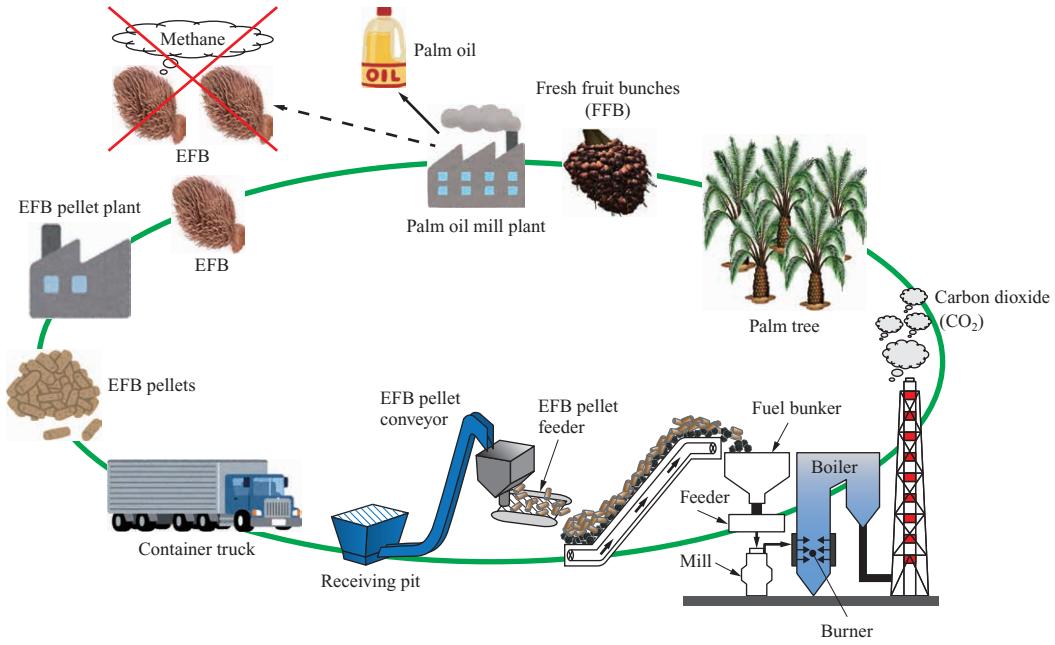
Sustainable Power Generation through Local Production and Consumption of EFB Pellets

Production of EFB pellets in Malaysia and their utilization for thermal power generation, being a first step to establish a sustainable power generation cycle

Most empty fruit bunches (EFB) generated in palm oil mill plants are not used beneficially. They are left on oil palm farms and emit methane gas into the atmosphere when they rot. We have turned them into pellets and conducted the first firing demonstration at a thermal power plant in Malaysia, taking the first step to establish a power generation cycle with local production and consumption of biomass fuel.

IHI Power System Malaysia Sdn. Bhd.
IHI Transport Engineering Malaysia Sdn. Bhd.
IHI Solid Biomass Malaysia Sdn. Bhd.



Power generation cycle with local production and consumption of EFB pellets

Pelletization and utilization of EFB

Palm oil is produced by digesting and pressing palm fruit at oil mill plants. Major by-products generated in this process are palm kernel shells (PKS) and empty fruit bunches (EFB). The percentages of PKS and EFB generated relative to the amount of palm oil produced are approximately 30% and 100% by weight, respectively. This means that the amount of EFB generated as a by-product equals the amount of palm oil produced. PKS has low water content and a high calorific value per unit value, and therefore is being used more and more as a biomass fuel. In contrast, EFB has high water

EFB pellet production processes

content and a low bulk specific gravity due to its fibrous structure. Therefore, EFB has low transport efficiency and is rarely used as a biomass fuel. Since around 2004, the IHI Group has been focusing on EFB, which is generated in large quantities in the process of palm oil mill, and studying how to use it as a fuel. We have been visiting palm oil mill plants to understand how EFB is generated in oil mill plants. Also, we have been comparing processing methods with a focus on the shape and properties in consideration of the method of transporting EFB from each oil mill plant to a thermal power plant, the ease of handling, and the usage, such as crushing and firing. Then, we finally decided to adopt pelletization and established processes that also incorporate a washing process to reduce ash. In 2018, we set up IHI Solid Biomass Malaysia Sdn. Bhd. (ISBM) and began commercial production of EFB pellets using these processes.

EFB pellet production consists of the processes of receiving, crushing, washing, drying, shredding, and pelletizing EFB. EFB contains a lot of alkaline components, such as sodium and potassium. In particular, potassium oxidizes during the fuel combustion process to form potassium oxide, which melts at low temperature. The potassium oxide is known to deposit on the heat-transfer surfaces of the boiler (e.g., evaporation tubes, superheater tubes, reheater tubes) and cause heat transfer failures. Therefore, we studied washing conditions through a series of washing tests focusing mainly on the amount of potassium, and determined the design standards for the production equipment.

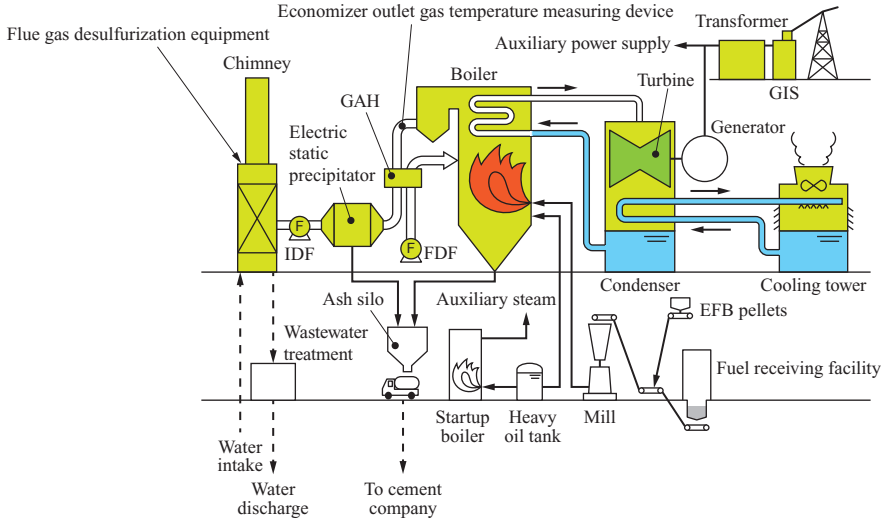
On the other hand, regarding the technologies to fire EFB pellets in a thermal power plant on the user side, in parallel with EFB pelletization research, we have been verifying the crushing and combustion characteristics with IHI's own combustion test facility. As for crushing, we have confirmed that EFB can be crushed properly with a low mixing rate of a few percent or less. With regard to combustion, we have confirmed that if EFB is not washed, the molten ash deposits and flows down the furnace wall.

Finally, we conducted a demonstration test aimed at establishing a local production and consumption cycle where EFB pellets produced in Malaysia, one of the largest producers of palm oil in the world, are consumed at a thermal power plant in Malaysia.

Kapar Power Station

We conducted an EFB pellet mix-firing demonstration test at Unit 3 (KEV-3) of Kapar Energy Ventures Sdn. Bhd. (KEV) in Malaysia in July 2022. KEV-3 is a 300 MW power generation facility that began operation in 1988 and uses a boiler supplied by IHI. It is a ternary-fuel power generation facility that can use coal, natural gas, and heavy oil as fuel, but is mostly operated with coal because coal is cheaper than the other fuels.

Thermal power plants consist of a steam turbine and generator system and a boiler system. In this EFB pellet firing demonstration test, there was a need to monitor the boiler system to change the fuel from coal to coal + EFB



(Note) GAH : Gas air heater
IDF : Induced draft fan
FDF : Forced draft fan
GIS : Gas insulated switchgear

Facility configuration of thermal power plants (example)

View of KEV-3

Item	Unit	Coal	EFB pellets
Higher calorific value	MJ/kg (as received)	26.29	19.13
Carbon (C)	wt%	65.56	45.11
Hydrogen (H)	wt%	4.46	5.11
Nitrogen (N)	wt%	1.17	0.10
Oxygen (O)	wt%	8.39	42.00
Sulfur (S)	wt%	0.32	0.08
Ash content	wt%	12.20	2.28
Water content	wt%	7.90	6.70

Fuel properties

pellets. KEV-3 adopts an opposed firing boiler equipped with 5 mills and 20 burners. Normally, the boiler is operated with four mills and uses one mill as a spare. During the firing demonstration test, no adjustments were made to the boiler and mills; their conditions were compared without changing the settings.

EFB pellet mix-firing demonstration test

In this firing demonstration test, IHI Power System Malaysia Sdn. Bhd. (IPSM) was in charge of test administration and evaluation, IHI Solid Biomass Malaysia Sdn. Bhd. (ISBM) was in charge of EFB pellet production, and IHI Transport Engineering Malaysia Sdn. Bhd. (ITEM) was in charge of the equipment for feeding EFB pellets. The test was conducted between July 21 and July 27, 2022. A temporary EFB pellet bunker and feeder were set up. EFB pellets were put in a flexible container bag, hoisted with a mobile crane, and loaded into the EFB pellet bunker. The rate of the fuel loading conveyor was approximately 300 t/h. To achieve a target mix-firing rate of 1% calorific value base (cal.%), the target amount of EFB pellets to be fed was set to 4.5 t/h. The actual mix-firing rate was calculated to be 1.4 cal.% based on the total amount of coal loaded and the total amount of EFB pellets. Also, because EFB pellets are sensitive to water (EFB pellets deform when they absorb water), a temporary building was constructed in the flexible container bag storage area to prevent exposure to rainwater.

Fuel was loaded into the bunker twice a day. At the time of mix-firing, EFB pellets were fed onto the coal being loaded on the conveyor, thereby achieving the target mix-firing rate. In the one-week mix-firing demonstration test, the EFB pellet bunker and the unit for loading EFB pellets onto the fuel loading conveyor were open to the atmosphere, and therefore, a lot of dust was generated. In commercial operation, dust control measures, such as dust collectors, are required.

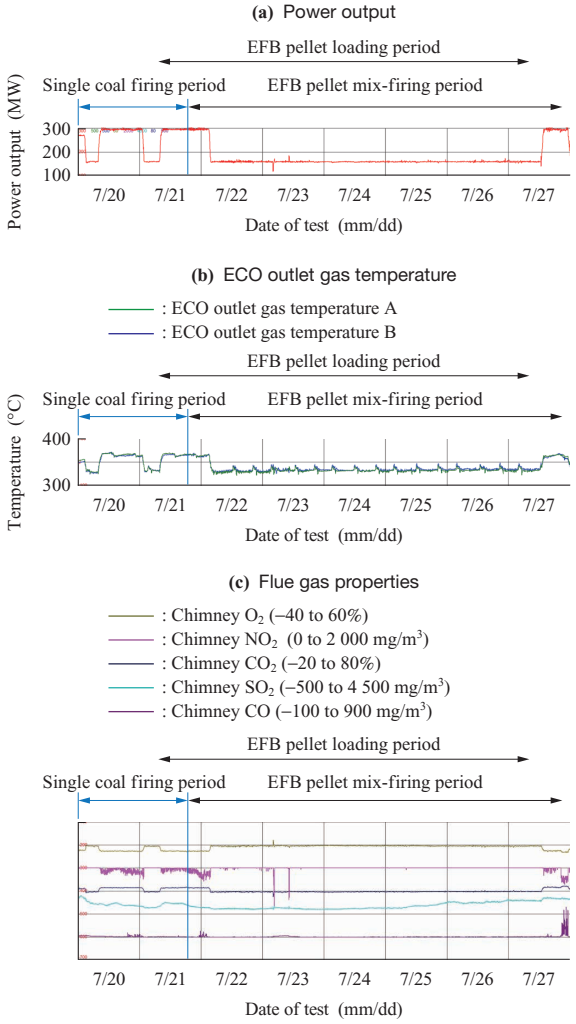
We compared the representative properties of coal and EFB pellets during the mix-firing demonstration test. As a result, we found that the EFB pellets had lower nitrogen (N) content, sulfur (S) content, and ash content than coal, which means that the reduction of nitrogen oxide (NO_x), sulfur oxide (SO_x), and ash can be expected. During the entire mix-firing demonstration test period, bituminous coal of the same brand was used, but on and after July 25, coal with a different shipment number was used.

Boiler condition

During the mix-firing demonstration test period, the boiler load was set to 300 MW or 160 MW according to the power demand in Malaysia. During this period, the power demand in Malaysia as a whole was low, and therefore, the boiler was operated at the lower load for most of this period. For each load, we compared the economizer (ECO) outlet gas temperature and the NO_2 concentration and SO_2 concentration at the chimney between single coal firing and mix-firing with EFB pellets. If ash deposits on the heat-transfer surfaces, including those in the furnace, the amount of heat absorbed at the boiler furnace and the convective heat transfer areas downstream of the boiler furnace decreases, and as a result, the ECO outlet gas temperature increases. This allows us to judge whether or not there is influence of mix-firing with EFB pellets.

Since EFB has lower N content and S content than coal, both NO_2 and SO_2 can theoretically be reduced by mix-firing with EFB pellets. In reality, however, no differences were observed in the boiler condition trend between single coal firing and mix-firing with EFB pellets, hidden by fluctuations in the fuel properties. On July 25, 2022, the shipment number of coal changed although the brand remained unchanged, and after that, the SO_2 concentration increased gradually. Also, the ECO outlet gas temperature under the 160 MW condition increased slightly, but on and after July 26, it was constant without fluctuations. Even coal of the same brand has different properties depending on when it was mined, which had influence on the test results as above.

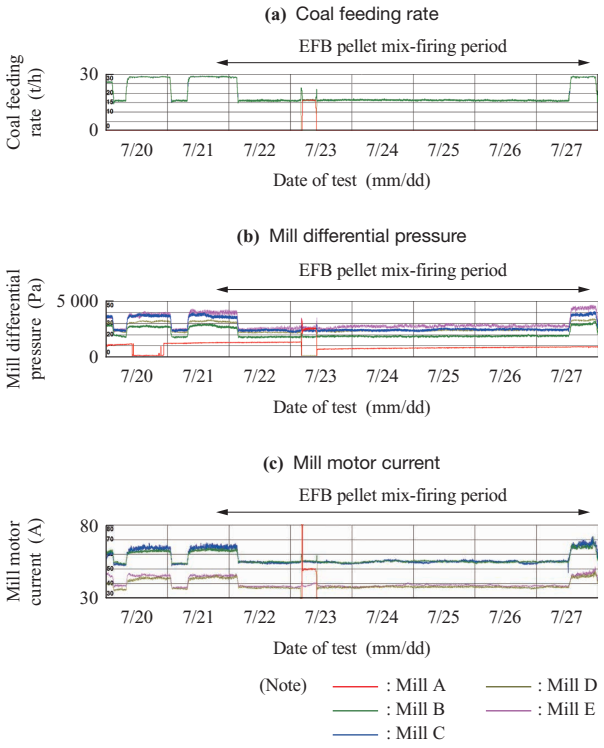
We confirmed that the main steam temperature and main steam pressure were stable throughout the EFB pellet mix-firing demonstration test period, not affected by mix-firing with EFB pellets.



Trends in the boiler condition

Mill condition

Since coal and EFB pellets were loaded into the mills at the same time and crushed immediately, we expected that the test results would be affected directly by EFB pellets and the mill differential pressure and mill motor current would increase. EFB has a fibrous structure and has lower crushability than coal. This increases the amount of EFB circulating in a mill, resulting in increased mill differential pressure. Also, the low crushability leads to increased crushing power, eventually resulting in an increased mill motor current. Since the wear condition of the mill components differs from one mill to another, the statically determined mill differential pressure and mill motor current differ from one mill to another. In reality, however, the trends in the mill condition, like those in the boiler condition, were almost the same between single coal firing and mix-firing with EFB pellets. This allows us to conclude that there is load margin in the crushing capacity under both the 300 MW condition and 160 MW condition, suggesting that the mix-firing rate can be increased further.



Trends in the mill condition

Summary and future actions

This EFB pellet mix-firing demonstration test was observed not only by the KEV owner but also by the Ministry of Energy and Natural Resources and the Ministry of Environment and Water of Malaysia, showing a high degree of attention to the test. Malaysia is the second largest palm oil producer in the world, which means that Malaysia generates the second largest amount of EFB in the world, giving it a high potential to produce EFB pellets. At the mix-firing demonstration test, we successfully established local production and consumption processes using EFB in Malaysia. In the future, IPSM, ISBM, and ITEM will continuously work together to accelerate our efforts to achieve the following two goals.

(1) Increasing the production of EFB pellets
(2) Establishing an incentive program for biomass power generation

The second one should be done by government agencies. However, we are working with relevant agencies, for example, by introducing efforts in Japan.