Concawe
Environmental Science for European Fuel Manufacturing

# Report

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# Guideline for the technical assessment of the suitability of a new material in the production of marine fuels

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# Guideline for the technical assessment of the suitability of a new material in the production of marine fuels

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# EXECUTIVE SUMMARY


**Guideline for the technical assessment of the suitability of a new material in the production of marine fuels**

This Concawe guideline provides a structured, two-level assessment process for evaluating the suitability of new materials in marine fuel production and blending. The aim of the document is to provide a methodology to demonstrate that a new material is safe, compatible, and effective for use on ships, thereby supporting the industry's transition to lower carbon fuels.

This document covers conventional and non-conventional materials including, but not limited to, off-specification FAME and those derived from vegetable oils, biomass waste, used oils, recycled components, forestry residues and other lignocellulosic material.

The outlined process involves detailed testing, documentation, and collaboration between producers, users and other stakeholders, if necessary, culminating in sea trials to confirm the fuel's acceptable performance.

A Level 1 assessment is carried out by the producer/supplier of a new material to determine if it can be considered as an acceptable fuel or blend component, which they can market confidently without further evaluation.

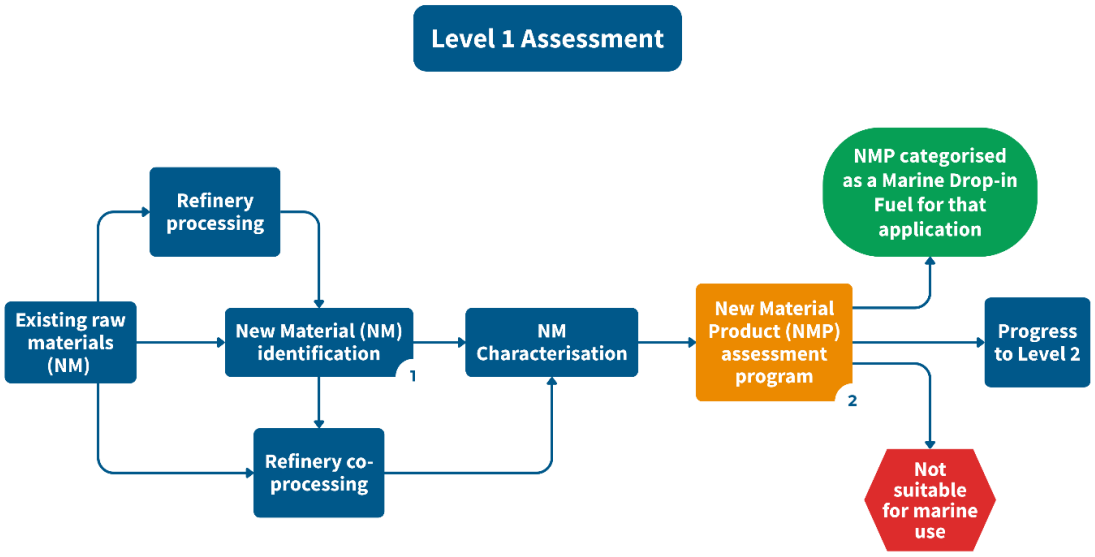
A Level 2 assessment is advised when the Level 1 assessment does not provide enough confidence in the fuel's acceptability for use. It is likely to involve the user, producer/supplier and possibly require the participation of other stakeholders.

Acceptability of the fuel as determined by the Level 2 assessment consists of analytical techniques, engine bench testing and ultimately, if further confidence is required, a sea trial assessment.

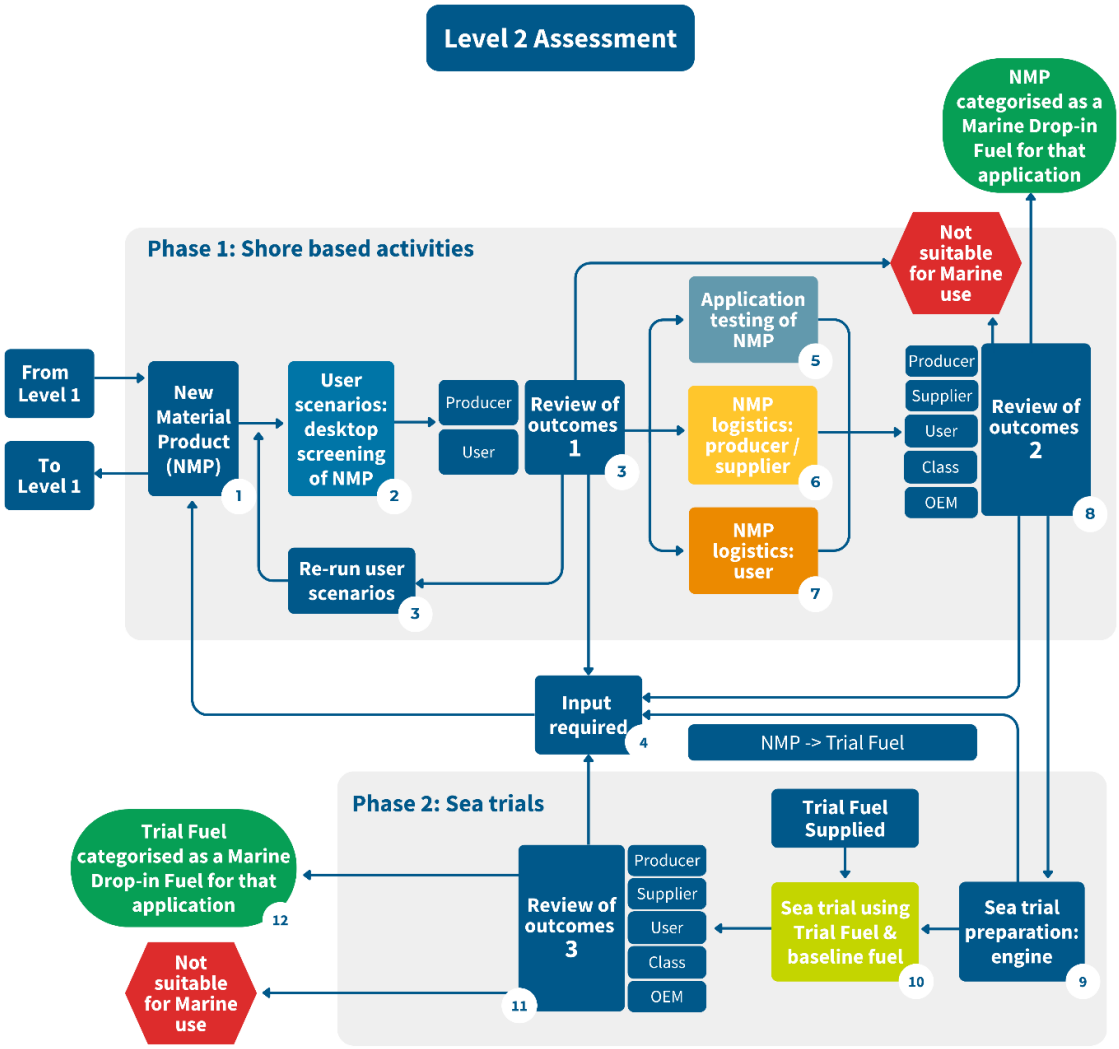
The sustainability aspects of marine fuels using such New Materials, driven by the need to reduce GHG emissions, are not covered within the scope of this document.

To assist the user, the guideline is illustrated in the form of flow charts. An overview of the Level 1 and Level 2 guidelines are shown below:

Note: Appendix VIII provides a poster overview of all flowcharts in the guideline.




If the Level 1 Assessment outcome is that further assessment is required, the Level 2 Assessment is then used:




Note: Stages 1-12 correspond to the detailed Level 2 assessment process described across pages 25 - 28.

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This Concawe technical guideline provides a structured technical assessment approach to evaluate whether a fuel resulting from the inclusion of a New Material is safe, compatible, and effective for use on ships.

The sustainability aspects of these marine fuels using such New Materials, driven by the need to reduce GHG emissions, are not covered within the scope of this document.

This document identifies important factors to consider when using a New Material in a marine fuel rather than a comprehensive list of requirements. It is intended to be guideline based on best practices and is not intended to be a specification.

# GLOSSARY

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| BDN | Bunker Delivery Note |
| CA | Crank Angle |
| CIMAC | Conseil International des Machines à Combustion |
| CFPP | Cold Filter Plugging Point |
| CP | Cloud Point |
| DG | Diesel Generator |
| DSC | Differential Scanning Calorimetry |
| DTA | Differential Thermal Analysis |
| DTOT | Diesel Thermal Oxidation Tester |
| FIA-100 | Fuel Ignition Analyser |
| FP | Flash Point |
| FSN | Filter Smoke Number |
| FTIR | Fourier Transform Infrared Spectroscopy |
| GC-MS | Gas Chromatography–Mass Spectrometry |
| HFRR | High-Frequency Reciprocating Rig |
| HLPS | Hot Liquid Process Simulator |
| HOTSPIN | Heated Centrifuge Sediment Separation Test |
| HS | High Sulphur |
| IDIDs | Internal Diesel Injector Deposits |
| IMO | International Maritime Organization |
| IP | Institute of Petroleum Test Method |
| JFTOT | Jet Fuel Thermal Oxidation Tester |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MBG | Microbiological Growth |
| MCR | Maximum Continuous Rating |
| MSC 286(86) | Marine Safety Committee Resolution 286(86) |
| MGO | Marine Gas Oil |
| NM | New Material |
| NMP | New Material Product |
| OEM | Original Equipment Manufacturer |
| PP | Pour Point |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |
| RF Grades | Residual Fuel Grades |
| ROHR | Rate of Heat Release |
| RSSOT | Rapid Small Scale Oxidation Test |
| SDS | Safety Data Sheet |
| SFOC | Specific Fuel Oil Consumption |
| SIP | Ship Implementation Plan |
| SMS | Safety Management System |
| TDC | Top Dead Centre |
| TSP | Total Sediment Potential |
| ULS | Ultra Low Sulphur |
| VLS | Very Low Sulphur |
| VLSFO | Very Low Sulphur Fuel Oil |
| WAT | Wax Appearance Temperature |
| WG7 | Working Group 7 (CIMAC Fuels Group) |

# 1 INTRODUCTION

The shipping industry is experiencing a substantial transformation to comply with stricter environmental regulations and ambitious de-carbonisation targets. This transition involves achieving higher efficiency gains and introducing higher levels of low carbon fuels into marine fuel blends.

Bunker fuel producers, purchasers, and ship operators are therefore confronted with the challenge of determining the suitability of an increasingly diverse range of alternative marine fuels and fuel blends now being offered as drop-in replacements for conventional petroleum diesel fuel systems.

As the variety and availability of new products and feedstocks for low carbon liquid fuels increases, developing comprehensive individual specifications becomes more complex. At the time of writing, the ISO 8217 international marine fuel standard [3] does not consider or make reference to some of these potential new materials.

There is currently no available accepted guidance for assessing the suitability of the inclusion of alternatively sourced new materials for use in the production of marine fuels, hence the drive for this guidance document based on best practices.
It is important to note that merely meeting the technical specifications outlined in ISO 8217 or other relevant standards for marine fuel does not necessarily ensure that the fuel is suitable for use on board a ship.

This Concawe technical guideline provides a structured, high-level assessment methodology for evaluating the technical suitability of new materials to produce a marine drop-in fuel.

A new material could be utilised either itself as a marine fuel or blended with conventional, petroleum derived fuel products. The resulting end fuel product being considered as a marine drop-in fuel.

For the purpose of these guidelines the following definitions apply:

A **New Material** is a biogenic, recycled carbon, e-source or other, petroleum source or otherwise, material that has either not been used previously, or not at the now intended blend ratio, including very low levels as used for additive purposes.

A **Marine Drop-in Fuel** is intended as a direct replacement of a conventional, petroleum derived, distillate or residual grade fuel oil and which has been demonstrated as having acceptable performance characteristics when used as intended. Due to technical considerations, it may consist, in whole or in in part of, a New Material. A Marine Drop-in Fuel should be capable of being used without modifications or adjustments not available onboard to existing arrangements and assigned combustion equipment.

This guideline' should be used based on specific end-use interests, rather than reading the guideline in a sequential manner like a book.

This guideline is not exhaustive but highlights important considerations when assessing the suitability of the new material. Adoption of this guideline may reduce the uncertainty of the suitability of new products entering the market. This approach recognises the responsibility of producers and users to complete pre-use suitability assessments to ensure ships are aware of the fuel handling characteristics to mitigate onboard risks safely.

## 1.1. OBJECTIVE OF THE DOCUMENT

This Concawe guideline is intended to provide a structured assessment process that can be used by both producers and users to technically evaluate whether a fuel product resulting from the use of a new material is 'bunker suitable' in the given context.

## 1.2. IMO MARINE BEST PRACTICE GUIDANCE

IMO Best Practice Guidance [1][2] state that it is the responsibility of both producers and users to ensure, within their own areas of responsibility, that any new fuel product is 'bunker suitable' before being used as a marine fuel. Those IMO guides however do not give further direction on how that might be demonstrated, which this Concawe guide aims to offer more detail.

**The producers/suppliers:** Manufactures or buys, owns, stores and sells bunkers. Distributes bunkers from pipelines, trucks and/or barges. May blend products to meet the customer's specifications. May own or charter a distribution network or may hire delivery services from a third party. Issues the bunker delivery note (BDN)

**Buyer/User:** is the entity which will actually use the resulting fuel product – effectively the ship owner / operator.

Further detail on producer/supplier responsibilities are referred to Annex VII.

## 1.3. ISO 8217:2024 CLAUSE 5.2

The ISO 8217 standard does not cover the potentially wide range of new materials currently under consideration (See ISO 8217 Annex A.4), however, Clause 5.2 of the Standard specifies that the supplied fuel must be acceptable for use:
*5.2 The fuel shall be free from any materials, including added substances and chemical species, at a concentration that causes the fuel to be unacceptable for use by way of a) jeopardizing the safety of the ship; or b) adversely affecting the performance of the machinery; or c) being harmful to personnel.*

## 1.4. USE OF THE NEW MATERIAL

The shift towards a lower carbon future has led to increased interest in utilising unestablished and non-standardised products. This trend presents the risk of unsuitable new materials being used without assessment for their suitability.

A New Material can be used:

- with crude petroleum in refinery processing, resulting in marine fuel or a blended fuel product, often called co-processing
- as a component of an existing conventional fuel
- as an additive for production purposes or to enhance the end-product's performance
- as a fuel grade product itself

Significant changes in blending ratios of the new material should each be separately assessed.

## 1.5. DOCUMENTATION OF THE ASSESSMENT PROCESS

These guidelines offer a template for documenting the assessment process, including product descriptions, criteria, findings, and considerations for logistics and fuel management.

## 1.6. THE TWO-LEVEL ASSESSMENT PROCESS OVERVIEW

### 1.6.1. Level 1 – Involving only the Producer

The Level 1 assessment determines if the New Material can be considered as a fuel or blending component acceptable for use and that the Producer can market confidently without further evaluation, or if it needs to proceed to Level 2 for further assessment.

### 1.6.2. Level 2 – Involving both Producer and User

A Level 2 assessment is necessary when Level 1 does not provide enough confidence of the fuel's acceptability. A user may request collaboration with the producer for this assessment.

Level 2 consists of:

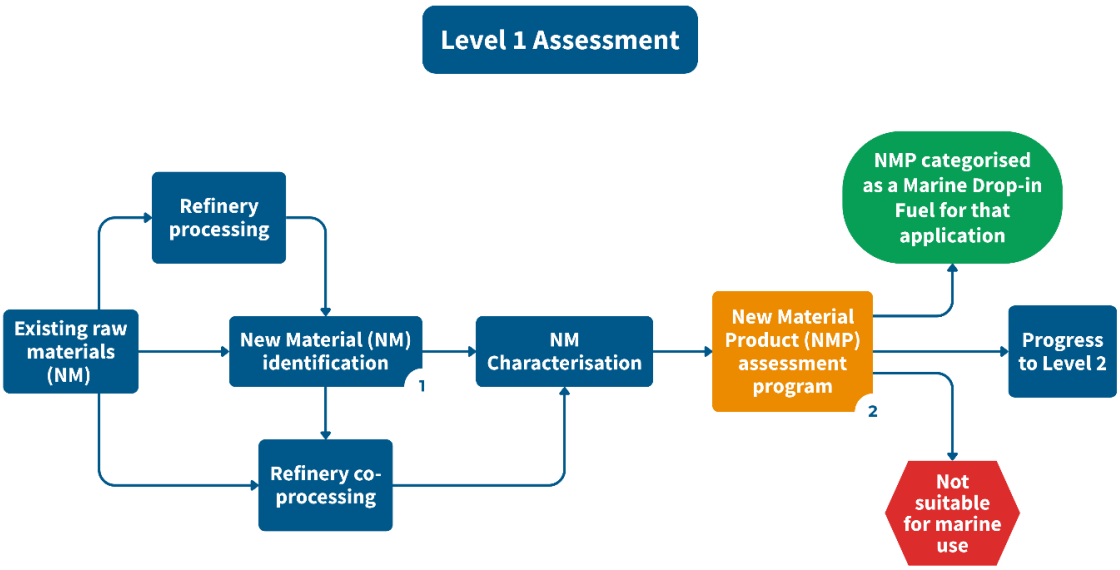
- Phase 1: Shore-based appraisals
- Phase 2: Sea trials

A satisfactory outcome of Level 2 would be that the assessed fuel product can be categorised as an acceptable marine fuel (Marine Drop-In Fuel) for the application in which it has been trialled.

# 2. LEVEL 1 - PRODUCER (REFINER OR BLENDER) ASSESSMENT PROCESS

A general overview of Level 1 for the producer's (refiner / terminal / blender) new material suitability for marine fuel use assessment process, is shown in Figure 1:

Figure 1: Level 1 General Assessment Overview




## 2.1. LEVEL 1, STAGE 1: NEW MATERIAL IDENTIFICATION

Any specific new material being considered during this assessment is designated as New Material (NM). A New Material (NM) can originate from diverse source materials.
Each NM can be accurately identified to distinguish it from other materials by:

- Feedstock from which it is sourced
- Production Process
- Chemical composition
- Physical characteristics
- Quality consistency – typical qualities
- Unique Identifier

Precise identification ensures clearer assessment outcomes and clarity for all involved in the process. Significant changes may necessitate re-evaluation.

## 2.2. USE OF NEW MATERIAL 'NM' TO PRODUCE CANDIDATE FUEL PRODUCT 'NMP'

The NMP is a result of one of the following:

### 2.2.1. Refinery Co-processing and processing

Co-processing is the integration of renewable feedstocks with conventional fossil feedstocks into refinery processing. This results in a range of potentially altered fuel product streams. For marine fuel production the co-processing streams may be used as a marine fuel itself or as a blending component and is already covered by ISO8217 as it falls under the general requirements of Clause 5.1.

Processing refers to the conversion of 100% renewable feedstocks, without the addition of any fossil feedstocks. Unlike co-processing, this pathway is not covered by ISO8217, as the standard does not address fuels derived exclusively from renewable feedstocks processed outside conventional fossil-based refinery schemes. Consequently, streams resulting from processing should be considered, within the present framework, as new materials and guided by the new material product assessment program to demonstrate their suitability in the production of marine fuels.

### 2.2.2. Blending

New Material, NM, is blended into an existing marine product stream to produce the fuel product.

### 2.2.3. Direct use as a marine fuel product

New Material, NM, can be used directly without further processing or blending

### 2.2.4. Fuel Additives

Fuel additives, can be considered as new materials.

Note: If there is a significant change in the characteristics of the New Material, NM or a significant change in its blend ratio/ treat rate, the significance of the change may need to be re-evaluated, and relevant parts of the assessment process rerun.

## 2.3. LEVEL 1, STAGE 2: PRODUCT NMP ASSESSMENT PROGRAM

Stage 2 of the Level 1 assessment is a detailed assessment of the product quality considerations of the New Material Product, NMP, illustrated in Figure 2

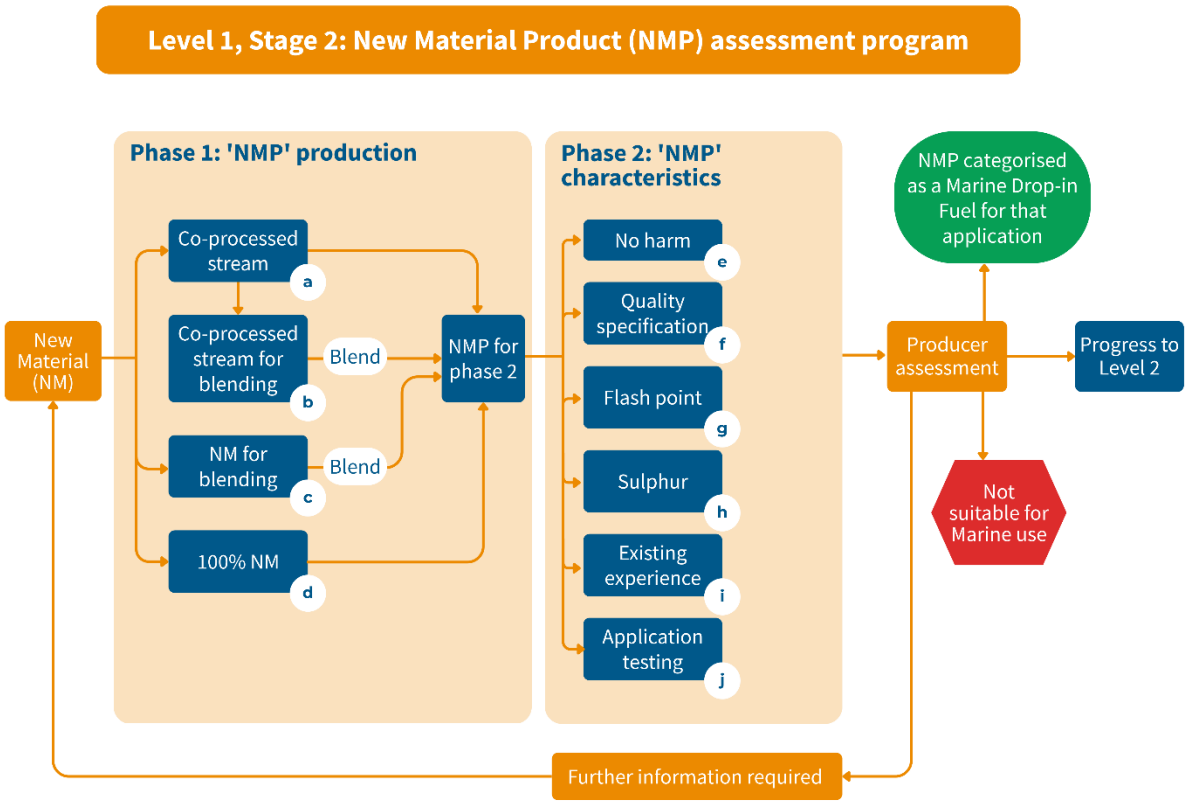
### 2.3.1. The outcome of this assessment process

The NMP is confirmed as being a suitable fuel; is a candidate to be evaluated at Level 2; or is not suitable for further consideration as a 'drop-in' marine fuel.

Alternatively, reformulation of the NMP may be required.

### 2.3.2. The assessment process

Figure 2: Assessment of production New Material Product (NMP)



### 2.3.3. The Producer's assessment of the NMP

**This is divided into two main phases: 1. Production and 2. Quality**

**Level 1, Stage 2: New Material Product (NMP) assessment program**

**Stage 2 Phase 1: NMP Production (a - d)**

**Information required for assessing the new material's production**

| | **Fuel Manufacture approach and multiple output streams** |
|---|---|
| **a** | Co-processing Stream Ratio where product is from co-processing directly:<br>The nature of the New Material, NM – Stage 1; and<br>The ratio of the new material to the petroleum feed rate during co-processing |
| **b** | Co-processed stream for blending. Where product is from co-processing for blending in a conventional fuel:<br>• The nature of the co-processed stream<br>• The nature of the New Material, NM – Stage 1<br>• The ratio of co-processed stream to the petroleum feed<br>• The ratio of the blend |
| **c** | NM for blending with another existing fuel product component<br>• The nature of the NM<br>• The nature of the components being blended with NM<br>• The ratio of blend components |
| **d** | **NM for itself** to be considered as a candidate as a marine fuel without any blending for NMP stage 2 assessment |

**Stage 2 NMP Product Quality Considerations (e-j)**

Product quality encompasses more than just meeting the numerical limits defined in specification tables such as ISO 8217. The following is a non-exhaustive list of considerations that may be used to determine the acceptability of the NMP.

Note: Section 2.4 provides details on analytical test methods and approaches.

| | |
|---|---|
| **e** | **No Harm**<br>• Personnel safety:<br>Consider additional hazards for example: skin contact, eye contact, inhalation or ingestion.<br>• Machinery:<br>Consider compatibility with existing fuels, existing fuel system and engine component materials (including any fuel tank coatings, equipment / piping seals and jointing materials).<br>• Treatment systems: |

| | |
|---|---|
| | Consider impact on conventional onboard fuel treatment systems (purifier and filters), on water sealed systems, and resistant to causing emulsions.<br>• Engine:<br>Consider corrosion, erosion, cavitation wear, deposit formation and cylinder lacquering in the engine or engine components. Also consider the impact on engine control systems, ignition behaviour, Rate of Heat Release (ROHR) and combustion profiles across all loads.<br>• Environment:<br>Sea – consider the impact of spillage or leakage to sea, either directly or as bilge water component.<br>Air –consider if combustion would result in unusual emissions containing harmful products. Considering regulatory controls.<br>Consider if waste residues from onboard treatment are capable of being landed to conventional slop reception facilities and meet national and international requirements. |
| f | **Quality Specification**<br>In addition to the requirements of marine fuel specifications, such as ISO 8217, it is useful to consider:<br>• If the product 'NMP' is a distillate or residual fuel type component.<br>• Is quality consistent. What are typical values, range of values.<br>• Applicability of test methods with respect to scope and precision.<br>• How do NMP qualities compare to those of current Marine Fuels and ISO 8217.<br>• Is the NMP categorised as a MARPOL Annex I (fuel oil) or Annex II (Chemical) product for bulk tanker carriage or is it not listed.<br>• What is the stability of the product during typical onboard storage, treatment and use conditions e.g. tendency to form sludge, adherence to surfaces or stratification?<br>• Compatibility with existing marine fuel products.<br>• Compatibility with new batches of the same NMP during top-up or bunkering (e.g. the risk of instability or formation of solid "asphalt-like" material when mixing different batches, as observed for some VLSFO fuels).<br>Further investigative analysis may be required depending on the nature of the 'NM' such as:<br>• Establishing in depth composition e.g. – GC-MS and FTIR fingerprint trace.<br>• Evidence of corrosive, erosive potential on metals and elastomer materials, seals and gaskets.<br>• Fuel system performance characteristics such as filterability and resistance to sludge deposition (centrifuge tests).<br>• Engine combustion performance characteristics.<br>• Tendency to form deposits at high temperatures pre and post combustion. |
| g | **Flash Point**<br>As required by national and international regulations (e.g. SOLAS regulation). |
| h | **Sulphur content**<br>As required by national and international regulations (e.g. MARPOL Annex VI Reg 14)<br>In this document Product 'NMP' is categorised as: |

| | |
|---|---|
| | • High Sulphur – HS (> 0.50%)<br>• Very Low Sulphur – VLS (> 0.10% - 0.50%)<br>• Ultra Low Sulphur - ULS (≤ 0.10%) |
| i | **Existing Experience**<br>Is there any experience in the use of this product as a fuel in the marine or in other industries? Consider combustion equipment types, the duration of use.<br>Are reports/studies available?<br>Consider the extent to which this product differs from the Producer's existing product characteristics. |
| j | **Application Testing**<br>The producer may choose to evaluate the NMP's performance using a shore-based test bench engine.<br>For more details see Level 2 Phase 1 Stage 5 (Section 3.1.5) |

## 2.4. ASSESSMENT METHODOLOGIES

This section provides useful explanations and suggested test methods for conducting the Level 1 Stage 2 assessments.

Although the product NMP, herein addressed as the Fuel, being assessed may fall outside the scope of the ISO 8217 marine fuels standard, it nevertheless should consider specification limits, and crucially Clause 5 which states:

> *5.2 The fuel shall be free from any materials, including added substances and chemical species, at a concentration that causes the fuel to be unacceptable for use by way of a) jeopardizing the safety of the ship; or b) adversely affecting the performance of the machinery; or c) being harmful to personnel*

*Important Note: The nature of a new material component or fuel may impact the applicability, functionality and precision of the test method.*

### 2.4.1. Hazardous Nature – Physical/Chemical, Health and Environment

A Safety Data Sheet (SDS) must accompany any fuel loaded on board a ship and address the hazardous nature of that fuel.
The requirements of the SDS are listed under the International Maritime Organisation (IMO) Marine Safety Committee resolution MSC.286(86). [5] See Annex I.

Other National/Regional land-based controls may apply, such as that of the European Union which is covered by the current legislative framework Regulation (EC) No 1907/2006. This is concerning the 'registration, evaluation, authorisation and restriction of chemicals' (REACH).

### 2.4.2. Stability and Fuel Compatibility

The formulation of a fuel blend resulting in a NMP needs to maintain sufficient asphaltene stability reserve to avoid the risk of becoming unstable resulting in potential heavy sludge deposition.

Attention needs to be given to ensuring that the NMP remains stable and homogenous through handling, storage and use; taking into account the thermal, mechanical, chemical properties and duration of storage conditions imposed on the fuel.

There are a number of influences that can dictate the length of time a fuel can be stored on board a ship and remain acceptable for use. This may be impacted by temperature control management in relation to cold flow properties and thermal stresses which may accelerate the de-stabilisation, shortening shelf life of the fuel.

When a fuel blend contains asphaltenes sufficient asphaltene stability reserve is required to ensure the asphaltenes do not become unstable and result in sludge deposition.

Ships may carry multiple fuels and the compatibility characteristics of the NMP with these other fuels need to be understood.

The stability and compatibility characteristics of the fuel can be investigated using a range of test methodologies. More detail on test methods available can be found in the following publications:
Concawe RPT 1911 - Study to evaluate test methods to assess the stability and compatibility of marine fuels in view of the IMO MARPOL Annex VI Regulation 14.1.3 for 2020 Sulphur requirements

CIMAC Guidelines (found in www.cimac.com -WG7) These include:
- 03/2024 *Overview and interpretation of total sediment test results in the context of ISO 8217.*[10]
- *01/2019- Marine fuel handling in connection to stability and compatibility.[11]*
*-Joint Industry Guidance – The Supply and use of 0.5% - sulphur marine fuels.[12]*

### 2.4.3. Cleanliness

ISO 8217:2024 defines limits on water content, metals and extraneous dirt content.
These limits are based on the expected capabilities of the on-board fuel treatment and conditioning systems to contaminants to acceptable levels.
These systems may employ gravitational settling, centrifugal separation and filtration.
Such systems also help to address contamination of water or abrasives that may occur on board the ship.

The fuel should not adversely impact these treatment mechanisms.

One test method which may be useful in assessing cleanliness is ASTM D1401 – *The water separability of petroleum Oils and Synthetic Fluids*

For more information*:*

CIMAC Guidelines (found in www.cimac.com -WG7) These include:
- 03/2024 *Overview and interpretation of total sediment test results in the context of ISO 8217.[10]*
*CIMAC Guidance 09/2024 v2 Design and Operation of fuel cleaning systems for diesel engines. [16]*

### 2.4.4. Resistance to thermal and mechanical stress

Following issues of sticking fuel pumps in the US Gulf coast area in 2018, Concawe worked on a project with the Savant Group which investigated the potential for rheology to determine the stability of the viscosity of a fuel under high temperatures and shear conditions.

ASTM is considering developing a standard test method based on this work. This is being evaluated by CIMAC WG7-Fuels.

### 2.4.5. Oxidation Stability

Oxidation stability is an important characteristic of distillate fuels that can affect the formation of sediment and increase in acidity during storage on board the ship.
The methods used for distillate fuel oil may not have been fully evaluated for a new material blend however could be used for indicative purposes. Examples are:

*ISO 12205 Determination of the oxidation stability of middle distillate fuels*

*EN 15751 – determination of oxidation stability by accelerated oxidation method (Rancimat)*

*EN 16091 - Determine of oxidation stability **by** Rapid Small Scale Oxidation Test (RSSOT)*

A combination of ASTM D4625 multi week storage test plus other tests such as oxidation and acidity tests may be useful in evaluating long term fuel storage stability.

## 2.4.6. Storage and handling

### 2.4.6.1.Thermal stresses

During storage, marine fuels can typically experience temperatures between 0°C and 50°C. In settling and service tanks, temperatures can reach 98°C and in engine booster systems can reach up to 150°C.

Fuel can also be subjected to mechanical and centrifugal forces at elevated temperatures during the cleaning process when water, dirt and sediment are removed. These stresses are further accentuated with high extreme pressure fluctuations and high velocity rate of spill at the fuel pumps typically found on most marine diesel engine fuel systems.

Test methods assessing the tendency to lacquering and deposit formation include Diesel Thermal Oxidation Tester (DTOT) based on the Jet Fuel Thermal Oxidation Tester (JFTOT) (ASTM D3241) and Hot Liquid Process Simulator (HLPS).

See also section on Oxidation stability.

### 2.4.6.2. Stratification

Stratification due to the separation of blend components can occur especially where there is a large density variance between components or when components are not fully miscible.

Laboratory simulations may be used to assess the tendency to stratify under various storage conditions. These tests typically involve storing samples of the fuel and measuring key parameters, such as density, from different layers in the sample over time.

### 2.4.6.3. Cold Flow properties

Cold flow properties can be understood by measuring characteristics such as:

*ASTM D6749 - Pour Point*

*ASTM D6371 - Cold Filter Plugging Point*

*ASTM D2500 - Cloud Point*

Considerations to be given to the composition of the fuel for which the conventional tests methods may not provide a full understanding of the fuel's cold flow properties, in particular longer term cold soaking type testing may need to be considered.

### 2.4.6.4. Wax Appearance and Wax Disappearance Temperatures

The wax appearance temperature and/or wax disappearance temperature test methods can be considered to aid fuel management decision making onboard.

Useful test methods are:

*IP 389 – Determination of Wax Appearance Temperature (WAT) of Middle Distillate Fuels by Differential Thermal Analysis (DTA) or Differential Scanning Calorimetry (DSC)*

*ASTM D8420 - Standard Test Method for Wax Appearance Temperature and Wax Disappearance Temperature of Petroleum Products and Liquid Fuels*

#### 2.4.6.5. Microbiological Growth (MBG) tendency

Hydroscopic fuels absorb water and this can promote microbiological growth in storage tanks.
The following test methods can be useful for determining aerobic microbial content in distillate fuels and associated water:

*IP 385 – Determination of the Viable Aerobic Microbial Content of Middle Distillate Fuels and Associated Water — Filtration and Culture Method*

*IP 613 – Determination of the Viable Aerobic Microbial Content of Fuels and Associated Water - Thixotropic Gel Culture Method*

*ASTM 7978 - Determination of the Viable Aerobic Microbial Content of Fuels and Associated Water— Thixotropic Gel Culture Method*

FAME containing fuels are known to present additional operational challenges, including water uptake (hygroscopic behaviour), reduced oxidation stability and cold flow limitations. Relevant guidance is therefore provided below.

Further information can be found in:

*Concawe Report no.9/09 – Guidelines for handling and blending FAME.[17]*

*CIMAC Guidance: 04/2024 Marine Fuels Containing FAME; A guideline for shipowners and operators.[13]*

### 2.4.7. Specific Energy

The specific energy value of a fuel is an essential characteristic for a ship planning long voyages and with limited volumetric tankage.

Historically calculation methods have been used, but these may no longer be applicable to fuels containing novel or bio-components.

Direct measurements of specific energy are:

*IP 12 - Determination of the Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimer*

*ASTM D240 - Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter*

For more detailed information on Specific Energy see ISO 8217:2024 Annex J

### 2.4.8. Lubricity

The lubricity characteristic of the fuel is important to ensure that fuel pump and injection systems are protected from an undue rate of wear and will continue to operate correctly.

A useful test method to assess lubricity is:

*ISO 12156 - Diesel fuel — Assessment of lubricity using the high-frequency reciprocating rig (HFRR)*

### 2.4.9. Material Compatibility

The compatibility of the fuel with the materials typically encountered in the supply chain and onboard should be assessed.

Engine and equipment manufacturers may need to provide guidance on the compatibility of a new fuel with their auxiliary and main machinery plants.
This may include ancillary equipment such as oily water separator plants, overboard discharge monitors, filters, coalescers and other fuel system components.

#### 2.4.9.1. Acidity

Some New Materials being considered for use may indicate a higher acid number, which typically is the case for some biomass feedstocks. Their impact on the typical materials expected to be used on board a ship should be assessed.

It is important to understand that the relationships between acidity and corrosivity of a fuel is complex. For more information, please refer to the ISO 8217:2024 Annex E.

*Further reference may be made to the Concawe document Report no.9/09 – Guidelines for handling and blending FAME.[19]*

#### 2.4.9.2. Corrosivity

The corrosion characteristics of a fuel should be evaluated and consider the typical operating conditions encountered on board.
Several corrosivity test methods may be applied, Including:

*IP 154 / ASTM D130 - Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test (Particularly at the higher temp of 100°C and 150°C)*

*ASTM D655 - Standard Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water (Rust Preventing Characteristics)*

*ASTM D664 - Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration (Strong Acid number – see ISO 8217:2024 Annex E)*

*ASTM D6594 - Standard Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135 °C (Using several metal coupons such as zinc, copper, lead, and tin alloys, along with aluminium, carbon steel, stainless steel all of which can be tested under this method for extended periods of 7 days, even up to 90 days.)*

#### 2.4.9.3. Elastomer compatibility

Fuels, especially those containing alcohols, esters and other polar components, may interact with seals, gaskets and flexible fuel pipes causing swelling, shrinking, and cracking which can lead to leaks.

Fully paraffinic fuels (fuels containing no aromatics), are also known to result in different seal swelling behaviour, possibly causing old seals to shrink and leak, requiring further caution in these cases.

When assessing elastomer compatibility, properties such as volume variation, hardness, tensile strength, and elongation should be compared before and after the elastomer is immersed in the fuel or component. ISO 1817:2024 provides useful guidance on the effect of liquids on vulcanized or thermoplastic rubber.[14]

Test conditions can be modified to resemble those encountered in the system. Residual type fuels can be tested at elevated temperatures e.g., 100°C for 4-7 days, whilst distillates can be tested at 50°C for 24 hours.

Typical Elastomers for testing may include Nitrile Rubber, Neoprene, Chloroprene, Natural Rubber, Hypalon, Styrene, Butadiene rubber, Butadiene Rubber, Fluorocarbon, Nylon, Teflon, and Viton.

### 2.4.10. Composition analysis

Methods such as GC-MS or FTIR can provide useful compositional information on a fuel, noting that many GC-MS methods are not standardised test methods.

Reference should be made to the Informative Annex B of the ISO 8217:2024 standard covering the composition of marine fuels.

## 2.5. FUEL APPLICATION PERFORMANCE ASSESSMENT OPTIONS

Carrying out application performance tests will provide further understanding of the product and how it might impact machinery.

### 2.5.1. Ignition and Combustion Laboratory based testing

A variety of cetane number test methods are given in ISO 8217, applicable to distillate type fuels.

Ignition and combustion characteristics can also be investigated using a constant volume combustion chamber technique, such as the Fuel Ignition / Combustion analyser (FIA -100) IP 541.

This technique allows for the determination of parameters such as ignition delay, main combustion delay (which can be converted to an estimated cetane number), end of main combustion, end of combustion, pre combustion period, main combustion period, after burning period, as well as the maximum rate of heat release. These values can be compared to those obtained on existing fuels.
*See CIMAC Guidance document 2011 Ref: Fuel Quality guide on Ignition and Combustion [8]*

### 2.5.2. Shore based Engine Test - Extended combustion performance

Shore based engine tests can be carried out at an engine testing facility using a single or multi-cylinder two-stroke or four-stroke engine.

Operating parameters are monitored and adjusted as necessary, while the impact on exhaust emissions and fuel system components such as injector nozzles is assessed.

The performance of the new fuel should be compared with the type of fuel it is replacing.
See Annex III for a typical performance template for recording results.

More detail on the processes in performing this engine test can be found in Section 3.1.5, Level 2 Stage 5: Application Testing.

### 2.5.3. Separator Performance

Separator test beds can be used to determine the impact of the fuel on the efficiency of separators, sludge generation and sludge consistency.

### 2.5.4. Sludging Tendency

On-board separator conditions may be simulated by the HOTSPIN test.

The HOTSPIN test is a heated, temperature-controlled centrifuge test used to evaluate the tendency of sediment and water in a fuel to separate under centrifugal force.

*See CIMAC Paper No. 238: Stability assessment of bio-residual marine fuels (RF grades) through extended TSP and spin testing [15]*

### 2.5.5. Fuel injector deposits and fouling tendency

Some OEM's and engine test laboratories have the facilities to replicate the fuel injection system and assess the impact of the fuel on the injection equipment. A fuel injection test rig is typically used to measure injector deposits in an actual injector in simulated operating conditions.

The Diesel Thermal Oxidation Tester (DTOT) based on the Jet Fuel Thermal Oxidation Tester (JFTOT) (ASTM D3241) can be used to assess the deposit forming tendency of the fuel at various temperatures.

The Komatsu JPI-5S-55 hot tube test method evaluates the thermal and oxidation resistance of lubricating oils and may be adapted to evaluate marine fuels.

# 3. LEVEL 2 - PREPARATIONS FOR AND IMPLEMENTING THE SEA-TRIAL

The outcome of the Level 1 assessment is either that the NMP is:

- Categorised as a Marine Drop-in Fuel for that application
- Requires further assessment – progress to Level 2
- Not suitable for Marine use

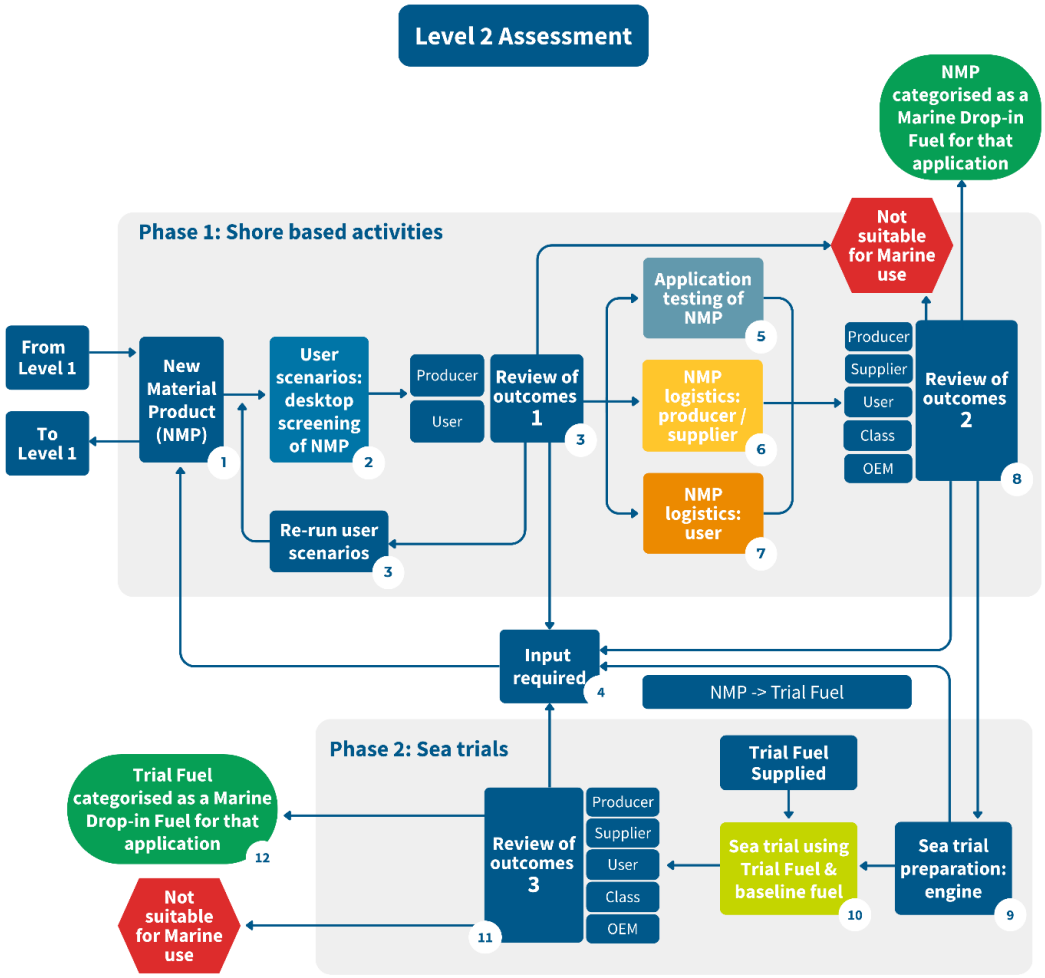
In the case of requiring further assessment, the Level 2 Assessment is described in this section. Whilst the Level 1 assessment only involved the producer/supplier, Level 2 assessment involves both the producer/supplier and the user of the fuel, whilst also considering the interests of other stakeholders. (Figure 3)

The source, nature or composition of the New Material may be such that the Level 1 assessment process cannot fully conclude that the trial fuel is 'bunker suitable' as intended. Therefore Level 2 allows for the product to be further evaluated under shore-based conditions (Phase 1) and onboard (Phase 2).

The user may need to involve shore-side departments such as technical, bunkering and commercial departments, as well as considering the impact of the fuel on the ship's crew.

Class, equipment manufacturers (OEM) and in some cases flag administrators may also need to be consulted along with other relevant stakeholders.

Figure 3: Level 2 General Overview Sea Trial



## 3.1. LEVEL 2 – PHASE 1 SHORE BASED PREPARATIONS STAGES 1 TO 8

### 3.1.1. Stage 1: NMP input from Level 1

Completion of the Level 1 assessment process by the Producer will have established the basic properties of the product such as composition, physical and several performance characteristics.

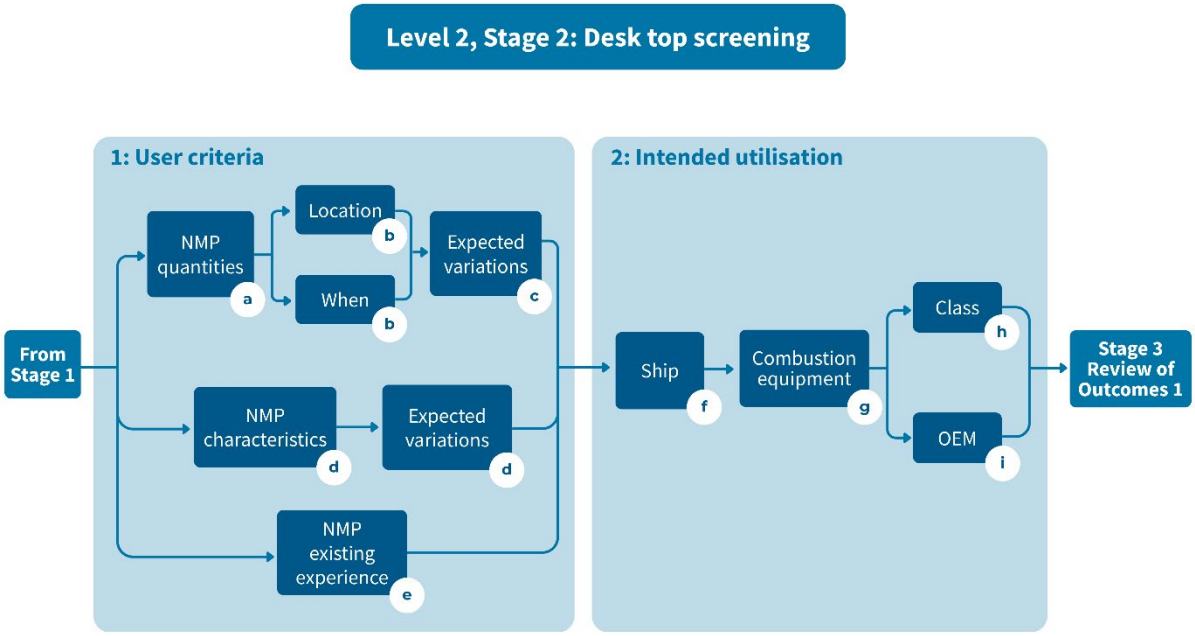
The purpose of Level 2 is to verify the expected performance outcomes under real operating conditions. A satisfactory result would qualify the fuel, and other fuels with similar characteristics, as a marine 'drop-in' fuel.

During Level 2 assessment any anomalies arising may require additional information to be sourced via Level 1.

### 3.1.2. Stage 2: User scenarios – desk top screening

A potential User of the fuel should assess whether they would be interested in sea trialling that fuel. If there are multiple users each should undertake their own assessment.
The component parts of such an assessment process are shown in Figure 4.

Figure 4: Desk top screening



**Level 2, Stage 2: Desk top screening**

## Sub-stage 1 (a -e) User Criteria

**For USER - Key questions to address and understand from the information provided by Producer**

| | |
|---|---|
| **Quantities** | |
| **a** | What are the expected quantities of the NMP which will be available?<br>(For the trial and thereafter) |
| **b** | At what locations will those quantities be available?<br>Are there seasonal or timing/notice aspects as to when the intended quantities would be available? |
| **c** | What variations in quantity could be expected? |
| **Characteristics** | |
| **d** | Is the NMP falling under a distillate or residual fuel category?<br>What analysis will be provided – typical values, range of values - How do those values compare to those of currently used fuels?<br>Will the delivered product quality vary between one bunker stem to another?<br>Will the supplier provide guidance on any unique aspects of the trial fuel e.g. handling? |
| **Existing Experience** | |
| **e** | Is there any experience of use of the NMP from other users at sea or elsewhere?<br>What combustion equipment was used. What was the duration of use? Can users be contacted and are reports available?<br>Experience of use in a similar engine type could mean the 'Application Testing stage' (Level 2, Stage 5) is not required. |

## Sub-stage 2 (f - j) Intended Utilisation

**These questions define the ship details in which the NMP will be assessed:**

| | |
|---|---|
| **f** | Which ship is to trial the fuel (Name / IMO No.)? |
| **g** | In what combustion equipment & ancillary machinery is the fuel to be used, such as:<br>• ME – Main engine – used for propulsion<br>• DG – Diesel generator engine used to provide ship's electrical power<br>• NEA – non-essential engine driving auxiliaries such as deck air compressor<br>• Boiler – Continuous combustion equipment, also other items such as inert gas generator<br>• Other – such as gas turbine or fuel cell<br>Identify machinery type & fuel system type. e.g. HFO vs MGO<br>Fuel system components may also be considered e.g. filters, separators and fuel treatment plant. |

| Classification Society | |
|---|---|
| h | This will be set by the Class of the ship:<br>Does Class consider the fuel as requiring special consideration when used for each combustion equipment?<br>If so, what are the relevant Class requirements?<br>What information and actions will be required – both before and after the trial? |
| **OEM – Original Equipment Manufacturer** | |
| i | For each selected combustion equipment consider the OEM guidance and warranty requirements. |

### 3.1.3. Level 2 Stage 3: 'Review of Outcomes 1'

**User and Producer Review**

Both User and Producer should review the outcomes from Stage 2 to decide:

- To continue the assessment of the trial fuel, with any reservations being managed under the ship's risk mitigation program, or by modifications or adjustments carried out onboard.
- That the user requires further information to re-run scenarios
- That additional information is required from the supplier, potentially including a reformulation and a subsequent re-run of Level 1 (See 3.1.4).
- That the trial fuel has not met requirements, the assessment is discontinued and the fuel is deemed 'Not suitable for marine use'.

### 3.1.4. Level 2 Stage 4: Input Required

**Producer - Additional Requirements**

Following the review of 'Outcomes 1,' additional information may be required before proceeding with the sea trial. This could include:

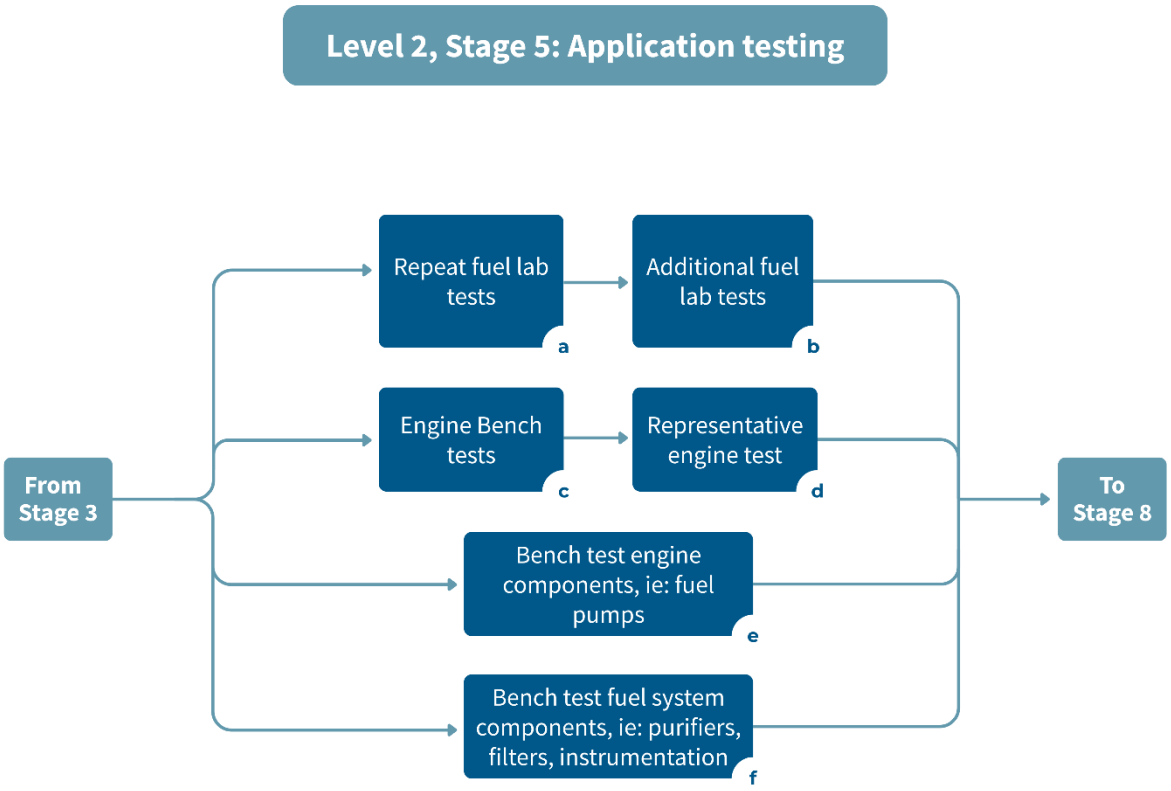
- data obtained from external sources or through further targeted testing, and
- changes to the production or supply of the trial fuel.

### 3.1.5. Level 2 Stage 5: Application Testing

Understanding how a fuel impacts on equipment and resolving any concerns is far easier to manage onshore. If the Producer has not completed application testing during Level 1, the following actions should be considered.

Figure 5 outlines the components included in the various application tests.

Figure 5: Application Testing



## Level 2, Stage 5: Application testing

The following is a non-exhaustive list of fuel application performance testing.

Refer to 2.5 and Annex III for further details.

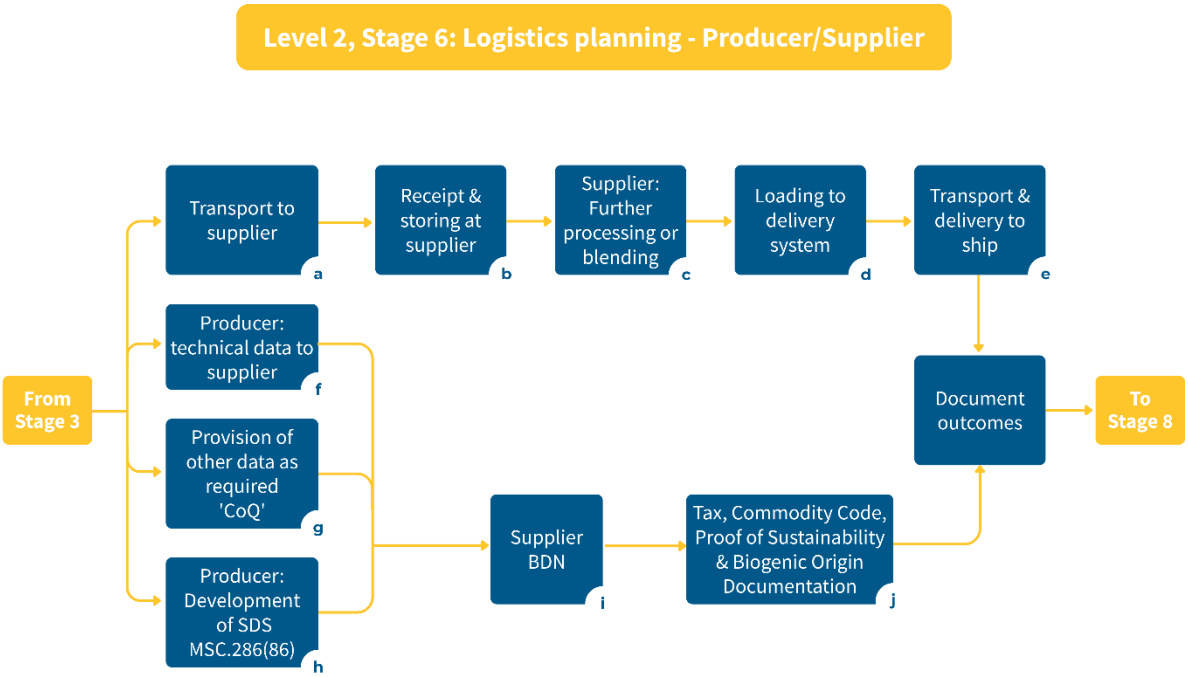
| | |
|---|---|
| a | **Repeat fuel lab tests**<br>Fuels to be used in application testing should be sampled, analysed and confirmed to be consistent with Level 1 findings. |
| b | **Additional fuel lab tests**<br>Additional analysis beyond standard marine fuel testing may be required to assess specific properties of the fuel and its suitability for use.<br>For example, evaluating compatibility with fuels that could be encountered during delivery or whilst in use, or assessing the fuel's impact on engine component materials. |
| c | **Engine Bench tests**<br>On-shore laboratory engine test bed facilities can be used to understand the fuel's performance on a combustion device. Findings can be compared with existing fuels.<br>Consider start-up, ignition delay/rate of heat release, stability of running condition, low / high load operation, stopping, and tendency to cause liner lacquering or deposits.<br>Consider emissions measurement to understand any impact on exhaust emissions.<br>Consider engine load ranges: 25% 50% 75% 100% (or as close to) which provides an overall performance coverage. |
| d | **Representative large scale engine tests** - if feasible<br>As per c) but using combustion equipment which is similar to that of an engine in which the trial fuel will be used. (eg: Similar injectors, fuel pump, piston geometry, combustion cycle, fuel preparation system etc.) |
| e | **Bench test engine components**<br>Consider the fuel's impact on deposits, engine components, including corrosion, erosion, abrasion, and other forms of degradation.<br>This assessment should consider:<br>• behaviour under both stopped and running conditions at different engine loads, and<br>• exposure to fluctuating temperatures and pressures—particularly the high pressures within the injection system and the heat release during ignition and combustion.<br>Consider how the fuel may affect needle sticking, injector nozzle deposits, IDIDs (Internal Diesel Injector Deposits) and the expected time between overhauls for key components such as fuel injection nozzles, fuel pump plungers and barrels, common rail high-pressure pumps and piston rings/liners |
| f | **Bench test fuel system components**<br>Consider the performance and impact of the fuel on purification, filtration, and other ancillary systems.<br>Consider impact on operability and self-cleaning functions, compatibility with fuel system instrumentation, and material compatibility with both metallic and sealing materials.<br>Consider the compatibility of the fuel with coated tanks. |

### 3.1.6. Level 2 Stage 6: Logistics – Producer / Supplier

This stage covers the key considerations when delivering the fuel from the producer to the receiving ship, including the documentation that must accompany the delivery.

If the producer is not the entity physically supplying the trial fuel to the ship, an additional supplier will also be involved in the process

Figure 6: Logistics planning - Producer / Supplier




The component parts of that assessment process are shown in Figure 6.

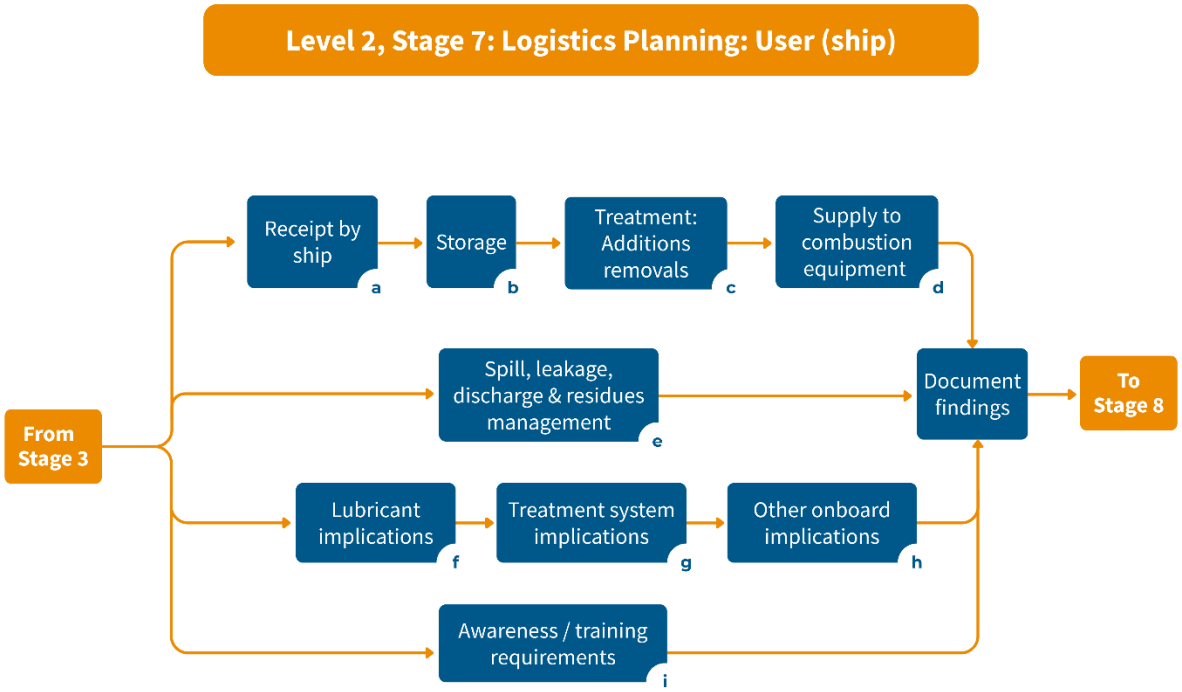
| Level 2, Stage 6: Logistics planning - Producer/Supplier<br>**In each activity consideration should be given to the relevant regulatory requirements.** | |
|---|---|
| **a** | How, what, when, and how much trial fuel will be delivered from the producer to the supplier? |
| **b** | How is the fuel to be handled and stored by the supplier?<br>Consider suitability of connecting hoses, storage tank, heating requirements and if grade segregation is required. |
| **c** | Is the product to be blended or processed before delivery? |
| **d** | What delivery method is to be used for supply? (e.g. barge, truck)<br>Is any special pre-loading preparation or after delivery cleaning required?<br>Are connecting hoses suitable for handling the fuel? |
| **e** | What technical data needs to be supplied to the ship, for example, fuel analysis, viscosity, cold flow properties? |

| | |
|---|---|
| | Are there any special provisions or handling advice for the ship to be aware of, for example: heating requirements, blending facilities, pumping, tank atmosphere, safety equipment? |
| **f** | Are all delivery details compliant with MARPOL Annex VI Regulation 18.5? |
| **g** | Is analysis compliant with MARPOL Annex VI Regulation 18.5? |
| **h** | Is the provided SDS (Safety Data Sheet) in accordance with MSC 286(86)? |
| **i** | Will the BDN (Bunker Delivery Note) be representative of the fuel supplied? |
| **j** | What other documentation is required? for example, relating to tax, commodity code, proof of sustainability, and biogenic origin documentation. |

### 3.1.7. Level 2 Phase 1 Stage 7: Logistics - User

This stage addresses the physical handling of the fuel onboard, from receipt, through storage and treatment, to eventual supply to the combustion equipment.

Figure 7: Logistics Planning: User (Ship)



The component parts of that assessment process are shown in Figure 7.

| Level 2, Stage 7: Logistics Planning: User (ship) | |
|---|---|
| **The following should be considered by the User** | |
| **a** | **Receipt by ship**<br>How will the fuel be received by the ship and how will it be handled?<br>Is there a need to minimise mixing with other fuels onboard?<br>Is there a requirement to sample the fuel during delivery? What analysis is required? |
| **b** | **Storage**<br>Does the receiving bunker tank require special treatment before, during or after use? Is tank cleaning required?<br>If tanks are coated, is the coating compatible with the fuel?<br>Does the fuel have any heating/cooling requirements?<br>Trial fuel segregation is recommended to enable an accurate evaluation of the product. |
| **c** | **Treatment**<br>What onboard treatment is required?<br>What are the treatment system requirements for settling, centrifuges and filtration?<br>How should the treatment system be changed over to and from the trial fuel?<br>Are additives required? If so, what quantities, how and when should they be applied – during bunkering, while in bunker tanks or in the post service tank system/ booster circuit? |
| **d** | **Supply to combustion equipment (service tank to engine)**<br>How will the fuel be supplied to the combustion equipment? Considering the fuel pump and injection mechanism? Is it common rail or jerk pump?<br>What heating or cooling is required?<br>How will combustion equipment not being used for the trial be isolated from the trial fuel?<br>How should the service system be changed over to and from the trial fuel? |
| **e** | **Spill, leakage, discharge and residues management**<br>Consider precautionary measures to prevent leaks such as jointing, seals, O-rings<br>Consider precautionary measures to contain deck spills and leakage.<br>Consider the impact of system discharges e.g. from purifiers / filters? Where are the discharges routed and what interactions are there with other materials and fluids?<br>Consider the impact on the oily water separator handling bilge or drain water.<br>Consider the impact on the disposal of residues ashore. |
| **f** | **Lubricant implications**<br>Are system / cylinder lubricants suitable for use with the fuel or is there a need to change-over? |

| | |
|---|---|
| | Consider monitoring of the lubricant oils (e.g. scrape down, system oils)<br>If a lubricant change-over is required, are there facilities to load and store the alternative lubricant?<br>How will the change-over be completed? |
| g | **Treatment system implications**<br>What settings need to be considered for separators, filters and heaters? |
| h | **Other onboard implications**<br>Consider ship's specific equipment not covered above |
| i | **Awareness / training requirements**<br>What safety / awareness training will be required by those onboard?<br>Consider the specific characteristics for the safe handling and storage of the trial fuel? |

### 3.1.8. Level 2 Stage 8: 'Review of Outcomes-2'

Both **User** and **Producer** to review the outcomes from Stage 1 to Stage 7

- Before progressing to a sea trial, ensure that no factors or undesirable elements have been overlooked
- If there are reservations about proceeding to a sea trial, can these be managed within the ship's risk-mitigation program?
- What further information is required before proceeding to sea trial?
- If the trial fuel has not met requirements, the producer may either consider reformulation and a subsequent re-run of Level 1, or the assessment may be discontinued and the fuel deemed 'Not suitable for marine use'.

Note: Provided no part of the fuel-system settings is adjusted beyond the limits specified in the engine Technical File, the fuel may be considered a 'drop-in fuel' (see definition in Section 1, Introduction).

If the fuel is considered for further evaluation by sea trial, it will be referred to as the 'trial fuel' for the purposes of that testing.

## 3.2. LEVEL 2 – PHASE 2 SEA TRIAL PLANS STAGES 9 TO 11

A sea trial is only be performed subject to the satisfactory completion of previous preparatory work.

The purpose of the sea trial is to assess whether the trial fuel is suitable for use in the assigned combustion equipment, storage, fuel system and auxiliary equipment arrangements.

### 3.2.1. Level 2 – Stage 9: Sea Trial Preparation

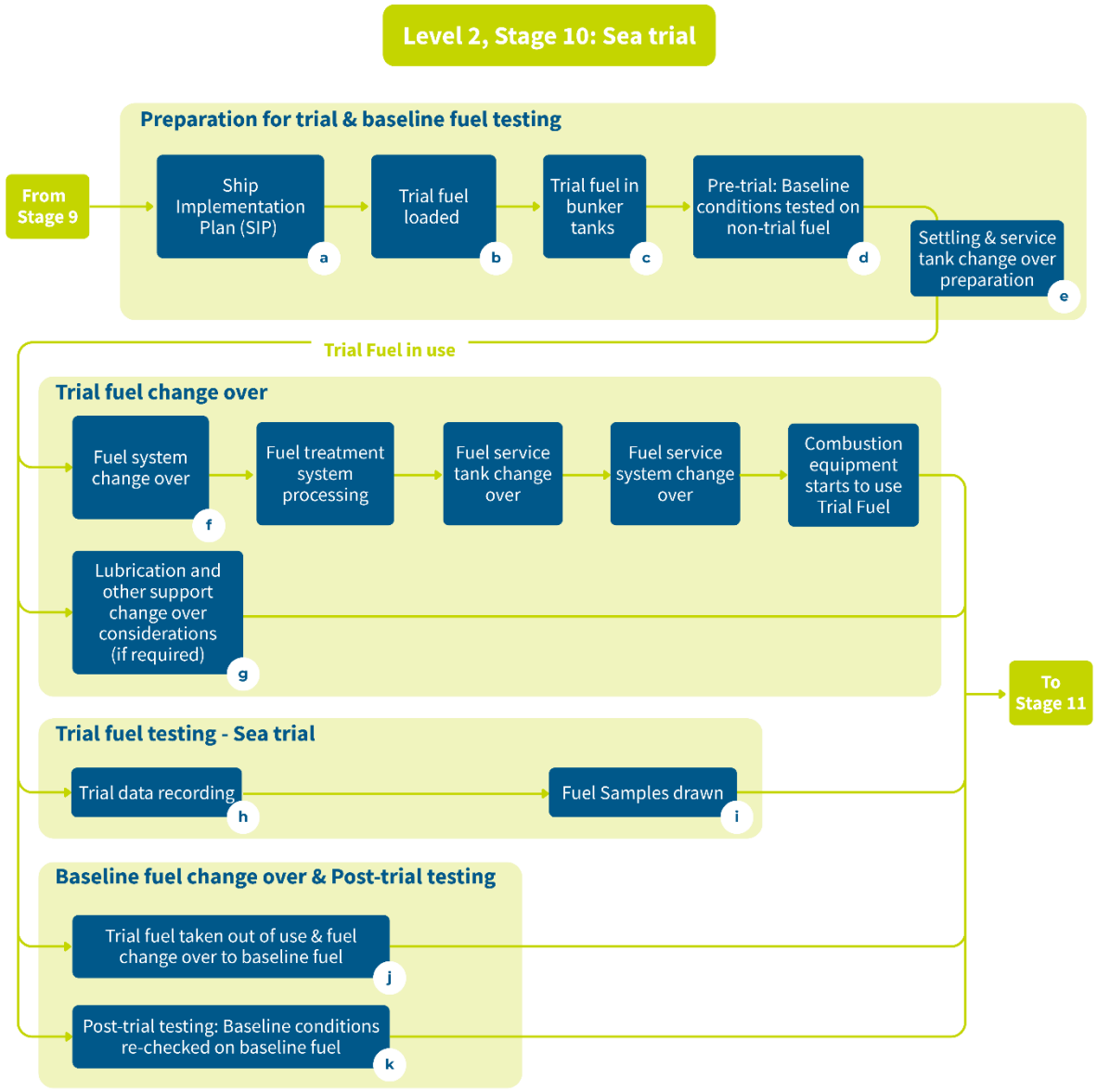
Prior to the sea trials the following key preparation activities are to be confirmed

- Trial Objectives and Ship Selection (see Annex IV for details)
- Risk Assessment overview (See Annex V for details)
- As required, obtain Class agreement, OEM support, and notify Flag and ship's underwriters
- Ship Implementation Plan (SIP) (See Annex VI for details)

### 3.2.2. Level 2- Stage 10 - The sea trial activity checks

The various component parts of the sea trial are shown in Figure 8

Figure 8: Level 2 Stage 10 - Sea Trial



**Level 2, Stage 10: Sea trial**

The following considerations are to be addressed by the ship

| | |
|---|---|
| **Preparation for trial & baseline fuel testing** | |
| **a** | **Ship Implementation Plan (SIP) (See Annex V)**<br>Include component monitoring intervals defined by running hours as discussed and agreed with the OEM.<br>Consider short term, mid-term and long-term running hours.<br>Consider typical operating and load condition ranges.<br>Trial duration may be adjusted subject to early-stage performance and equipment performance. |
| **b** | **Trial fuel loaded**<br>Quantity and expected storage duration. |
| **c** | **Trial fuel in bunker tanks**<br>Trial fuel is held in designated storage tanks. |
| **d** | **Pre-trial: Baseline conditions tested on non-trial fuel**<br>Establish pre-trial performance on conventional fuel and record the baseline conditions before bringing the trial fuel into use (see Annex II). |
| **e** | **Settling & service tank change over preparation**<br>Prepare settling and service tanks to receive the trial fuel as per the SIP including considerations for changeover. |
| **Trial fuel change over** | |
| **f** | **Fuel system change over**<br>• Fuel treatment system processing<br>• Fuel service tank change over<br>• Fuel service system change over<br>• Combustion equipment starts to use trial fuel<br>Trial fuel brought into use with assigned combustion equipment.<br>Considerations to be addressed:<br>• Fuel temperatures – be aware of thermal shock<br>• Fuel compatibility – be aware of possible incompatibility between existing and trial fuel during changeover (monitor fuel filters & pressures) |
| **g** | **Lubrication and other support change over considerations (if required)**<br>Consider other required fuel and lubricant system changeovers, for example mixing tank, and combustion equipment returns. |
| **Trial fuel testing - Sea trial** | |
| **h** | **Trial data recording** |

| | |
|---|---|
| | During the trial, monitor performance of all fuel, lubricant and auxiliary systems from storage to engine, in accordance with implementation plan. |
| i | <u>Fuel Samples drawn</u><br>Take samples from the fuel system, for example, before and after separators, filters & combustion equipment.<br>Take samples from the lubricating system, for example, crankcase and cylinder scrape-down oil<br>When drawing samples follow best practice standards for doing so such as ISO 3170 [18] |
| **Baseline fuel change over & Post-trial testing** | |
| j | <u>Trial fuel taken out of use & fuel change over to baseline fuel</u><br>Change system back to conventional baseline fuel, following same changeover procedure. |
| k | <u>Post-trial testing: Baseline conditions re-checked on baseline fuel</u><br>Record post-trial baseline conditions and check against pre-trial baseline data. |

### 3.2.3. Level 2 –Stage 11: 'No. 3 Trial Outcomes' Review of Sea-Trial

The sea trial is assessed by the stakeholders using the data recorded, to decide whether:

- The trial was successful - The sea trial met the desired outcomes, and the trial fuel could potentially be considered to be a marine drop-in fuel.
- The trial was not successful - The fuel did NOT meet requirements because of one or more unsatisfactory outcomes and is deemed 'Not suitable for marine use'.
- Further development is needed - The trial results were promising but further development is required to the fuel and/or modification of machinery.

## 3.3. LEVEL 2 STAGE 12: THE FUEL CATEGORISED AS A MARINE DROP-IN FUEL FOR USE IN A DESIGNATED MACHINERY PLANT

If there are no unresolved issues and the sea trials are satisfactory to all parties, then the fuel may be considered a marine drop-in fuel for the specific machinery application.[1]

To account for production variation of future batches of similar fuel, the trialled fuel should have a specific grade identifier and corresponding list of properties which is linked to both the production process and formulation.

Continued use of this fuel in the designated machinery application, would not likely need to be subject to any more than the usual monitoring. However, longer term monitoring protocols should be in place to build fuel management experience and assessment of the impact on the time between overhauls.

[1] This guidance document has considered various essential factors in evaluating the bunker suitability of a new material for use as marine drop-in fuel or blend component.

This document is not an exhaustive list of requirements, and each potential new material will have its own unique risks that will have to be considered.

## REFERENCES


1 IMO: MEPC.1/Circ.875 Guidance on Best Practice for Fuel Oil Purchasers / Users for Assuring the Quality of Fuel Oil Used On-Board Ships

2 IMO: MEPC.1/Circ.875/Add.1 Guidance on Best Practice for Fuel Oil Suppliers for Assuring the Quality of Fuel Oil Delivered to Ships

3 ISO: 8217:2024 – Products from petroleum, synthetic and renewable sources — Fuels (class F) — Specifications of marine fuels

4 IMO: MEPC.395(82) 2024 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)

***5*** IMO: MSC.286(86) Recommendations for Material Safety Data Sheets (MSDS)

6 MEPC.1/Circ.878 9 November 2018 Guidance on the Development of a Ship Implementation Plan for the Consistent Implementation of the 0.50% Sulphur Limit under MARPOL Annex VI

***7*** Energy Institute - Blending Components, Additives and Renewable Fuels – Factors for Consideration and Assessment of Suitability for Use

8 CIMAC Guidance: Fuel Quality guide on Ignition and Combustion 2011

9 CIMAC guidance: Design and Operations of fuel cleaning systems (v2) (09/2024)

10 CIMAC Guidance: 03/2024 Overview and interpretation of total sediment test results in the context of ISO 8217

11 CIMAC Guidance: – 01/2019- Marine fuel handling in connection to stability and compatibility

12 Joint Industry Guidance (2019) – The Supply and use of 0.5% - Sulphur marine fuels (see www.CIMAC.com WG7 Documents listing - key contributor).

13 CIMAC Guidance: 06/2024 Marine Fuels Containing FAME; A guideline for shipowners and operators

14 ISO: 1817:2024 - Rubber, vulcanized or thermoplastic — Determination of the effect of liquids

15 CIMAC Paper No. 238 - Stability assessment of bio-residual marine fuels (RF grades) through extended TSP and spin testing. CIMAC Congress Zurich 2025

16 CIMAC Guidance: 09/2024 v2 Design and Operation of fuel cleaning systems for diesel engines

17 Concawe Report no.9/09 – Guidelines for handling and blending FAME.

18 ISO: 3170:2004 Petroleum liquids — Manual sampling

# ANNEX I - MATERIAL SAFETY DATA SHEET REQUIREMENTS

All marine fuels delivered to a ship should be accompanied by a Material Safety Data Sheet (MSDS).

MSDS requirements for marine fuels is defined under the IMO resolution Marine Safety Committee MSC 286 86 (imo.org) [5]

For ease, the table containing the recommendations for a MSDS has been extracted from MSC 286 86 and shown below, however the latest requirements should be confirmed.

| Section | Heading | Content |
|---|---|---|
| 1 | **Identification of the substance or mixture and of the supplier** | • Name of the category – see guidance in annex 2 for MARPOL Annex I type oil cargoes and oil fuels.<br>• The name of the substances.<br>• Trade name of the substances.<br>• Description on Bill of Lading (B/L), Bunker Delivery Note or other shipping document.<br>• Other means of identification.<br>• Supplier's details (including name, address, telephone number, etc.).<br>• Emergency telephone number. |
| 2 | **Hazards identification** | • GHS* classification of the substance/mixture and any regional information.<br>• Other hazards which do not result in classification (e.g., hydrogen sulphide) or are not covered by the GHS. See Guidelines in annex 2. |
| 3 | **Composition/information on ingredients** | • Common name, synonyms, etc.<br>• Impurities and stabilizing additives which are themselves classified and which contribute to the classification of the substances.<br>• The chemical identity and concentration or concentration ranges of all ingredients which are hazardous within the meaning of GHS and are present above their cut-off levels. Cut-off level for reproductive toxicity, carcinogenicity and category 1 mutagenicity is 0.1%. Cut-off level for all other hazard classes is 1%. See Guidelines in annex 2. |
| 4 | **First aid measures** | • Description of necessary measures, subdivided according to the different routes of exposure, i.e. inhalation, skin and eye contact and ingestion.<br>• Most important symptoms/effects, acute and delayed.<br>• Indication of immediate medical attention and special treatment, if necessary. |

| Section | Heading | Content |
|---|---|---|
| **5** | **Fire-fighting measures** | • Suitable extinguishing media.<br>• Specific hazards arising from the chemical (e.g., nature of any hazardous combustion products).<br>• Special protective equipment and precautions for fire-fighters. |
| **6** | **Accidental release measures** | • Personal precautions, protective equipment and emergency procedures.<br>• Environmental precautions.<br>• Methods and materials for containment and clean-up. |
| **7** | **Handling and storage** | • Precautions for safe handling.<br>• Conditions for safe storage, including any incompatibilities. |
| **8** | **Exposure controls/ personal protection** | • Control parameters (e.g., occupational exposure limit values).<br>• Appropriate technical precautions.<br>• Individual protection measures, such as personal protective equipment. |
| **9** | **Physical and chemical properties** | • See Guidelines in annex 2. |
| **10** | **Stability and reactivity** | • Chemical stability.<br>• Possibility of hazardous reactions.<br>• Conditions to avoid (e.g., static discharge). |
| **11** | **Toxicological information** | • Concise but complete and comprehensible description of the various toxicological (health) effects and the available data used to identify those effects, including:<br>○ Information on the likely routes of exposure (inhalation, ingestion, skin and eye contact);<br>○ Symptoms related to the physical, chemical and toxicological characteristics;<br>○ Delayed and immediate effects and also chronic effects from short- and long-term exposure.<br>• Numerical measures of toxicity (such as acute toxicity estimates).<br>• See Guidelines in annex 2. |
| **12** | **Ecological information** | • Ecotoxicity (aquatic and terrestrial, where available).<br>• Persistence and degradability.<br>• Bioaccumulation potential.<br>• Mobility in soil.<br>• Other adverse effects.<br>• See Guidelines in annex 2. |
| **13** | **Disposal considerations** | • Description of waste residues and information on their safe handling and methods of disposal, in line with MARPOL requirements. |

| Section | Heading | Content |
|---|---|---|
| **14** | **Transport information** | • UN number, where applicable.<br>• UN Proper shipping name, where applicable.<br>• Transport Hazard class(es), where applicable.<br>• Special precautions which a user needs to be aware of or needs to comply with in connection with transport (e.g., heating and carriage temperatures).<br>• Note that this product is being carried under the scope of MARPOL Annex I. |
| **15** | **Regulatory information** | • Safety, health and environmental regulations specific for the product in question. |
| **16** | **Other information including information on preparation and revision of the MSDS** | • Version No.<br>• Date of issue.<br>• Issuing source. |

## ANNEX II – EXAMPLE SEA TRIAL MONITORING LOGS

The following tables are examples of sea trial monitoring logs showing each activity and component condition that is to be recorded by the ship. They identify specific fuel system and engine components along with operating parameters that would highlight any impact from the fuel.

| | | Voy day | | -3 | -2 | -1 | (D-day)0 | 1 | 2 | (D-day)3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Date | | | 30/11/2022 | 01/12/2022 | 02/12/2022 | 03/12/2022 | 04/12/2022 | 05/12/2022 | 06/12/2022 | 07/12/2022 | 08/12/2022 |
| | In port / At Sea | Voyage | | | In port/sea | At sea | At sea | At sea | At sea | At sea | At sea | At sea | At sea |
| | Fuel type | Aux 2 | | | *MGO* | *MGO* | NMP | NMP | NMP | NMP | NMP | NMP | NMP |
| | | ME | | | *MGO* | *MGO* | *MGO* | *MGO* | *MGO* | NMP | NMP | NMP | NMP |
| | Component RH AUX 2 | Inj 1 | | | 1927 | 1927 | 1927 | 1951 | 1975 | 2000 | 2024 | 2048 | 2072 |
| | | Inj 3 | | | 0 | 0 | 0 | 24 | 48 | 73 | 97 | 121 | 145 |
| | | Inj 5 | | | 263 | 263 | 263 | 287 | 311 | 336 | 360 | 384 | 408 |
| | Component RH ME | Inj 2 (aft) | | | 0 | 12 | 36 | 60 | 84 | 109 | 133 | 155 | 179 |
| | | Inj 5 (aft) | | | 0 | 12 | 36 | 60 | 84 | 109 | 133 | 155 | 179 |
| | ME reports extracted and submitted | Cocos | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | K-Chief ME Overview | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | ME PMI | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | AE reports done and submitted | Performance report | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | K-Chief Overview | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | Purifer samples taken | Before purifier | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | After purifier | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | LO samples taken | Aux 2 | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | ME | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | Scrape down samples taken | Cyl 1 | | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | Cyl 2 | | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | Cyl 3 | | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | Cyl 4 | | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| | | Cyl 5 | | | | | | | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| Onboard | FE test | Cyl 4 | | | | | | | *41* | | *73* | | *124* |
| Piston | Underside Inspection | All cylinders | | | | | | | | | | Yes | |
| Injector changed and tested | ME | Inj cyl 2 aft | | | | | | | | | | | |
| | | Inj cyl 5 aft | | | | | | | | | | | |
| | AUX 2 | Inj cyl 3 | | | | | | | | *Yes* | | | |
| | | Inj cyl 1 | | | | | | | | | | | |
| | | Inj cyl 5 | | | | | | | | | | | |

| | |
|---|---|
| AE | Auxiliary Engine |
| Aft | Aft (Towards the rear of the engine) |
| Aux | Auxiliary System/Component |
| Cyl | Cylinder |
| FAME | Fatty Acid Methyl Ester |
| FE | Fuel Equipment |
| Inj | Injector |
| K-Chief | Electronic engine monitoring/recording system |
| LO | Lubricating Oil |
| ME | Main Engine |
| MGO | Marine Gas Oil |
| NMP | New Material Product |
| PEMPI | Planned Engine Maintenance / Performance Indicator |
| PMI | Pressure Measurement Indicator |
| RH | Return Header |
| VLSFO | Very Low Sulphur Fuel Oil |

# AE Performance test

| | Units | AE 2 | | AE 2 | | AE 2 | |
|---|---|---|---|---|---|---|---|
| Date & Time | | | | | | | |
| Engine number | | | | | | | |
| Load, % of MCR | % | | | | | | |
| Shaft Power kW | kW | | | | | | |
| Engine speed | RPM | | | | | | |
| Alternator load | ekW | | | | | | |
| Alternator V / A | V/A | | | | | | |
| Operating hours | hr | | | | | | |
| TC speed | RPM | | | | | | |
| Exh. temp b/a TC | °C | | | | | | |
| Ch. Air Temp | °C | | | | | | |
| LT b/a air cooler | °C | | | | | | |
| LT aft LO cooler | °C | | | | | | |
| LT pressure | Bar | | | | | | |
| LO t. b/a cooler | °C | | | | | | |
| LO pressure | Bar | | | | | | |
| FO pressure | Bar | | | | | | |
| Charge Air press. | Bar | | | | | | |
| Start air press. | Bar | | | | | | |
| FO temp. | °C | | | | | | |
| FO density(15°C) | °C | | | | | | |
| Ambient temp. | °C | | | | | | |
| Barometric press. | Bar | | | | | | |

| Cyl. No. | | Exh. temp. | Rack pos. | P max | P comp | °C | Exh. temp. | Rack pos. | P max | P comp | °C | Exh. temp. | Rack pos. | P max | P comp | °C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | |
| Mean values: | | | | | | | | | | | | | | | | |

## ANNEX III – EXAMPLE TEST BENCH - ENGINE PERFORMANCE MONITORING LOG

| | Data from Test Bench Lab report | Observations on comparing Base Fuel against trial fuel<br>% change estimates<br>Lab. observation comments | | | |
|---|---|---|---|---|---|
| | **Load Condition** | **25%** | **50%** | **75%** | **100%** |
| **Combustion characteristics** | | | | | |
| 1 | Rate of Heat Release (ROHR) | | | | |
| 2 | Max Cylinder Press. | | | | |
| 3 | Crank Angle (CA) off TDC at Max Cylinder Press | | | | |
| 4 | SFOC g/kWh | | | | |
| 5 | Exhaust Gas Temp | | | | |
| 6 | Start of Comb | | | | |
| 7 | Centre of Comb | | | | |
| 8 | End of Comb | | | | |
| Other Lab Observations | | | | | |

| | Data from Test Bench Lab report | Observations on comparing Base Fuel against trial fuel<br>% change estimates<br>Lab. observation comments | | | |
|---|---|---|---|---|---|
| | **Load Condition** | **25%** | **50%** | **75%** | **100%** |
| **Exhaust Emissions** | | | | | |
| 9 | HC g/kWh | | | | |
| 10 | $O_2$ g/kWh | | | | |
| 11 | $CO_2$ g/kWh | | | | |
| 12 | CO g/kWh | | | | |
| 13 | $SO_2$<br>(or sulphur content) | | | | |
| 14 | NOx g/kWh | | | | |
| 15 | Filter Smoke Number (FSN) | | | | |
| Other Lab Observations | | | | | |

Transients between the load points should be tested and observed for any different behaviour in engine performance or emissions.

## ANNEX IV – EXAMPLE TRIAL OBJECTIVES AND SHIP SELECTION

The objectives of the trial and expected outcome should be clear and well defined. The selection of a suitable ship for a trial should be supported with input from both deck and engineering teams.

| Key areas to address | | Response |
|---|---|---|
| **a** | What are the trial objectives? | |
| **b** | Which combustion device is to be trialled? e.g. main or auxiliary engine, boiler. | |
| **c** | How will baseline conditions prior to trial commencement be established for shipboard machinery including for fuel treatment? (e.g. purifiers & filters) and combustion devices:<br>– condition of which components to be checked and recorded<br>- which operational values / settings to be checked and recorded | |
| **d** | What is the intended duration for the trial? Are the objectives to carry out a performance or an endurance trial? | |
| **e** | What are the operational values and settings to be recorded during the trial? | |
| **f** | Is the required monitoring and measurement instrumentation in place and in good working order or does additional equipment need to be installed? | |
| **h** | How will the data from the trial be recorded and shared with the relevant stakeholders? | |
| **j** | What fuel and lubricating oil samples are to be drawn before, during and after the trial? When drawing samples follow best practice standards for doing so such as ISO 3170 [18]<br>Are there external monitoring / testing services which will need to be engaged e.g. for combustion and or exhaust emissions, shaft torque | |

## ANNEX V - EXAMPLE RISK ASSESSMENT OVERVIEW

The Risk Assessment to be carried out should follow the User's standard approach as part of the ship's Safety Management System (SMS) procedures.

The following list is not exhaustive and the ship specific arrangements and conditions need to be considered.

| | | Response |
|---|---|---|
| a | The outcomes of this Risk Assessment may impact the Ship Implementation Plan. | |
| b | Class may request to review the Risk Assessment prior to a Sea Trial. | |
| The potential risks associated with the nature of the fuel should be evaluated. | | |
| c | Bunkering | |
| d | Storage | |
| e | Transfer – between storage tanks and to settling tank | |
| f | Treatment | |
| g | Service system including fuel return lines | |
| h | Combustion device including lubrication | |
| j | Combustion device exhaust duct components | |
| k | Spills and leakage including fuel oil drain system<br>Discharges and draining's<br>Handling and disposal of collected material<br>Environmental impact | |
| If a lubricant changeover is required | | |
| l | Alternative lubricant loading and storage | |
| m | Lubricant change over | |
| n | Lubrication effectiveness | |
| During fuel changeover | | |
| p | Other engine room systems which will need to be changed over to use the fuel | |
| Other aspects for consideration | | |
| q | Health | |
| r | Environmental | |
| s | Sailing conditions – operating location / weather / ship traffic / crew | |
| t | Emergency equipment – safety critical equipment isolated from the trial fuel | |

## ANNEX VI – EXAMPLE SHIP IMPLEMENTATION PLAN (SIP)

In preparation for the 2020 transition to VLSFO most ships will have developed a Ship Implementation Plan. This plan may be considered as a basis for carrying out a Sea Trial of a new fuel.
The following considerations are not exhaustive, and the ship specific arrangements and conditions need to be considered. MEPC.1/Circ.878 provides useful guidance for the development of a SIP.

| | | Response |
|---|---|---|
| a | The Risk Assessment should be referred to | |
| b | Which bunker tank is to be used to receive the fuel?<br>Does that tank require draining / cleaning / inspection prior to loading?<br>Are heating arrangements required and in good order?<br>Are other considerations due to nature of the fuel? | |
| c | How will the fuel be routed into the intended bunker tank?<br>Is clearance of lines from manifold to tank after use necessary? | |
| d | How will the fuel be routed from bunker tank to settling tank?<br>Is clearance of transfer lines after use necessary? | |
| e | How will the treatment system be changed over to handle the fuel?<br>Are the settling tanks required to be drained before refilling with fuel?<br>Is cleaning of the settling tank required?<br>How will purifiers be changed over to handling the fuel?<br>What changes are required to purifier pre-heating / settings / fittings?<br>What changes are required to purifier waste streams? | |
| f | How will the service tank arrangement be used to hold the fuel without mixing with other fuels?<br>Will service tanks be lowered before first fill with the fuel? | |
| g | How will the fuel be brought into use on the combustion equipment?<br>Are adjustments required to the viscosity control?<br>How will filters be monitored and managed?<br>Are adjustments to settings needed to the combustion equipment? | |
| h | Are there items in the exhaust from the combustion equipment which could be affected by use of the fuel e.g. turbochargers, exhaust gas recirculation, selective catalytic reduction devices, exhaust gas boilers & inline instrumentation? | |
| j | How would any spills or leakage be handled during loading, transfer, treatment, use?<br>Are special clean-up / holding arrangements required?<br>Is the bilge oily water separator able to handle the new fuel?<br>How will discharges from fuel treatment systems be handled? | |
| k | Provide training material to ship's staff – safety, environmental and onboard operations. | |
| l | Will lubricants (system / cylinder) need to be changed over to use the fuel?<br>How will that grade be loaded, stored and brought into use?<br>Consider rate of use, special cleaning and monitoring requirements. | |
| m | Is there other equipment that needs to be changed over when using the fuel? | |
| n | At end of the trial period what will be the arrangements for taking the fuel and alternative lubricant out of use? | |
| o | Is there any missing information or procedures required to enable the fuel to be used? | |
| p | Complete ships SMS as required? | |

## ANNEX VII – ADDITIONAL PRODUCER/ SUPPLIER RESPONSIBLITIES

Once a fuel has been confirmed as suitable for use, it is important for producers and suppliers to consider other responsibilities before it is supplied to end users. Such considerations may include, but are not limited to:

- **Compliance with Standards and Regulations:** Producers may also be committed to adhere to relevant fuel quality standards and regulations, such as those of the European Commission, IMO MARPOL Annex VI, or Marine Safety Committee (MSC).

- **Quality Assurance and Control:** Quality assurance and control measures to maintain a consistent fuel quality of the final product, which may require regular fuel analysis, sampling, and testing.

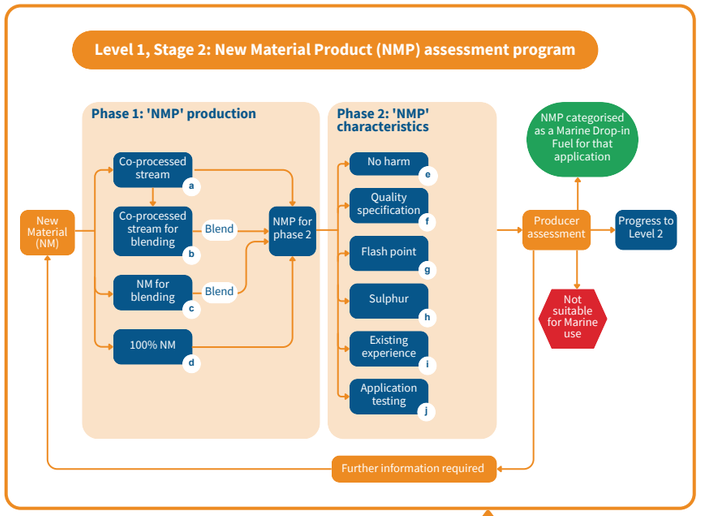
- **Traceability and Legality:** Some fuels or components may require traceability of origins and compliance with legal and sustainability requirements, including maintaining proper documentation.

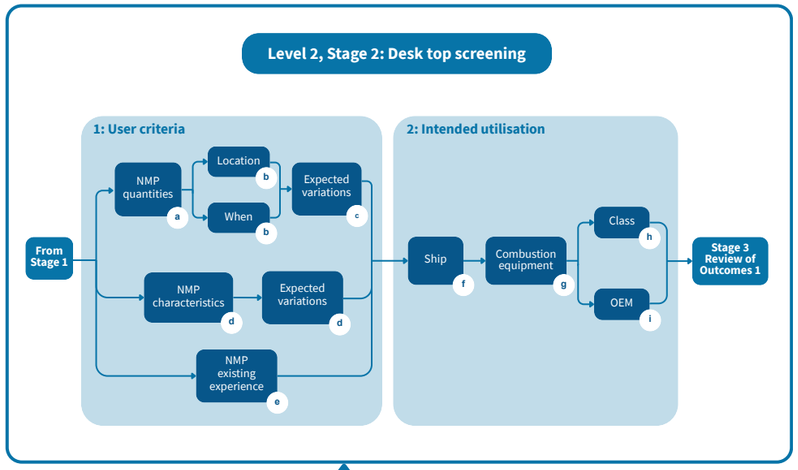
- **Handling and Storage:** Producers/suppliers should ensure that during transportation, handling, and storage, until the point it is delivered to the end user, the fuel is not contaminated or degraded and that it remains suitable for use.

# ANNEX VIII – OVERVIEW OF ALL FLOWCHARTS

This overview is provided overleaf in poster format which could be printed separately on large format to assist the user wishing to implement this guideline.

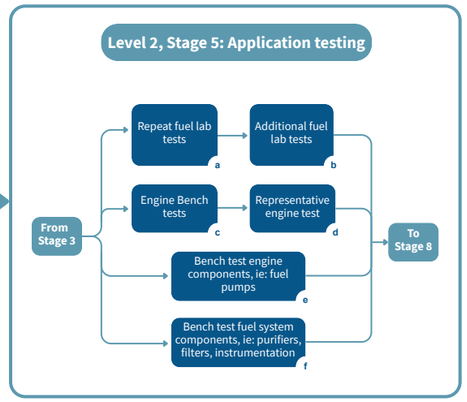
# Marine Fuels Guideline Flow Chart Overview

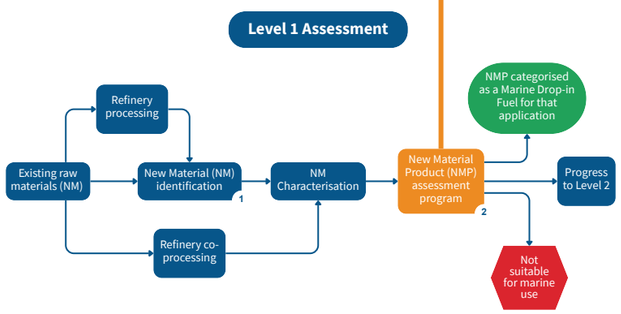



Where a numbered stage is highlighted in a different colour, this indicates that the stage is elaborated in a separate flow chart for that stage.

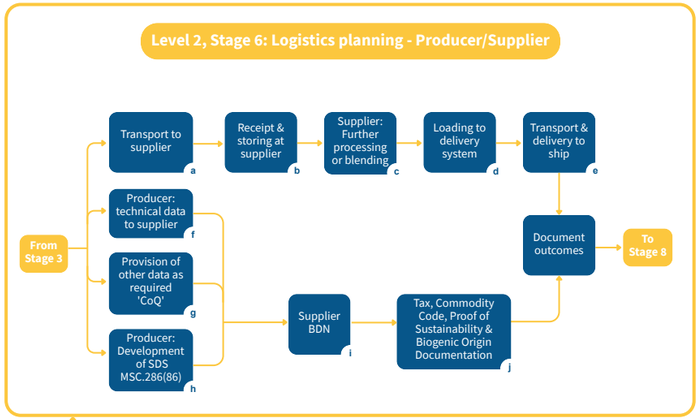
This overview shows Level 1 and Level 2 assessments together with their respective stages.

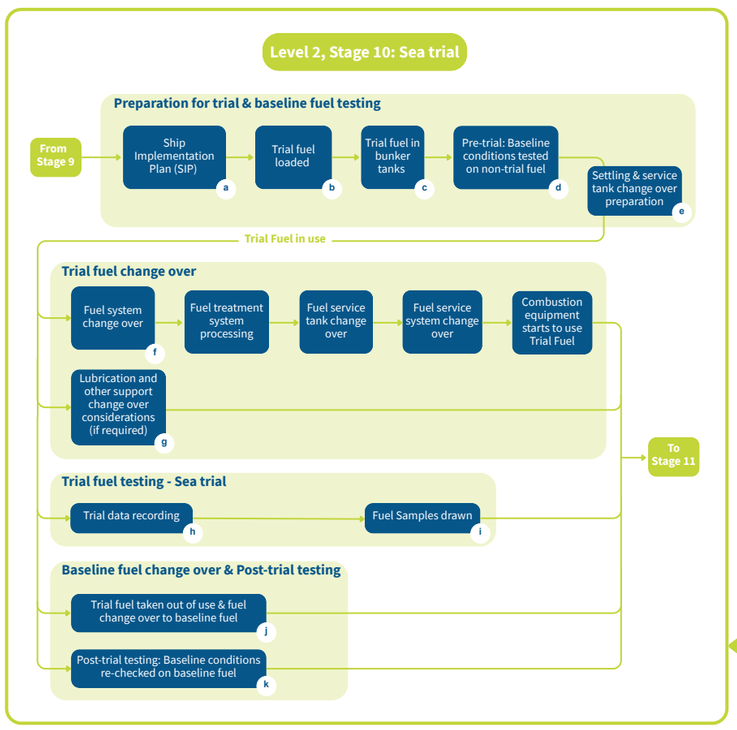


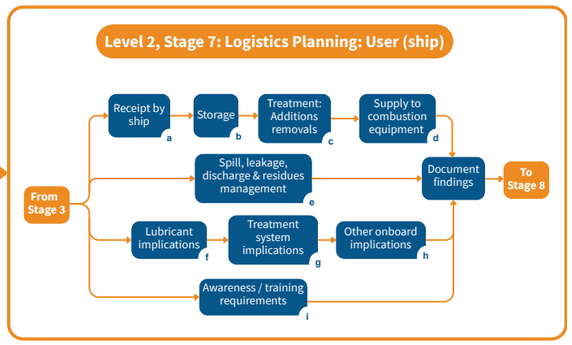







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