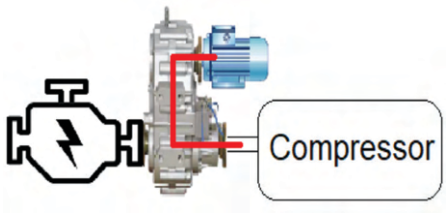
power take-offs are equipment like a gearbox or power take-off application that allows single or multiple pumps to be driven from a single prime mover. This multiple/split type power take-off is a combination of different propulsion technologies. In the hybrid transmission system, an electric motor performs the function in place of the engine, such as exerting force to the transmission shaft.

The split shaft power take-offs are advantageous to use because of their properties that include:

- Multiple outputs
- Various styles and sizes
- Standard PTO is driven by a pulley for versatility
- A shiftable compressor can drive both the electric motor and main engine
- Fuel is utilized efficiently and the cost is beneficially optimized
- Waste from fish preservation onboard is reduced

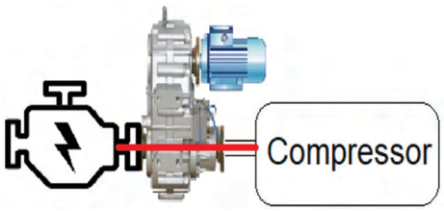
The refrigeration system could use either the electric motor or the engine, as the energy source to keep its compressor going. The functions of such energy sources are summarized below:

1) Hybrid refrigeration system driven by an electric motor



In general, the compressor of the refrigeration system is driven by an electric motor, the size of which depends on the cooling capacity or cooling efficiency of the compressor. This means that a lot of electricity is needed from the diesel generator. Since the electricity demand is defined as fuel consumption, even when a fishing vessel moored at the fishing port/jetty, it will still be able to operate the refrigeration system through the electric motor. This is because fishing vessels must continue to run either through its diesel generator ordinarily or by utilizing the shoreline power source when the main engine stops. But whenever the fishing vessel leaves the pier/port and the main engine is in use, the refrigeration system can change the mode of operation to engine mode so that the compressor would continue to function.

2) Hybrid refrigeration system driven by the propulsion engine



The merit of the refrigeration system is driven by the propulsion engine. Whenever the fishing vessel leaves from the fishing port to the fishing ground for a certain fishing period, it will take time to operate the engine. Therefore, using the engine drive mode will result in energy utilization without using the electricity sourced from the diesel generator.

4.1.2.4 Reduction of Carbon Emissions

Catch per unit of fishing effort and greenhouse gas emission of a purse seine fishing vessel is among the most important factors that determine the impacts of the increasing contribution of Southeast Asian fisheries to global seafood production. Purse seine fishing is one of the activities that significantly contribute to the region's seafood production but requires considerations in terms of the energy use (man and machine), and in mitigating the negative impacts of fishing activities and vessel operations on the environment.

A privately-owned purse seine fishing vessel in southern Thailand, the "Nor Lapprasert 8" has been commissioned by SEAFDEC/TD through a collaborative arrangement since 6 July 2018 for a pilot project on labor reduction onboard fishing vessels during the fishing operations, as well as enhancement of the working practices and living conditions onboard the vessels following proper hygiene and adopting the low-impact and fuel efficient (LIFE) fishing concepts to catch fish, and preserving the freshness of the catch at sea for the benefit of the consumers. The initial activity using this pilot purse seine fishing vessel was launched through a joint fishing operation between the local fishers and SEAFDEC staff from 8 to 12 February 2019 and continued thereafter. During the trial period, the pilot project has shown improved efficiency of the fishing gears (net plan), fishery machinery, and fish handling tools. After more than three years of research on fuel saving/ energy efficiency using this pilot vessel by adopting the appropriate technology on improving energy efficiency, SEAFDEC has contributed to the improvement of fishing practices and working conditions onboard fishing vessels, and reduction of the manpower onboard purse seine fishing vessels. The summary of such efforts made by SEAFDEC/ TD is shown in **Table 64**.

After implementing the project, the new carbon emission record is shown in **Table 65**, while the changes and improvements compared before and after the implementation of the project using the pilot purse seine fishing vessel, are shown in **Table 66.**

Table 64. Summary of the data on the operation of the pilot purse seine fishing vessel (from 2019 to date)

Total fishing operation (no. of days)	Total fishing voyage (no. of trips)	Total fish catch (kg)	Total fuel consumption (l)	Total engine operation (h)
219	20	260,500	54,035	4,919
Ave fuel consumption per hour) (l)	Ave fuel consumption per voyage or trip (l)	Ave no. of fishing days per voyage (day)	Ave catch per fishing voyage (kg)	Catch per 1.0-liter fuel consumption (kg)
10.98	2,701.75	11	13,583	4.82
Ave fuel consumption (l/day)	Ave selling price of catch (THB/kg)	CPUE (kg/day)	CO_2 emission per day (kg CO_2)	CO_2 emission per 1.0 kg of catch (kg CO_2)
246.73	30	1,189.49	651.36	0.5475

Table 65. New carbon emission recorded about the pilot purse seine fishing vessel

Ice consumption/trip reduced by	Compared to emission kg CO_2	New total emission/trip kg CO_2	New emission per 1.0 kg of catch (kg CO_2)
150 box = 36 tons	972	6160	0.453

Table 66. Improvements made before and after the implementation of the project using the pilot purse seine fishing vessel (2019-2021)

Aspects to be improved	Before project implementation	After project implementation
Manpower onboard (MO)	more than 30 fishers	17 fishers
Average hauling time	About 1.5 h	30 min
Living space (LS)	72 m^2 (2 levels: 3m x 6m each) shared by 29 fishers (skipper uses different area), each fisher occupies 2.50 m^2 of workspace	72 m^2 (2 levels: 3m x 6m each) shared by 17 fishers (skipper uses different area), each fisher occupies 4.23 m^2 of workspace
Total catch (TC) recorded on logbook	260,500 kg	
Ave catch per voyage	13,583 kg	
Total gross income (at THB 30/kg)	USD 260,500	
Fishing trip (FT): Thailand regulations indicate that fishing vessel more than 30 GT is permitted to go fishing for not over 240 days/year		219 days (11 days/trip)
GHG emission	0.5475 $KgCO_2$ to catch 1.0 kg of fish	0.4530 $KgCO_2$/kg of fish (to catch 1.0 kg)

greenhouse gas emission (GHG Emission) refers to the carbon emission or the release of carbon dioxide gas from burned fossil fuel into the atmosphere. Included in Table 66 are some facts about greenhouse gas emissions from the fisheries sector considered as one of the sources of carbon emission that fuels climate change.

Fuel Consumption (FC): the rate at which an engine uses fuel, expressed in units such as voyage per liter, liters per working hour, or liters per kilogram of the catch. The pilot purse seine fishing vessel makes use of Cummins Engine brand model K-500. Since the first fishing operation until now and referring to the data record for fuel consumption, the average fuel consumption, working-hours of engine operation, and the CO_2 emitted had been recorded in detail as shown below:

For the sake of showing an example, consider 1.0 liter of diesel that weighs 835 g. Diesel consists of 86.2 % carbon or 720 grams of carbon per liter of diesel. To burn this carbon to CO_2, 1920 g of oxygen is needed. The sum is then 720 + 1920 = 2640 g of CO_2/liter of diesel. It should be noted that in the U.S.A., the electricity generated by the electric power industry results in the emission of carbon dioxide (CO_2) which is equal to about 0.99 pounds of CO_2 emitted per kWh.

As shown in **Table 66**, 0.5475 $KgCO_2$ is emitted to the atmosphere while catching 1.0 kg of fish before the project implementation. After the project implementation, 0.4530 $KgCO_2$ is emitted per kilogram of fish caught.

GHG emission (before project implementation)
= 0.5475 $KgCO_2$ to catch 1.0 kg of fish
GHG emission (after project implementation)
= 0.4530 $KgCO_2$/kg of fish

Moreover, the fuel consumption of propulsion engine is 246.73 liters/day, then correspondingly the gas emitted from fuel consumption is: 246.73 × 2.64 $kgCO_2$ = 651.36 $kgCO_2$/liter.

Catch Per Unit Effort (CPUE): also called the catch rate, is frequently the single most useful index for long-term monitoring of a fishery. Declines in CPUE imply that the fish population cannot support the level of harvesting. Increases in CPUE could mean that a fish stock is recovering, and more fishing effort can be applied. CPUE can therefore be used as an index of stock abundance, where some relationship is assumed between that index and the stock size. The simple calculation of CPUE is the total catch divided by the total amount of effort used to harvest the catch.

$$\text{CPUE} = \frac{\text{Total catch (kg)}}{\text{Total amount of effort used to harvest the catch}}$$

$$\text{CPUE of pilot purse seine fishing vessel} = \frac{260{,}500 \text{ kg}}{219 \text{ days}}$$

CPUE = 1,189.49 kg/day
= 4.82 kg of catch/liter of fuel consumption
Or equivalent to = 1 kg of catch/0.2074 liter of fuel consumption

4.1.2.5 Reducing Labor in Purse Seine Fishing Operations

Due to the kinds of equipment being used for fishing and set up onboard many fishing vessels, *e.g.* purse seiners and trawlers, a large number of workers is required in fishing vessels, especially in the case of Thailand. For example, purse seiners require as many as 30 - 40 fishers onboard while trawlers require up to 22 fishers onboard. In the case of purse seiners in Thailand, heavy demand for labor comes from the enormous weight of the catch, while the nets are largely pulled aboard by hand. In view therefore of such a scenario, the Department of Fisheries (DOF) of Thailand had approached SEAFDEC/TD and with the collaboration of the Pattani Fishery Association in southern Thailand, to design a more labor-efficient purse seiner. In 2018–2019, experts from SEAFDEC/TD worked with the vessel owner on the project that aimed to design and reconfigure a 91-GT purse seiner (Nor Larpprasert 8) based in Pattani Province and used as the pilot fishing vessel for this project.

The design and reconfiguration of the fishing vessel included the installation of a multi-purpose crane, hydraulic system, power block, and central cooling with refrigeration system, on the purse seiner. The crane and power systems facilitate the hauling of nets that was done before by fishers, and the refrigeration system prolongs the preservation of the catch, thereby increasing its value in the market. The costs of the reconfiguration had been shared, with SEAFDEC paying for the equipment and the vessel owner paying for the installation as well as the acquisition of new nets. The installation of the new equipment in 2018 took two months because of the extensive optional renovations, although SEAFDEC estimated that installation of similar equipment installation on other fishing vessels would take less than one month to complete. SEAFDEC also reported that the technology and equipment are promptly available in Thailand and spread the information to all major stakeholders and important fishing ports of Thailand to also undertake the appropriate vessel improvement.

Cost-Benefit Analysis (before and after reconfiguration)

Before the equipment installation, the vessel required around 30 fishers for each seven-to-ten-day fishing trip, yielding a catch that was worth about USD 15,833, based on the vessel owner's price estimates and cross-checked with SEAFDEC experts. Such manning level also meant that the fishers' living space of 72 m^2 (4 levels of 3m x 6m space) was shared among 29 fishers (the skipper sleeps in a different area), and implied that each fisher occupied an average of 2.5 m^2 of space onboard, before the reconfiguration.

Since the installation of the new equipment in early 2019, the purse seiner has seen an approximate reduction of 37 percent in terms of labor required. The power block, crane, and hydraulic systems enable net hauling to be done more efficiently by fewer fishers. In this case, the fishers needed onboard have gone down from 27 to 17, while the average time for hauling the fishing nets is less than an hour and 30 minutes, down from more than two hours before the reconfiguration. With more adjustments, SEAFDEC forecasts that eventually, the manning will come down to 14 or 15 men, about half of the original fishing crew. The total costs of labor per year will be reduced as well, from USD 137,237 per year to USD 108,100 in the second year after reconfiguration, even with an increase of monthly wages for fishers to USD 400 per month, which is at par with past policy proposals made by Thai vessel owners and workers' organizations. The costs of workers' permit will also be reduced along with the overall cost of the workforce by 45 percent (*i.e.* to approximately USD 2,633) in two years. Even accounting for the increases in base pay of the fishers, supervisors, and skippers, the savings from the total labor cost are significant at approximately 21 percent.

The central cooling and refrigeration systems have proven to reduce the quantity of low-quality fish, especially the fish caught on the first few days at sea which loses its value as the quality deteriorates from 34 percent down to around 10 percent. This means that with the current renovations, 90 percent of the catch can be sold at full market price (up from 70–80 percent of the quantity before the installation), increasing revenues by roughly 10 percent from USD 15,833 to USD 17,416 on average per trip.