Why accurate testing of Energy Content (Net Heat of Combustion) is essential for Bio-Marine Fuels

Newsletter Update as on 08 January 2025

Introduction

Bio-marine fuel is widely adopted as a drop-in fuel to achieve the current emission requirements in the shipping industry. ISO 8217:2024 specification allows bio-marine fuels to contain up to 100% fatty acid methyl ester (FAME). The major production route of FAME is transesterification of vegetable oils, animal fats or used cooking oils with methanol using alkaline catalysts. The ISO 8214:2024 version has included additional test parameters to measure FAME content, energy content and oxidation stability for bio-marine fuels.

Accurate Net Specific Energy (NSE) assists with efficient fuel consumption management

In this newsletter article, we review why one of the most important testing parameter or property of bio-marine fuel is Energy Content. **Accurate measurement of NSE for energy content of bio-marine fuels is essential for efficient fuel management onboard ships with respect to:**

1. Fuel consumption
2. Voyage planning
3. Operating cost
4. Machineries or equipment performance
5. Emission & environmental implications

Why accurate testing of Energy Content is an essential test parameter for Bio-marine fuel

Marine fuel containing FAME typically has lower energy content compared to conventional marine fuels.

The heating value of a fuel is the total energy released as heat when a fuel undergoes complete combustion with oxygen under standard conditions. The chemical reaction is typically a hydrocarbon reacting with oxygen to form carbon dioxide, water and heat as shown in the equation below:

Hydrocarbon + Oxygen → Carbon Dioxide + Water + Heat Released

Conventionally, NSE of marine fuels (which consist of predominantly hydrocarbons from petroleum sources) is calculated using a formula specified in Annex of ISO 8217 (Annex J of ISO 8217:2024) with acceptable accuracy. **For marine fuels containing FAME, the NSE cannot be calculated using the formula specified in Annex J of ISO 8217:2024 and shall be measured using ASTM D240 method.** FAME molecules contain the Carbonyl group and Ester bonds as shown in Figure 1 below and do not consist purely of carbon and hydrogen atoms.

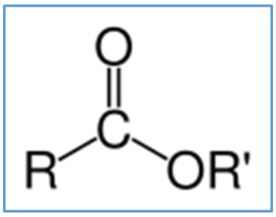


Figure 1: An Ester of a Carboxylic Acid

The density of potential energy of a hydrocarbon is determined by the number of carbon to hydrogen bonds that can be replaced by oxygen to carbon (CO2) and oxygen to hydrogen bonds (H2O), in other words, the amount of energy released is dependent on the oxidation state of the carbons in the hydrocarbon. For marine fuel containing FAME, the FAME molecule itself contains oxygen atoms in the Carbonyl group and Ester bond. The Ester group of FAME has a carbon forming 3 bonds with oxygen atoms, **this means esters are more oxidised than hydrocarbons and esters release less energy content when compared to hydrocarbon since higher oxidation reactions are needed for hydrocarbons.**

The paragraphs above explain the reasons marine fuel containing FAME typically have lower energy content compared to conventional marine fuels, which consist of predominantly hydrocarbons and the calculated formula for NSE is not applicable to marine fuel containing FAME.

According to ASTM D240 test method, heat of combustion is determined by burning a weighed sample in an oxygen bomb calorimeter under controlled conditions. The heat of combustion is computed from temperature observations before, during, and after combustion, with proper allowance for thermochemical and heat transfer corrections. The average of gross specific energy (GSE) or gross heat of combustion, and NSE or net heat of combustion of MGO, VLSFO, HSFO and Bio-marine Fuels are tabulated in Table 1 below:

Table 1:

Average Energy Content	MGO (calculated by Annex J of ISO 8217:2024)	VLSFO (calculated by Annex J of ISO 8217:2024)	HSFO (calculated by Annex J of ISO 8217:2024)	B24 Biofuel (measured by ASTM D240)	B30 Biofuel (measured by ASTM D240)
Average Gross Specific Energy (or Gross Heat of Combustion), MJ/kg	45.671	43.960	42.719	42.502	42.104
Average Net Specific Energy (or Net Heat of Combustion), MJ/kg	42.907	41.501	40.398	40.094	39.726

Note: The average GSE and NSE for each of the fuel types was obtained from at least 50 samples.

Based on Table 1, bio-marine fuel B30 has 8% lower energy content when compared to MGO. The energy content of bio-marine fuel will become lower when the FAME content is higher.

Energy content of marine fuel containing FAME shall be determined by ASTM D240 method and cannot be calculated using the current NSE formula, which is commonly used for the conventional marine fuels.

The discrepancy of NSE (or net heat of combustion) and GSE (or gross heat of combustion) of bio-residual marine fuels, B24 & B30, obtained from measurement using ASTM D240 and calculation using Annex J of ISO 8217:2024 is shown in Figure 2, 3, 4 & 5 respectively and tabulated in Table 2 and Table 3 respectively.

Table 2:

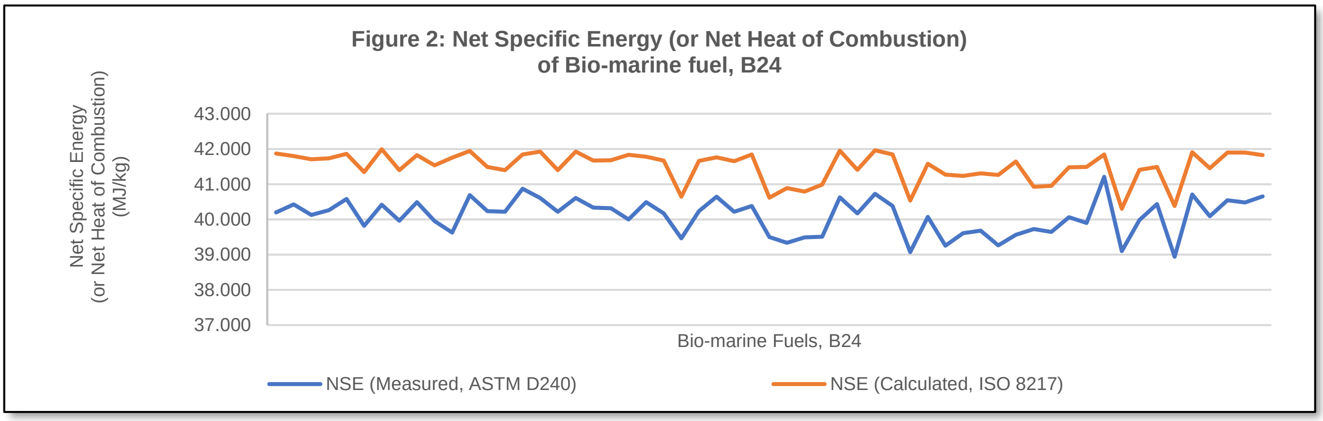
Bio-residual Marine Fuel	Average Net Specific Energy Measured by ASTM D240 (MJ/kg)	Average Net Specific Energy Calculated by Annex J of ISO 8217:2024 (MJ/kg)	Average Discrepancy of Net Specific Energy Measured by ASTM D240 and Calculated by Formula Specified in Annex of ISO 8217 (MJ/kg)
B24	40.094	41.500	-1.41
B30	39.726	41.441	-1.72

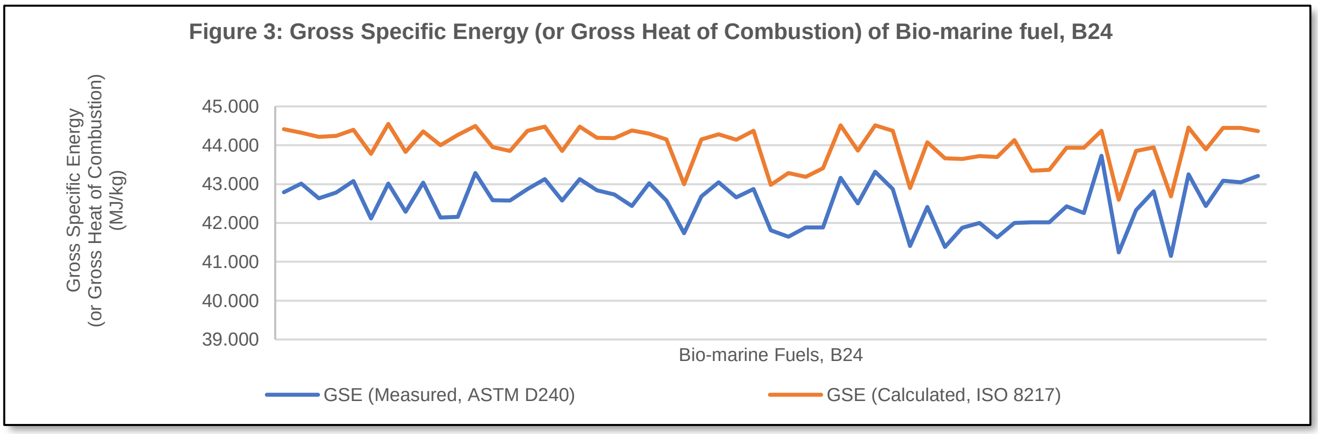
Table 3:

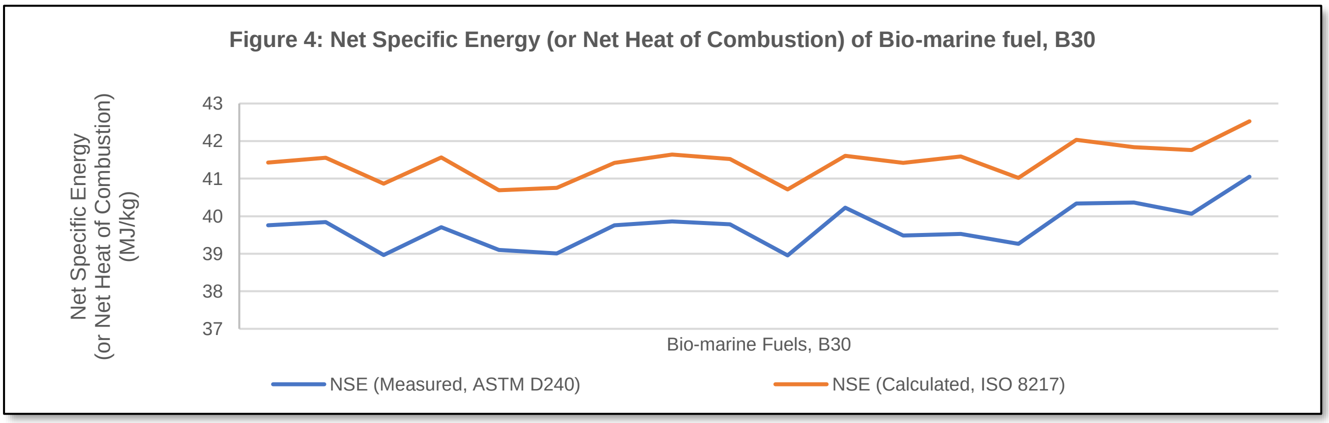
Bio-residual Marine Fuel	Average Gross Specific Energy Measured by ASTM D240 (MJ/kg)	Average Gross Specific Energy Calculated by Annex J of ISO 8217:2024 (MJ/kg)	Average Discrepancy of Gross Specific Energy Measured by ASTM D240 and Calculated by Formula Specified in Annex of ISO 8217 (MJ/kg)
B24	42.502	43.975	-1.47
B30	42.104	43.900	-1.80

NEWSLETTER

Graphical comparison of ASTM D240 vs ISO 8217 testing outcomes of Net and Gross Specific Energy (NSE/GSE) of B24 & B30 Bio-marine fuels







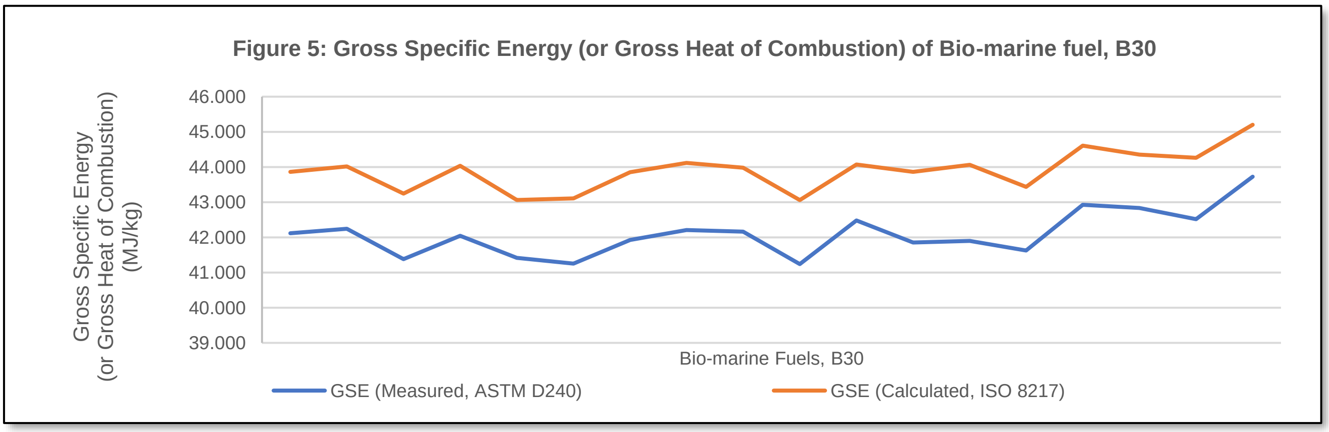


Table 2 and Figure 2 above show that the NSE obtained by calculations using Annex J of ISO 8217:2024 is approximately 3.5% higher for B24 when compared to NSE obtained by measuring using ASTM D240, **this again proves that the calculated NSE of bio-marine fuel is not accurate, and that this formula is not applicable to bio-marine fuels. Clause 6.18 of ISO 8217:2024 stipulates that NSE (or net heat of combustion) of marine fuel containing FAME shall be measured using ASTM D240.**

Situation to further understand higher fuel consumption rate of marine fuel containing FAME due to lower energy content

Scenario:
A ship uses 5,612MT of VLSFO throughout the year during her Europe voyages (From the last port to Europe and up to the first port after Europe and within Europe).

Calculations if the use of Biofuel comes into play:
If she decides to use Biofuel Grade of B24 for the same Europe voyages maintaining the same amount of power consumption from 5,612MT of VLSFO, she would need to lift 5,612 * 1.024 (10% of 24% BF) = 5,747 MT of Fuel as 24% Biofuel would contribute to 21.6% of equivalent energy compared to that of VLSFO if the Biofuel energy content is found to be 10% lower than that of VLSFO.

Conclusion & Maritec-NAIAS Recommendation

Based on the data evidence shared, it clearly indicates that bio-marine fuels have lower energy content when compared to conventional bunker fuels, which will contribute to a higher fuel consumption rate. Furthermore, the current formula used to calculate NSE of conventional marine fuels is not applicable to bio-marine fuel.

For efficient bio-marine fuel management onboard ships and for accurate measurement of energy content of bio-marine fuels, **Maritec strongly recommends that Energy Content for all bio-marine fuel should be determined in advance and further, the NSE (or net heat of combustion) should be measured using ASTM D240 method before is it used onboard vessels.**

Maritec-NAIAS provides latest ASTM D240 testing and other Enhanced Analysis options/packages for Alternative/Bio-marine fuels, in addition to standard regulatory testing requirements.

For more information on our Fuel Quality Testing services & solutions visit https://www.maritec.com.sg/services/Fuel_Testing&Solution or write to us at admin@maritec.com.sg