuation in power during shelling
- Energy losses with an energy-related cause
- Higher energy use in paddy drying due to poor control of hot air/poor combustion in dryer furnace
- High transmission and distribution losses caused by low power factor
- High energy losses in furnace/boiler due to high stack gas losses (more relevant to parboiled rice product)

Energy losses with a material-related cause

- Inefficient combustion caused by improper sizing of coal
- High steam consumption in dyeing process caused by too high liquor-to-cloth ratio

Poor product quality with an energy-related cause (non rice sector)

- Thin zinc layer caused by high temperature of zinc bath in galvanizing
- Uneven strength of forged products caused by low/non-uniform temperature in furnace



The most critical and important task is to continue asking “why” until you have found the real cause or “root cause” of the problem. For example *a common problem with low rice yield is often paddy quality (excess moisture). This is the root cause of low yield but not the only cause; it is necessary to look at all possible causes, including technology-related.*

Task 7: Identify RECP options to apply RECP techniques

After cause analysis, the next creative phase in RECP methodology is a brainstorm session with the RECP team and others external experts/local resource persons to identify possible RECP options from the cause analysis list. The focus must always be on the most important resources and easy to implement options.

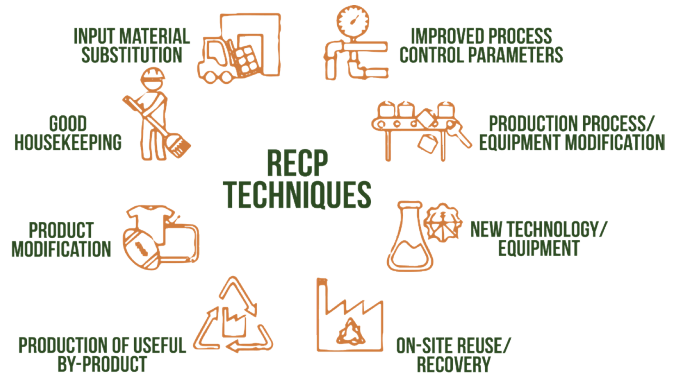
Ask the question: What can we do to reduce material and energy consumption and various losses using the proposed eight RECP techniques?

RECP options fall in the following categories RECP techniques

- * Good housekeeping
- * Improved process control parameters
- * Production process/equipment modification



- * *New technology/equipment*
- * *Input material substitution*
- * *On-site reuse/recovery*
- * *Production of useful by-product*
- * *Product modification*



After identifying and agreeing on options, categorize them into three groups:

- *Low/no cost easy to implement options that can be implemented directly (obvious options, low hanging fruits or LHF)*
- *Options that require further information and analysis (technical, financial, environmental including production quality)*
- *Options that can be considered at a later stage depending on resources (examples include co-generation from rice husk, briquetting of rice husk as fuel, oil extraction from bran in a cooperative approach)*

A few questions to be considered for RECP related option screening:

- *Which option/measure will best achieve the goal of RECP?*
- *What are the main benefits of RECP measure implementation?*
- *Does the necessary technology exist nationally or globally?*
- *Does necessary technical skill to operate, maintain and sustain technology exist?*
- *How much would it tentatively cost (implementation cost and operational cost)?*
- *What are other potential areas will be affected?*

Task 8: Select RECP option for implementation based on feasibility analysis and available resource

The purpose of this task is to determine which options are technically feasible, financially viable and environmentally desirable. Based on the feasibility analysis and priority of management, an action plan should be made, specifying in what order techno-economically viable options should be implemented.



Output of Task 8

- * *Proposal that is approved by management/decision maker*
- * *Recommended/selected options for implementation*
- * *How to make an action plan for implementing RECP options including vendor selection and soliciting technical and commercial proposals, such as a paddy drier*
- * *List of options that require further investigation, such as rice husk gasification, briquetting of rice husk and market for husk briquettes*

The RECP team is now equipped to allocate a ranking to each agreed option

- *Implementation in very short-term (e.g. <2 months)*
- *Implementation in short-term (e.g. 3 to 6 months)*
- *Recommended for implementation in medium-term (1 year)*
- *Recommended for implementation in long-term (>2 year)*
- *Recommended for further investigation or consideration at a later stage*
- *Non-feasible options*

Task 9: Start implementing the RECP solution from Step 8 and solicit external assistance from project

The purpose of this task is to kick-start the real, on the ground implementation of agreed technologically viable options with the following considerations.

- * *Implement feasible options in order of priority of management and return on investment*
- * *Monitor results and compare with before and after RECP implementation both in terms of financial and environmental benefits*
- * *Discuss findings/experiences both success as well as less successful with top management and project implementing agency*



Output expected from this task of implementation

- *Improved resource efficiency, reduced production costs, reduced environmental emissions and improved shop floor working environment*
- *Explain the project outcome to top management and plan the next steps*

Tasks involved

- *Step 9a: Performance evaluation of implemented options*
- *Step 9b: Record and report the results of RECP performance evaluation*
- *Step 9c: Evaluation meeting with RECP members followed by top management*

Without monitoring it will be very difficult to convince management that energy efficiency projects are beneficial to the company. You need to prove especially the financial benefits of implemented options to receive support for future projects.

It is also important to communicate (interim) results throughout this phase to management and staff to:

- * *Show management that RECP implementation is a good management tool for business in order to gain support for future projects*
- * *Reward staff for their efforts to improve resource efficiency and reduce waste generation and to encourage them to continue RECP with new options and sustain the implemented options*

Task 10: Record and report implementation results including untold experiences

Carry out the implementation as per resource availability and monitoring plan.

Record results for each option:

- *Economic results*
- *Environmental results*
- *Other results: Occupational Safety and Health, product quality, reduced rejection/second grade product, any other benefits*
- *Barriers encountered*

Results must be communicated to key staff in participating units. The implementing agency should document the results (both success as well as failure, if any) for wider dissemination of results throughout the sector.

The experience of the RECP team in RECP implementation will enable a technology-oriented resource improvement and by-product usage in the second cycle of the RECP implementation phase, which is in any case a continuous process.

8.2. Benchmarking

It is very important to be familiar with benchmarking from a similar type of product, process and size (production capacity) to compare a company's performance and work out RECP potential. The establishment of benchmarks of specific resource consumption allow the amount of raw material at one mill to be compared with the national average.

The study and identification of major sections and equipment responsible for low yield, high wastage and excess resource use like energy, is an opportunity for the identification of RECP application.



Some information on benchmark from small micro mills are discussed here as example:

Yield of rice (BRY, MRY and HRY)

- * *Electrical consumption in a rice cluster in India study indicated that specific energy consumption (SEC) is comparatively higher at 38 kWh/t of rice production in mill having 1TPH capacity as compared to the 2 TPH which is 23.09 kWh/t and average electrical consumption is 26.15 kWh/t.*
- * *As per the studies conducted by Waste Minimization Circles (WMC), the range of electrical energy is between 17.5–23 kWh/t. Therefore, benchmarks could be the 20 kWh but the target has to be agreed on by the RECP team as per real expected result. In case of other energy source used like diesel oil or steam relevant benchmark considering product quality shall be worked out.*
- * *The energy requirement in China for milling one ton of rice was 25 kWh or 6.9 l of diesel. The resulting of 0.25 ton of husk from one ton of rice can produce 100–104 kWh of electricity through a gas engine generator set yielding 85–115 kWh of surplus energy.*



9.0. RECP OPPORTUNITIES IN RICE MILLS

Generic RECP opportunities in rice milling including harvesting, post-harvesting and milling process related to yield and quality are discussed in Section 6. In this section, detailed RECP opportunities related to energy efficiency are elaborated.

Energy efficiency

Economic, environmental and social pressures for energy and material efficiency have been increasing in the past few decades, resulting in noticeable advances in process and product design and in making waste more recyclable and reusable. According to the World Energy Council, energy efficiency has a broader meaning than mere technological efficiency of equipment; it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic output. Energy efficiency is associated with economic efficiency and includes technological, organizational as well as behavioral changes. The importance of the energy intensity of national economies as an indicator of sustainable development was agreed in Agenda 21, which states that “reducing the amount of energy and materials used per unit in the production of goods and services can contribute both to the alleviation of environmental stress and to greater economic and industrial productivity and competitiveness”.

The rice industry is one of industries that consumes the most energy. However, by-products are a source of energy; if the rice husk is used as a fuel, the reduction in the use of rice husk would enable the rice industry to spare the rice husk.

The energy requirements for milling rice depend on the quality and type of grains, process, equipment and other parameters. These include grain quality, uniformity of grain size, grain hardness, quality of final product, type/capacity/age/combination of equipment used, fuel or power source, efficiency of drives and power transmission. A variety of factors affect the energy requirements in rice milling industries. Energy saving could be achieved by the following:

- * Energy efficient processes for paddy dryer systems
- * Energy-efficient electric motors
- * Efficient compressors and a routine audit to reduce losses
- * Less long power chains as well as uniform quantity of raw material
- * Contribution of processing waste and by-products to captive power generation
- * Use of energy-efficient processes and equipment
- * Recovery and recycling of thermal energy, proper insulation in parboiled rice mills, etc.

The world's greatest energy resource is the energy we currently waste. Eliminating unnecessary emissions associated with careless and inefficient energy consumption, coupled with more low-carbon alternatives, offers the most direct path to achieving enormous and sustained emissions reductions. Currently as well as the near future, energy efficiency will remain potentially the most important and cost-effective means for mitigating greenhouse gas emissions from industry.



9.1. Major energy consumers in rice milling

9.1.1. Energy efficiency in polishers

Faulkner et al. (1969) reported that the major portion of total energy consumed in milling of paddy is due to the polishing of rice, concluding that a polisher with finer emery grains consumed less energy, while the increase in speed and operating pressure resulted in a higher energy consumption which needed to be balanced. The power required per ton of rice varied with variety, degree of polish and number of polishers used (Sarda, 1966).

With such a variety of factors affecting the recovery of head rice and the energy requirements in rice milling undertaken largely in unorganized sectors, no comprehensive efforts appear to have been made for its assessment in Indonesia.



9.1.2. Energy efficiency in motors (main drives used in milling)

Motors are the main energy consuming equipment in any processing facilities and the following RECP measures will be looked into:

Replacing the existing inefficient motors with energy-efficient motors (EEM-1):

The efficiency of a motor is determined by intrinsic losses which can be reduced only by a change in motor design. Intrinsic losses are of two types: fixed losses independent of motor load, and variable losses dependent on load.

Fixed losses consist of magnetic core losses and friction and windage losses. Magnetic core losses (sometimes called iron losses) consist of eddy current and hysteresis losses in the stator. They vary with the core material and geometry and with input voltage. Friction and windage losses are caused by friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts.

Variable losses consist of resistance losses in the stator and in the rotor and miscellaneous stray losses. Resistance to current flow in the stator and rotor result in heat generation that is proportional to the resistance of the material and the square of the current (I^2R). Stray losses arise from a variety of sources and are difficult to either measure directly or to calculate, but are generally proportional to the square of the rotor current.

During the energy audit, like any other sectors rice mills were also observed, using motors which had been rewound many times in the past. Some of them are reported to be rewound more than five times. It was suggested to replace the existing motors which were already rewound more than three times, with EEM-1 labeled motors to reduce electrical consumption and losses significantly while in operation. The energy loss due to each rewinding is about 3 to 5 per cent and could vary depending on the quality of work.

Recommendations

All motors that had been rewound more than two to three times and under-loaded motors can be replaced with EEM-1 motors for energy savings. These motors are commonly found in all the rice processing industries including the parboiled rice mills.

9.1.3. Power factor improvement by installing capacitors

Most of the units have scope for improving this incentive percentage from 0.5 to 1.5 per cent. The power factor can be improved by the installation of capacitors and replacement of the derated existing capacitors.

9.1.4. Variable frequency drives

Variable frequency drives are used to drive the equipment according to speed by varying the frequency supply. The following advantages can be achieved by implementing variable frequency drives in both rice mills.

Reduction in energy consumption in motors is possible according to the following load conditions:

- * *Attain 95 per cent efficiency during the full load conditions*
- * *Maintain good power factor (PF)*
- * *Motors and equipment when overloaded gets protected and also power quality will be maintained*
- * *Protection over and under voltage, over temperature and other faults are protected by the VFD*

- * *Reduction in maintenance cost due to frequent failures*
- * *Maximize power distribution system*
- * *Eliminate mechanical shock and stress on power trains (couplings, belts, drive shafts, gear boxes, etc.)*

9.2. Dos and don'ts in energy conservation

- * *Don't emphasize mistakes from the past. It is better to talk about the present.*
- * *Don't worry too much about theory or principles. Don't spend too much time in discussion or analysis of problems in meeting rooms.*
- * *Don't think that an activity can be done perfectly from the beginning.*

It is necessary to do the job continuously by having experiences and judging by ourselves.

- *Do start with an activity that requires no or a small amount of investment.*
- *Do raise awareness so that all employees understand the necessity and importance of energy conservation and participate in it.*
- *Do start the activity now without postponing until tomorrow.*



10.0. MAIN ENVIRONMENTAL ISSUES OF RICE MILLING

Environmental issues related to rice milling depend on the process and technology used. Much of the discussion on resource efficiency tends to focus on the development of new technology, or on upgrading old technology. Yet one of the most effective ways of creating more resource efficient systems is to ensure the management of resource use through a dedicated, structured framework that improves performance and maximizes resource savings over time. If implemented correctly, such systems can deliver major cost savings, increase productivity and competitiveness, and also reduce the environmental effects of industrial growth. Some of the generic environmental issues are:

- * *Water used for soaking the paddy, especially for parboiled rice production, if not properly treated could result in water pollution and odor nuisance to local community*
- * *Effluent produced during cleaning of equipment may cause water pollution through insufficient treatment of effluent*
- * *Air pollution both on-site and in the surrounding locality may result from release of dust to the atmosphere from handling or processing of the paddy or its by-products (in fact, this is the major environmental concern for rice mills)*
- * *High internal and external noise levels may generate health hazards to employees and nuisance to the local community both from processing and transportation*
- * *Disposal of solid wastes, particularly trashes, surplus rice husk and bran, as well as other wastes generated from the cleaning process, when all of these are actually resources if used efficiently*
- * *Raw materials (paddy) and by-products especially bran, a raw material for edible oil, may be subject to infestation with mold, fungus, pest and contamination (birds contaminated with avian flu can leave their droppings in the rice mill)*
- * *Pollution risks to water bodies and soil from spillage and leakage of fuels that may be stored on site*
- * *Potential methane emission from biodegradation of stored biomass*
- * *Safety hazards due to risks of fire by accident or auto burning*

10.1. Fugitive emissions and environmental aspects in rice mills

Sources of fugitive emissions in rice mills

In rice mills, fugitive emissions are generated from various sections during handling of paddy, cleaning and milling of paddy, handling and storage of husk, and handling, storage and disposal of boiler ash due to various activities in the mills. Brief descriptions of sources of fugitive emissions are given below.

1. Fugitive emissions during handling of paddy from unloading

- *During unloading of paddy (cutting open the gunny bags and releasing paddy)*
- *At different stages of lifting and discharging of paddy rice through bucket elevator*
- *Transfer points (belt to belt; belt to elevator; elevator to silo)*
- *Locations of free fall of paddy (fine dust getting airborne due to free fall)*

2. Fugitive emissions during cleaning of paddy

- *During pre-cleaning (mostly in rotary drums – fines separated due to movement and free fall of paddy)*
- *During paddy cleaning in paddy cleaner/vibrating screen (due to rigorous movement of paddy, fines are generated)*
- *De-stoner machines (fines get extracted)*
- *Final cleaning in paddy cleaners (fines are extracted out)*

3. Fugitive emissions during milling of paddy

- *At different stages of lifting and discharging of paddy/rice through bucket elevator (fines get airborne due to movement, fall of paddy/rice)*
- *During de-husking of paddy in hullers (fines are generated due to breaking of paddy)*
- *At aspirators used for husk removal (fines are extracted)*
- *During polishing of rice (fines are generated due to polishing)*
- *During grading of rice in rice grader (fines carried along with rice)*



4. Fugitive emissions from handling and storage of rice husk

- *During conveying of rice husk from milling section to husk storage area (un-separated fines are blown along with husk)*
- *At rice husk storage area (fines get airborne due to wind currents)*
- *During conveying and handling of rice husk to boiler section (fines contained in the dry husk, get airborne during transport/conveying and free fall of husk)*

To address and mitigate the aforementioned environmental concerns, the following RECP measures are particularly relevant for rice mills:

- * *Good and adequately maintained drainage to facilitate run-off and minimize the likelihood of flooding*
- * *Regular inspection of bulk storage tanks to minimize the risk of surface water pollution*
- * *Installation of interceptor traps for solids, oil and fuel to reduce the controlled release of contaminated water via the surface drains*
- * *Separation of milling areas from all other areas of operation*
- * *Waterproofing of mill floor and all other floors*
- * *Walls designed to prevent accumulation of dust and entry of rodents, birds or pests*
- * *Adequate ventilation to prevent dust pollution and reduce heat*
- * *Prevention of build-up of dusts on machinery and ledges, and in the building*
- * *Design of chimney and vents of sufficient height and appropriate technology to avoid causing local nuisance of dust and smoke emissions*
- * *Measures to control noise levels at the site boundary*
- * *For parboiling mills, locating the steam-generating units away from storage and immediate work areas*
- * *Locating the soaking tanks close to the drying area*
- * *Locating the steaming tanks close to the soaking tanks and using non-corrosive metal*
- * *Reuse of rice husk as fuel for paddy drying, steam generator, or gasifier*
- * *Sale of rice husk or high crystalline silica produced from controlled burning of rice husk*
- * *Use of more efficient variable-speed drive motors for controlling combustion of rice husk*

10.2. Rice processor challenges

Challenges for rice processors include the following:

- * *High investment cost of modernizing rice mills for high technical performance*
- * *Increasing energy pricing will increase cost of operation*
- * *Limited access to repair facilities and services like refurbishing of rubber rollers*
- * *Low quantity/seasonal fluctuation of paddy arrival at rice mills, affecting the duration of rice mill operation in a year*
- * *Low quality of paddy received at rice mills*
- * *Lack of access to grid electricity in some rural places thus affecting adoption of electric-operated rice processing machines necessary for product quality*
- * *Poor road infrastructure especially in areas of paddy rice growing region thus affecting transportation of material/product and marketing*
- * *Eating habits/choice of national consumers limiting productivity and quality, such as a preference for soft rice (milling rice), not parboiled, having better yield and nutritive value*

10.3. Opportunities for rice millers

There are also some opportunities along with the challenges discussed above:

- * *Increasing market for rice due to growing population and per capita consumption*
- * *Availability of machinery at a wide range of prices*
- * *Credit availability from local banks to buy paddy*
- * *Rice has been identified as a strategic crop for poverty alleviation by the Government of Indonesia and development partners. Thus, interventions for improved rice processing have considerable potential for national and international support.*



11.0. BY-PRODUCTS FROM RICE MILLS AND THEIR UTILIZATION

A significant quantity of the rice milled in Indonesia today is milled for the country's own consumption at small rice mills scattered all over the country. The husk is sometimes used as food for chickens together with broken rice. Sometimes the husk is collected and burned, with the ash used for cleaning utensils. Broken rice is used for animal fodder.

Incomplete combustion of rice husk generates ash with very high carbon content which is reported to be rarely briquetted and used as fuel for cooking in biomass stoves. More potential usages of rice milling by-products are discussed briefly below.

11.1. Energy production potential in rice mills (by-product from rice mills)

The saving of the husk as a source of energy will lead to co-generation of thermal energy in furnaces for boilers and dryers in the rice industry and elsewhere. Energy conservation in the rice industry will therefore result in a reduction of the use of fuels and electricity. Such an assessment will help to determine energy use patterns as well as total energy consumption in the rice mill sector in Indonesia and provide better guidance to plan the conservation and application of energy substitute technologies.

Basically, in the rice mills (generally which have no access to grid electricity, or energy costs are high as in the case of Cambodia), two types of energy production systems are commercially available:

1. Gasification

The producer gas is a combustible gas mixture obtained by gasification of biomass which is rice husk in rice mills. The gasification involves burning rice husk under restricted air supply. It involves: (a) oxidation of the carbon into carbon dioxide and carbon monoxide, reduction of carbon dioxide into carbon monoxide, (b) release of H_2 from chemical bond and (c) the formation of small quantities of methane gas (CH_4).

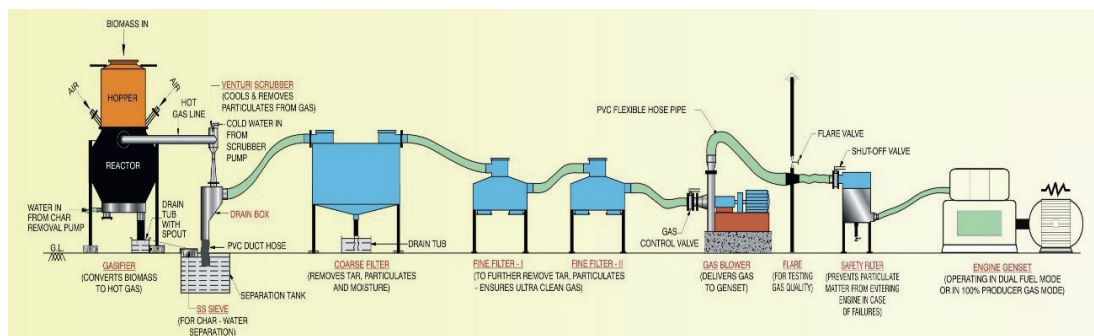


Figure 6: Gasification scheme

2. Direct combustion

The most commonly adopted method of burning the solid fuels is used in direct combustion. It is reported that the rice milling industry generated more than is consumed. Approximately 200 kg of husk was obtained from milling one ton of paddy. This produced 660 kg of steam, which generated 100 kWh of electricity through steam turbine. But milling one ton of paddy required only 65 kWh of electricity, thus rendering 35 kWh as surplus energy. Various physical factors which affect the burning of the rice husk and the efficiency of the furnace are the variety of rice husk, the particle size of the husk, the moisture content of the husk, size grading and the rate of air flow through the bed and the height of fuel bed.

In a co-generation plant, the steam turbine extracts some energy from steam to convert and supply mechanical power to the mill. The exhaust steam supplies heat for parboiling.



Figure 7 Rice husk based power plant in Thailand

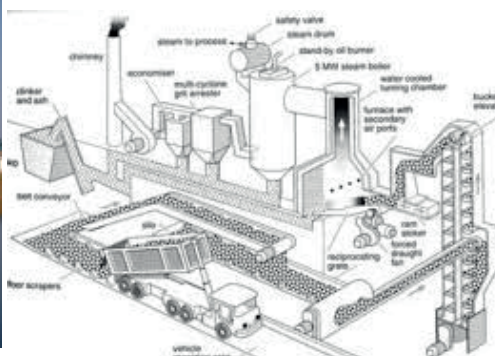


Figure 8 Layout of rice husk based cogen in Ankor Rice Cambodia

Paddy husk fired furnaces

- * **Box-type furnace:** utilizes the rice husk as a source of fuel for paddy drying in the rice milling industry. It is equipped with an inclined grate adjustable at 40°, 45° and 50° and consists of cast iron bars arranged in a staircase fashion.
- * **Cyclone-type husk fired furnace:** operates similarly to a vortex burner. The centrifugal force keeps the fuel particles rotating in fixed circles according to their size in equilibrium against the drag of inwardly spiraling air so that the relative motion between the air and the fuel accelerate combustion. With the husk feed rate of 25 kg/h, the supply of 2,100 cm³ of heated air-flue gas mixture can be

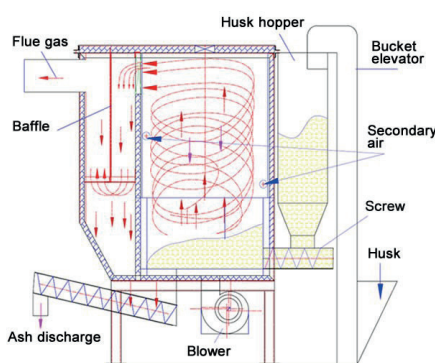


Figure 9 Cyclone type RH furnace

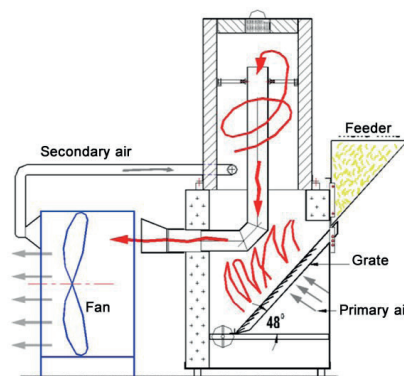


Figure 10 Box type RH Furnace

maintained at 90 °C or it can generate the steam at the rate of 42 kg/h.

- * **Fluidized bed husk fired furnace:** is considered the best suited in terms of improving combustion efficiency. The fuel-air mixture enters the outer chamber tangentially in the annular space, the mixture takes a circular path in the outer chamber and raises up to the dome and enters into the central cylinder to clear out the furnace into the blower. The temperature of this zone is always above 600°C.

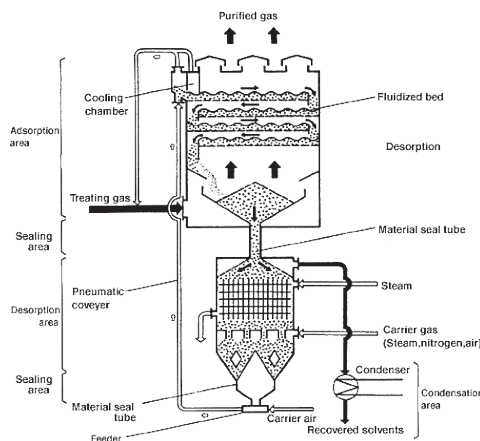


Figure 11 Fluidized bed husk fired furnace



12.0. POTENTIAL OF ENERGY GENERATION FROM RICE HUSK

UNIDO and its on-going programmes globally are working to enhance the long-term viability of renewables and other sustainable energy sources by improving the efficient use of energy in industry and generating energy from renewable sources. Biomass specially agro-residue are on the major source for renewable energy, which ultimately helps cut costs, create employment opportunities and mitigate the effects of climate change.

Rice husk as biomass fuel for power generation

Rice husk is the only rice mill residue that is considered relevant when it comes to renewable energy. It is estimated that 350 MWe could be generated from rice husk (considering the 40 per cent rice husk available for energy generation), which is equivalent to 25 per cent of the total electricity that could be generated from biomass available in Indonesia. As can be expected, the bulk of this capacity would come from Java. Significant additional capacities could come from Sumatra, Sulawesi and Kalimantan.

So far due to availability of fossil fuels at a reasonable price (especially coal), rice husk is not a common fuel used for power generation in Indonesia. However, there is significant international experience of using rice husk for power generation, and a few examples are provided in boxes below:

BOX 1: THAILAND

In Thailand, the husk is commonly used as fuel for power generation and as fuel in cement kilns. When used in cement kilns the crystalline silica helps to improve the quality of the cement. One of the biggest alcohol producers in South-East Asia, Thai Alcohol is using rice husk and biogas as fuel for processing of the alcohol. The plant is not connected to the public grid. In 2005, the plant was paying USD\$50 per ton of rice husk.

BOX 2: THAILAND

On the central plain of Thailand, north and north east of Bangkok, a number of rice husk fired power plants have emerged during the last ten years. Due to energy policy and electricity payment schemes, most of the plants are just below 10 MW. Most of the power plants are equipped with a bagging unit for bagging and exporting white ash; this business generates almost as much money as the sale of electricity.

These power plants generally use 40 bar water tube steam boilers and 8-10 MW steam turbines with the possibility of extracting steam for paddy drying. The electrical efficiency (fuel to electricity) is around 18 per cent.

BOX 3: INDIA

In India, over 300 industrial units requiring co-generation like pulp and paper, chemical and textile have installed rice husk-based co-generation units for their captive power consumption. However, due to increasing demand and the cost of rice husk, other biomasses are also used in combination.

13.0. RICE HUSK USAGE OTHER THAN POWER

Rice husk as building materials

Low-carbon, white husk ash suitable for use in manufacturing building materials – particularly refractory building materials – is prepared by first removing volatile constituents by heating the husks to a relatively low temperature below ignition point. Rice husks are usually used but wheat, oats or barley husks can also be used. Fixed carbon is then oxidized in the presence of a reagent by heating the husks to a second temperature above the separation temperature but below the crystallization temperature of the SiO₂ in the husks. This is followed by heat treatment at a third temperature above the crystallization temperature of the SiO₂ to produce a uniform SiO₂ crystal structure.

Rice husk briquettes

Rice husk is a rather bulky material, but also a good fuel with a lower heating value of almost 4 kWh/kg. Storage and handling could be made easier if the rice husk is briquetted. Briquetted rice husk could be used both for domestic use like substitute kerosene for cooking and/or as easy-to-transport carbon neutral fuel for industrial boilers to generate thermal and electrical energy. Rice husk briquetting is widely practiced in countries like Cambodia and Myanmar. In these countries, briquetted rice husk is sold as fuel to fulfill the thermal energy requirement in the textile and garment industry, which seeks carbon-neutral fuel as part of their environmental sustainability programme.

Fine biomass gasification (FBG)

For smaller mills, especially those not connected to the grid and using fossil fuels for energy, the rice husk can be fed into a gasification process. Countries like Cambodia, with poor access to energy, have used FBG in rice mills successfully for over a decade. The simple gasification process is depicted as below:

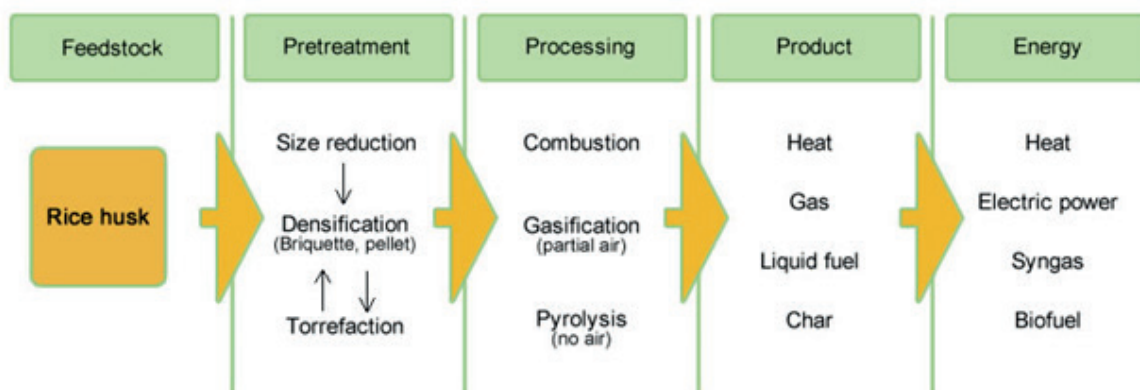


Figure 12: The simple gasification process



14.0. RICE HUSK ASH (RHA) POTENTIAL USAGE

Rice husk ash, which is approximately 25 per cent of the rice husk quantity, is considered a problematic waste for disposal. It has burnt cone-like structures which, when dispersed into the air, can lead to eye problems, and its dark color is often rejected by farmers. However, husk ash is an important resource and some possible usages (CPCB 2012) are briefly discussed below:

Use of rice husk ash in cement concrete mix as Silpozz

Voids can form in concrete mixes if curing is not done properly, which reduces the strength and quality of the concrete. The particle size of cement is about 35 microns, silpozz, a product made out of rice husk ash, is finer than cement, with a particle size of 25 microns, so that it fills the interstices in between the cement in the aggregate, meaning it can reduce the amount of cement in the concrete mix.

Rice husk ash is a good super-pozzolan. Silpozz can be used on a large scale to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes, high performance concrete, high strength, low permeability concrete, for use in bridges, marine environments, nuclear power plants, etc. This market is currently filled by silica fume or micro silica, imported from Norway, China and also from Burma.

Uses of Silpozz:

Typical uses of Silpozz made from rice husk boiler ash are described below:

1. For strength:

Silpozz has the potential to be used as a substitute for silica fumes or micro silica at a much lower cost, without compromising on quality. Adding Silpozz to a concrete mix even in low replacement will enhance the workability, strength and impermeability of concrete mixes, while making the concrete durable to chemical attacks, abrasion and reinforcement corrosion.

2. For waterproofing:

Silpozz has excellent water resistance (impermeability) properties and is used in waterproofing compounds to give better results. It reduces the water penetration by as much as 60 per cent.

3. For better concrete in the marine environment:

Adding Silpozz to concrete and paints helps to reduce the chloride ion penetration by as much as 50 per cent in the structure, thus extending the life of the building.

4. For lower heat of hydration:

Adding Silpozz to concrete lowers the heat of hydration by as much as 30 per cent and prevents the formation of cracks during casting.

**Source: www.ricehuskash.com/details.htm - N. Singhania, NK Enterprises, Orissa*

5. Use of rice husk ash in manufacturing Pozzolana cement*

Pozzolan are materials containing reactive silica and/or alumina which on their own have little or no binding property but, when mixed with lime in the presence of water, will set and harden like cement. Pozzolana are an important ingredient in the production of alternative cementing materials to Portland cement (OPC).

Alternative cements provide an excellent technical alternative to OPC at a much lower cost and have the potential to make a significant contribution towards the provision of low-cost building materials. Pozzolan can be used in combination with lime and/or OPC. When mixed with lime, pozzolan will greatly improve the properties of lime-based mortars and concretes rendering it suitable for use in a

wide range of building applications. Pozzolana can be blended with OPC to improve the durability of concrete and its workability, and considerably reduce its cost. The comparison of three cements are shown in the following table:

Table 1: Showing Characteristics of Three Cements being marketed

Cement Type	OPC Grade 43	OPC Grade 53	PPC Birla Smart
Fineness m^2/kg	293	329	350
Initial Setting Time	155 minutes	120 minutes	140 minutes
Compressive Strength (MPa)	3 days	38.0	28.0
	7 days	46.0	35.0
	28 days	56.0	48.0



Rice husk ash has been successfully used as a pozzolana in commercial production in a number of countries including Columbia, Thailand and India. To produce the best pozzolana, the burning of the husk must be carefully controlled to keep the temperature below 700°C and to ensure that the creation of carbon is kept to a minimum by supplying an adequate quantity of air. At burning temperatures below 700°C ash rich in amorphous silica is formed which is highly reactive.

6. Grinding of rice husk ash for use in cement production*

The second step in processing is grinding the rice husk ash to a fine powder, and ball or hammer mills are usually used for this purpose. Crystalline ash is harder and will require more grinding in order to achieve the desired fineness. Fineness similar to or slightly greater than that of OPC is usually recommended for pozzolan although some have been ground considerably finer.

7. Utilization of rice husk ash in lime stabilization of poor soils*

Many procedures have been developed to improve the physical behavior of soil by incorporating a wide range of stabilizing agents, additives and conditioners. The effectiveness of such agents relies on the formation of cementing bonds between the particles in the soil system.

**Cumulative generation of ash requires a large space for disposal. Utilization of rice husk ash by exploiting its inherent properties is the only way to solve the environmental and disposal problem of the ash. A number of researchers have studied the physical and chemical properties of rice husk ash. Rice husk ash cannot be used alone for stabilization of soil because of the lack of cementitious properties. The high percentage of siliceous material in rice husk ash indicates that it has potential pozzolonic properties.*

Definitions related to rice husk/ash utilization:

Amorphous silica: Rice husk is burnt in controlled temperatures below 7000°C. The ash generated is amorphous in nature. The transformation of this amorphous state to a crystalline state takes place if the ash is exposed to high temperatures above 8500°C.

Green concrete: Green concrete, as the name suggests, is eco-friendly and helps save the environment by using waste products generated by industries in various forms (like rice husk ash, micro silica, etc.) to make resource-saving concrete structures. Use of green concrete helps to save energy, emissions and wastewater. Green concrete is often cheap to produce as it uses waste products directly as a partial substitute for cement, thus saving energy consumption in the production of cement. Finally, green concrete has greater strength and durability than normal concrete.



8. Possible alternative uses of rice husk rather than as boiler fuel

Rice husk can be put to use as building material, fertilizer and insulation material, as well as fuel. Some of the current and potential applications are listed below (apart from fuel):

➤ **Chemical (catalyst and for WWTP):**

Rice husk can be used to produce mesoporous molecular sieves, which are applied as catalysts for various chemical reactions, as adsorbent in wastewater treatment.

➤ **Building material:**

Rice husks are a good insulating material because they are difficult to burn and less likely to allow moisture to propagate mold or fungi. Rice husks, when burned, produce silica, which provides excellent thermal insulation.

➤ **Fertilizer:**

Rice husks are organic material and can be composted. However, their high lignin content can make the process slow. Sometimes earthworms are used to accelerate the process. Using vermicomposting techniques, the husks can be converted to fertilizer in about four months, but due to the long gestation period, this is not a preferred method.

➤ **Silicon carbide (SiC) production:**

Rice husks are a low-cost material from which “silicon carbide whiskers” can be manufactured. The SiC whiskers are then used to reinforce ceramic cutting tools, increasing their strength tenfold.

➤ **Juice extraction:**

Rice hulls are used as a “press aid” to improve the extraction efficiency of apple pressing.

➤ **Pillow stuffing:**

Rice hulls are used as pillow stuffing. The pillows are loosely stuffed and considered therapeutic as they retain the shape of the head. Since 2009, in China, RH pillows have become popular, and are considered a luxury item.

➤ **Animal fodder:**

Rice husk is an inexpensive by-product of rice processing sector having significant amount of silica but considered as a source of fiber that is a filler ingredient in cheap pet foods.

15.0. SPECIFIC BARRIERS IN THE IMPLEMENTATION OF RECP IN GENERIC AND MICRO-SECTORS

The implementation process of RECP in small industries has often experienced delays because of the following obstacles:

- *A public policy concerning the implementation of RECP has not been completed*
- *Retrieval of national technological information/case examples concerning RECP (best practice and best available technology) is difficult to retrieve*
- *Capacity building and RECP experience in the industrial sector, associations, governmental apparatus, consultancy is limited*
- *The RECP implementation mechanism that is suitable for the manufacturing and service sector has not yet been fully developed*
- *In unorganized sectors, weak credentials mean there is no funding mechanism to facilitate the adoption of RECP measures*
- *Lack of incentives to motivate and possibly subsidize activities of companies that have already applied RECP*

In regard to promotion of clean/renewable energy using agro residue biomass, the following barriers stand out:

- *Weak implementation of renewable energy policy, or policy does not provide adequate incentive*
- *PLN's monopolistic position and perceived inefficiency discourages sellers (or at least does not provide incentive to potential sellers)*
- *Uneconomical nation-wide electricity tariff*
- *Lack of fiscal incentives for clean and renewable energy technology*
- *Lack of policy and regulatory coordination on rural electrification*
- *Power Purchase Agreement's (PPA) pricing and conditions*
- *Lack of institutional capacity*

15.1.1. Barriers specific to industrial policy

The interviewed stakeholders in the rice mill sector have commonly pointed out the absence of government support in the sector, including paddy (or rough rice) production and post-harvest processing (which includes rice milling).

➤ Finance

Access to finance remains a key barrier for SMEs. According to a report from the International Finance Corporation, “although in the aggregate SME lending is growing rapidly (from a small base), the vast majority of SMEs in Indonesia continue to face constraints in access to credit. Bank lending is heavily collateral based – and with weak land titling and collateral documentation, especially for land, many SMEs find the banking sector hard to access.” There are further reasons for banks not to finance SMEs; in terms of administrative lending requirements, SMEs “often provide insufficient or unfeasible collateral and have inadequate financial reports and/or business licenses.” Banks continue to perceive SMEs businesses as high risk because of the following:

- *SME products are regarded as innovative products*
- *SMEs need seed capital to develop new products*
- *SMEs are in the developmental stage*
- *SMEs need extensive funding but have not entered their mature period*
- *SME businesses are seasonal, such as plantation and fisheries*



The banks themselves face constraints when it comes to sustainable energy or environmental finance despite the exposure offered by the environmental finance program of the Ministry of Environment and Forestry. These constraints include:

- *Limited knowledge in waste management and clean development infrastructures*
 - *Lack of uniformity in implementation by banks*
 - *Rigid conditions from foreign partners*
 - *Limited experience of sustainable banking, which is still a new concept in Indonesia*
- Industry and technology

The palm oil and rice mill industries in Indonesia can benefit from awareness-raising and capacity building particularly on renewable energy, including the latest developments in these two closely interrelated markets (IFC-2009).

16.0. CONCLUSION

Problems in the Indonesian rice economy are complex and require appropriate approaches to ensure food sufficiency. Rice production has been very dynamic and supported by capable land resources, although relatively localized particularly in the Java-Bali, South Sulawesi and South Sumatra regions.

In its work over the decades to promote sustainable industry, UNIDO has long been a champion of the ideas of recycling, regeneration, innovation and sustainability, integral to the circular economy. By producing more using less, keeping products in use as long as possible, it foresees a transformation from consuming to safeguarding the finite resources of the planet, as we continue to create jobs and income through inclusive and sustainable industrialization.

UNIDO pursues these goals through projects and activities that increase the capacity of industry, governments, environmental service providers and other entities to use more resource-efficient and low-carbon production. Examples include training and information material such as generic and sector specific manuals. This manual is one of the manual in series of manuals produced by RECP Indonesia programme implemented by UNIDO and supported by SECO Switzerland.



REFERENCES

BEE. (2011). Manual on Energy Conservation Measures in Rice Milling Cluster Warangal, Apitco Ltd., Hyderabad.

BEE. (2012). Manual on Energy Conservation Measures in Rice Milling Cluster Ganjam, Zenith Energy Pvt Ltd., Hyderabad.

CPCB. (2012). Comprehensive Industry Document Series: COINDS/82/2012-13 Guideline for (i) siting of rice shellers/mills; (ii) handling and storage of rice husk and (iii) handling, storage and disposal of ash generated in boiler using rice husk as fuel.

Faulkner MD, Reed GN, Brown DD (1969): Report to the Government of India on Increasing Milling Out turns of Rice from Paddy in India, Sep. Quoted by **Wimberley JE**, Evaluation of Modern Rice Milling Programme in India, The Ford Foundation, New Delhi, October, p 1

Goyal et al. (2014). Energy use pattern in rice milling industries—a critical appraisal. Journal of food Science Vol51(11) 2014.

IFC. (2009). [Online]. Scoping study: Clean Technology opportunities and barriers in Indonesian Palm Oil and Rice Mill Industries - Final Report. Available from: <http://documents.worldbank.org/curated/en/638541495084053792/text/115100-WP-ID-Scoping-study-clean-technology-opportunities-PUBLIC.txt>

NCPO. (2015). Industrial Energy Efficiency case study Chea Hap Rice Mill Cambodia. www.cambodian-cpc.org

NCPO. (2014). Industrial Energy Efficiency case study Norm Srim Rice Mill Cambodia. www.cambodian-cpc.org

NCPO. (2014). Industrial Energy Efficiency case study Vinh Cheang Rice Mill Cambodia. www.cambodian-cpc.org

Rice Knowledge Bank. [Online]. Available from: <http://www.knowledgebank.irri.org/rkb/index.php/rice-milling/commercial-rice-milling-systems/husking>

Rice Knowledge Bank. [Online]. Available from: <http://www.knowledgebank.irri.org/rkb/index.php/rice-milling/commercial-rice-milling-systems/paddy-pre-cleaner>

Rice Knowledge Bank. [Online]. Available from: <http://www.knowledgebank.irri.org/rkb/index.php/rice-milling/commercial-rice-milling-systems/husking/steel-husker>

Rice Knowledge Bank. [Online]. Available from: <http://www.knowledgebank.irri.org/rkb/index.php/rice-milling/commercial-rice-milling-systems/husking/rubber-roll-husker>

Rice Knowledge Bank. [Online]. Available from: <http://www.knowledgebank.irri.org/rkb/index.php/rice-milling/commercial-rice-milling-systems/rice-milling>

Rajkumar P, Varadharaju N, Sreenaryanan VV (2004). Studies on milling out turn of paddy varieties using rubber roll Sheller. Madras Agric. J. 91(1-3):1-4,.

Sarda. (1966). Enzymes in Food Processing-Proteolytic Enzymes- Technology & Engineering, Food science, Elsevier Science, 1966.

UNIDO (2017) Annual report 2017 - UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA.

World Bank. (2006). [Online]. Unlocking Indonesia's Domestic Financial Resources: The Role Of Non-Bank Financial Institutions. Available from: <http://documents.worldbank.org/curated/en/204991468283755820/text/377570v10ENGLI10914130NBFIO1PUBLIC1.txt>

ANNEX 1

(a) Installation of rice husk based co-generation system:

Installation of a rice husk based co-generation system in parboiled rice mills was one of the energy saving options identified during the technology audit. The small portion of power can be produced by installing the energy-efficient boiler and also a turbo generator. The output steam from the turbine can be used for the paddy processing in the parboiled rice mills at required operating conditions. The system is the environmentally-friendly, economical and sensible way to produce power simultaneously and a significant amount of money is saved as well as reducing GHG emissions.

With rising energy costs and unreliable grid power, there is considerable potential for industries to opt for energy-efficient techniques to reduce costs. Rice mill clusters require electricity as well as heat in the form of steam or hot water for their operations. These requirements are normally met through different energy sources.

Higher energy conversion efficiencies will contribute to lower emissions, in particular with regard to CO₂, the main GHG. The co-generation plant consists of a high pressure boiler, extraction cum back pressure turbine and alternator of required capacity, through which steam of required pressure can be extracted without any energy waste. This will greatly improve the system efficiency, though this technology is applicable to acquire both thermal and electrical energy.

(b) Rice husk based power generation system

Rice mills are generally in remote location and often having no access to grid power. Several power generator technologies such as gasifier are used in many countries like Cambodia, Lao DPR and Myanmar successfully. Indonesia is also using this gasifier technology which need to be upgraded and upscaled.



ANNEX 2

RECP applications: Case examples

RECP provides a practical framework that is applicable in a wide range of industry sectors, including on a small scale. A few examples are provided briefly below:

- ✎ In **Chea Heap Rice Mill** (Cambodia), the potential of RECP, yield improvement, quality improvement and GHG emissions were evaluated. Possible efficiency measures were identified and techno-economically viable options were implemented. The company invested \$450,000 and reported direct savings of \$246,000 and a GHG reduction of 191t of CO₂ per annum. Due to increased unit operations (for export quality rice), energy specific energy consumption has increased for additional process steps resulting in higher energy and GHG emissions, but this was offset by efficiency improvement.
- ✎ **Vinh Cheang Rice Mill** (Cambodia) evaluated the potential of RECP and the impact of GHG emissions. Possible efficiency measures were identified and techno-economically viable options were implemented. Company has implemented seven medium and high cost options with an investment of \$1,480,000 with reported direct savings of \$612,800 and GHG reduction by 510t of CO₂ per annum.
- ✎ **Norm Srim Rice Mill** (Cambodia) implemented RECP options and during execution, the company invested \$370,000 and reported direct savings of \$601,920 and GHG reduction by 692t of CO₂ per annum. Due to increased unit operations (for export quality rice), energy specific energy consumption has gone up for paddy drying, storage, conveyance and color sorting operations which resulted in higher energy and GHG emissions, but this was offset by the implementation of RECP measures.
- ✎ The **Value Initiative Programme** (Indonesia) reached out to 2,700 tofu and tempeh producers, who on average were able to reduce costs by 15 per cent through use of gas powered cookers, application of stainless steel equipment, and application of good manufacturing, hygienic and waste management practices.
- ✎ A **ceramics workshop** (Viet Nam) was able to reduce breakage/wastage by 20 per cent through improvements in the design of tableware items.
- ✎ The **ACIDLOOP project** (India) assisted with RECP interventions in small scale electroplating workshops. It was found that workshops could typically save approximately \$15,000 by investing about \$120 in insulating hot process baths with polypropylene balls. Similarly, introducing water cascading at a cost of about \$150 could also achieve up to \$15,000 annual savings.
- ✎ The **Bureau of Energy Efficiency** (India) found that small scale rice mills can improve their energy efficiency through typical measures like individual drive systems, efficient motors, voltage stabilizers, use of lighter plastic buckets in bucket elevators and efficient huskers and separators. These investments had typical payback periods ranging between 18 to 24 months.
- ✎ The 23-room **De La Paix Hotel** in Luang Prabang (Lao PDR) improved operation and maintenance of water heaters, air conditioners and lighting. The energy consumption per guest per night was reduced by 50 per cent. Investments mounted up to \$12,000 yet were recovered in less than 3 months.
- ✎ The 69-room, 3-star **Golf Hotel in Hoi An** (Viet Nam) was able to cut energy use by over 20 per cent through proper placing of air conditioner units, de-lamping and better housekeeping, saving in excess of \$3,500 annually. It also contributed to sustainability initiatives in local crafts industries, in particular for noodle production and lantern making.
- ✎ The **Green Handicrafts project** in Viet Nam supported growers, grass-roots producers and small enterprises to adopt cleaner production and design practices in bamboo and rattan, sea grass, silk, handmade paper and lacquer ware value chain sectors. A total of 48 small enterprises were



audited, 65 trainers trained and these provided grass-roots training to 1,430 household producers. Moreover, sustainable product design support was provided to 21 enterprises. The project resulted in a 16.5 per cent income increase over 3 years for the participating crafts producers, relative to a 9.2 per cent income increase for other crafts producers.

- **Tum Ring rubber factory** identified and implemented four RECP measures with an investment of \$110,000. These interventions yielded benefits of approximately \$132,480 and GHG reductions of 251t of CO₂ per annum. Most of these energy savings were from fuel substitution for the rubber dryer.



CONTACT PERSON

FOR FURTHER INFORMATION:

MINISTRY OF ENVIRONMENT AND FORESTRY

(Kementerian Lingkungan Hidup dan Kehutanan)

Noer Adi Wardoyo: adiw_n@yahoo.com

Gedung Manggala Wanabakti Blok VII Lt. 8

Jalan Gatot Subroto, Jakarta 10270

Phone: 021 – 5733433

Website: standardisasi.menlhk.go.id

MINISTRY OF INDUSTRY

(Kementerian Perindustrian)

Teddy C. Sianturi: tsiantut@gmail.com

Jl. Gatot Subroto Kav. 52-53 20th Floor, Jakarta Selatan 12950

Phone: 021 – 5255509

Website: <http://www.kemenperin.go.id>

INDONESIA CLEANER PRODUCTION CENTRE

(Pengembangan Produksi Bersih Nasional)

Timotheus Lesmana Wanadjaja: timotheus.lesmana@gmail.com

Sutera Niaga III Block C No. 17, Alam Sutera RT. 004/001

Kel. Pakulonan, Kec. Seprong Utara, Kota Tangerang Selatan 15334

Website: <http://produksibersih.org>

UNIDO REPRESENTATIE

Esam Alqararah: E.Alqararah@unido.org

UNIDO Office Jakarta

Menara Thamrin Building, Jl. M.H. Thamrin Kav. 3, Jakarta Pusat

Phone: 021 – 29802300

Website: www.unido.org

ECONOMIC DEVELOPMENT COOPERATION (SECO)

Martin Stottele: martin.stottele@eda.admin.ch

Embassy of Switzerland, Jakarta 12950

Phone: 021 – 5256061

Website: <https://www.seco-cooperaton.admin.ch>

PROJECT MANAGER

Christian Susan: c.susan@unido.org

United Nations Industrial Development Organization

Phone: +43 1 26026 3541

Website: www.unido.org

RECP - INDONESIA

Permod Kumar Gupta: P.Gupta@unido.org

Salil Dutt: S.Dutt@unido.org

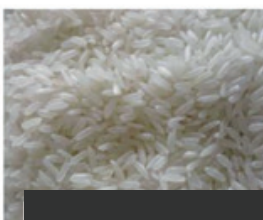
Phone: +62 812 9135 3373



Paddy Rice



Brown Rice



White Rice

Resource Efficient and Cleaner Production (RECP) project Indonesia assists governments, institutions and industry to best adapt their production methods, move towards resource efficient cleaner production systems and develop sustainable, resource efficient solutions. Efficient utilization of resources – raw material, energy, water and auxiliaries – becomes crucial for the survival of businesses, which generally operate on low profit margins and are mostly family-owned traditional units. Moreover, production processes are mostly based on obsolete technology, or even improved technology which has become inefficient over time. The inefficient utilization and excessive use of resources also contributes to exceeding levels of material and energy intensities and environmental footprints.



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria

Telephone: +43 (0) 1 26026-0, Fax: +43 (0) 1 26926-69

Email: unido@unido.org, Internet: www.unido.org