

A MARINE FUEL BLEND

FIELD

The present invention relates to a marine fuel blend as well as use of a marine fuel blend and a method for manufacturing the marine fuel blend.

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BACKGROUND AND OBJECTS

Marine fuels are traditionally based on fossil oil and are usually of higher viscosity than for example gasoline and diesel used for land vehicles. However, due to the problems related to pollution and climate change, there exists a need to also provide marine fuels having a lower sulphur content, for example. Another need is to reduce the emission of greenhouse gas (GHG) emissions. It is indeed an aim of the International Maritime Organisation IMO to reduce the total annual GHG emissions from international shipping by at least 50 % by 2050, compared to the level of 2008. This target may be achieved by improving for example efficiency of motors and operations, but also alternative fuels are needed.

Natural or raw cashew nut shell liquid (natural CNSL) is a by-product of the cashew industry, directly extracted from the shell of the cashew nut, fruit of the cashew tree, *Anacardium occidentale*. The oil is extracted from the cashew nut shell, which is a pericarp fluid of the cashew nut shell. Natural CNSL is a mixture of four components, all of which are substituted phenols: anacardic acid, cardanol, cardol and 2-methyl cardol. Physically extracted natural CNSL contains about 70 wt-% of anacardic acids, about 18 wt-% of cardol and about 5 wt-% of cardanol. The physically extracted natural CNSL may be processed such that the anacardic acid is decarboxylated into cardanol, leading to so-called technical CNSL. The technical CNSL may be further purified by distillation.

Asphaltenes are large aromatic molecules that are suspended colloids in crude oil and heavy fuel oil. Asphaltenes stay dispersed in the oil when they are surrounded by resins (polar aromatics) and the oil is then said to be stable. Under unfavourable solvent conditions resins are desorbed from asphaltenes causing asphaltenes to flocculate. This precipitation will increase the sediment amount in the oil. Large sediment amounts cause problems when operating vessels, especially in filters and separators. When asphaltene containing fuel is stored for a long period of time and/or heated, its stability begins to deteriorate and asphaltenes precipitate out from the fuel causing an increase of the sediment amount.

It is an aim to provide a use for cashew nut shell liquid (CNSL). Another aim is to provide an alternative marine fuel and marine fuel blend. A still further aim is to provide a marine fuel blend that has less fossil-based components than traditional marine fuels, i.e., to provide a marine fuel blend having a renewable component therein. A still further aim is to provide
5 a marine fuel blend where the asphaltenes are stabilised and do not form sediments. A still further aim is to provide a marine fuel blend, which allows reduction of greenhouse gas emissions.

SUMMARY OF THE INVENTION

The invention is defined by the features of the independent claim. Some specific
10 embodiments are defined in the dependent claims. According to an aspect, there is provided a marine fuel blend having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and comprising 0.5 – 50 vol-% of refined cashew nut shell liquid, which cashew nut shell liquid comprises at least 50 wt-% of cardanol, the marine fuel blend fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate
15 marine fuels.

According to another aspect, there is provided a use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol as asphaltene stabiliser for marine bunker fuels having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996. Another use of refined cashew nut shell liquid comprising at least 50 wt-% of
20 cardanol is as a marine fuel component, the resulting marine fuel blend having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels. A still further use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol is for improving storage stability of marine bunker fuels.

According to yet another aspect, there is provided a method for manufacturing a marine fuel having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, comprising mixing a residual fossil-based component with 0.5 – 50 vol-% of refined cashew nut shell oil, which cashew nut shell oil comprises at least 50 wt-% of cardanol, the resulting marine fuel fulfilling at least one of the categories of ISO
25 8217:2017(E) for residual and distillate marine fuels
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DETAILED DESCRIPTION

In the present description, weight percentages (wt-%) are calculated on the total weight of the blend. Volume percentages (vol-%) are also calculated on the total volume of the blend.

The term “renewable” in the context of a renewable fuel component refers to one or more
5 organic compounds derived from any renewable source (i.e., not from any fossil-based source). Thus, the renewable fuel component is based on renewable sources and consequently does not originate from or is derived from any fossil-based material. Such component is characterised by mandatorily having a higher content of ^{14}C isotopes than similar components derived from fossil sources. Said higher content of ^{14}C isotopes is an
10 inherent feature characterizing the renewable fuel component and distinguishing it from fossil fuels. Thus, in fuel blends, wherein a portion of the blends is based on partly fossil based material and partly renewable fuel component, the renewable component can be determined by measuring the ^{14}C activity. Analysis of ^{14}C (also referred to as carbon dating or radiocarbon analysis) is an established approach to determine the age of artefacts based
15 on the rate of decay of the isotope ^{14}C , as compared to ^{12}C . This method may be used to determine the physical percentage fraction of renewable materials in bio/fossil mixtures as renewable material is far less aged than fossil material and so the types of material contain very different ratios of ^{14}C : ^{12}C . Thus, a particular ratio of said isotopes can be used as a “tag” to identify a renewable carbon compound and differentiate it from non-renewable
20 carbon compounds. While the renewable component reflects the modern atmospheric ^{14}C activity, very little ^{14}C is present in fossil fuels (oil, coal). Therefore, the renewable fraction of any material of interest is proportional to its ^{14}C content. Samples of fuel blends may be analysed post-reaction to determine the amount of renewable sourced carbon in the fuel. This approach would work equally for co-processed fuels or fuels produced from mixed
25 feedstocks. It is to be noted that there is not necessarily any need to test input materials when using this approach as renewability of the fuel blend may be directly measured. The isotope ratio does not change during chemical reactions. Therefore, the isotope ratio can be used for identifying renewable isomeric paraffin compositions, renewable hydrocarbons, renewable monomers, renewable polymers, and materials and products derived from said polymers,
30 and distinguishing them from non-renewable materials. Feedstock of raw material of biological origin means material having only renewable (i.e., contemporary or biobased or

biogenic) carbon, ^{14}C , content which may be determined using radiocarbon analysis by the isotopic distribution involving ^{14}C , ^{13}C and/or ^{12}C as described in ASTM D6866 (2018). Other examples of a suitable method for analysing the content of carbon from biological or renewable sources are DIN 51637 (2014) or EN 16640 (2017).

- 5 For the purpose of the present invention, a carbon-containing material, such as a feedstock or product is considered to be of biological i.e., renewable origin if it contains 90 % or more modern carbon (pMC), such as 100 % modern carbon, as measured using ASTM D6866.

In the present description, by "category of ISO 8217:2017(E) for residual and distillate marine fuels" is meant the various categories (such as DMX, DMA, DFA, DMZ, RMA,
10 RMG, RMD, RMG etc.) listed in Tables 1 and 2 of the standard, as "category ISO-F-". A marine fuel blend fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels is thus a marine fuel blend which fulfils all the requirements of a single category, such as RMG, i.e. that can be used in applications where a marine fuel classified as RMG is required.

- 15 According to an aspect of the present invention, there is provided a marine fuel blend having a kinematic viscosity of 1-700 mm^2/s as measured at 50 °C according to EN ISO 3104:1996, and comprising 0.5 – 50 vol-% of refined cashew nut shell liquid, which cashew nut shell liquid comprises at least 50 wt-% of cardanol, the marine fuel blend fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels.

- 20 The marine fuel blend thus comprises a certain amount of refined cashew nut shell liquid, also called in this description refined CNSL or simply CNSL, while it may also be called refined cashew nut shell oil (CNSO). Indeed, in the present description of the invention, the abbreviation "CNSL" is to be understood as refined CNSL, not natural or raw CNSL. The marine fuel blend also fulfils at least one of the categories of ISO 8217:2017(E) for marine
25 fuels, the standard listing several different marine fuel categories. The present marine fuel blend thus allows providing a decarbonised marine fuel blend to meet the stricter environmental requirements. It also provides a marine fuel blend that comprises components that are not usable for food industry. The renewable component used in the present marine fuel blend is scalable and economical.

As shown below in the Experimental part, the long term storage as well as asphaltene stabilising effect of CNSL has been investigated and proven by analytical means. It has thus been demonstrated that cashew nut shell liquid keeps the asphaltenes soluble in the solution and the aged sediment limit in the specification ISO 8217:2017 is fulfilled. Furthermore, the aged sediment limit is withheld for months at elevated temperature compared to the reference. Additionally, the stabilising component is renewable and provides a way to reduce greenhouse gas emissions.

Asphaltenes are large aromatic molecules that are suspended colloids in crude oil and heavy fuel oil. Asphaltenes stay dispersed in the oil when they are surrounded by resins (polar aromatics) and the oil is then said to be stable. Under unfavourable solvent conditions resins are desorbed from asphaltenes causing asphaltenes to flocculate and precipitate. This precipitation will increase the oil's sediment amount. Large sediment amounts cause more operation problems on a vessel and increase separator sludge waste amounts. When asphaltene containing fuel is stored for a long period of time and/or heated, it begins to deteriorate and its sediment amount increases.

A particular advantage of the present marine fuel blend is therefore that the use of CNSL in the blend allows the use of components that would normally not be usable for marine fuel, in particular components in which the solvency power is poor or components in which the nature of asphaltenes is such that they are less soluble and more prone to flocculation and precipitation in the regularly used marine fuel components. The CNSL containing blend thus has a higher solvency power of asphaltenes than regularly used marine fuel components. The content of asphaltenes and other compounds affecting the stability of the marine fuel blend depends on the origin of the crude oil and the processing it has gone through, if the blend comprises fossil components. As will be shown below in the Experimental part, the present marine fuel blend has the advantage of a long-term storage stability, which is crucial for marine fuel use.

The marine fuel blend comprises 0.5 – 50 vol-% of refined cashew nut shell liquid, the rest of the blend (i.e. up to 100 vol-%) being other suitable component(s). The blend may thus comprise from 0.5, 1, 1.5, 2, 3, 4, 5, 7, 10, 12, 15, 17, 20, 22, 25, 27, 30, 32, 35, 37, 40 or 42 vol-%, up to 2, 3, 4, 5, 7, 10, 12, 15, 17, 20, 22, 25, 27, 30, 32, 35, 37, 40, 42, 47 or 50 vol-% of refined CNSL. The amount of refined CNSL may be for example 0.5-30 vol-%, 0.5-20 vol-% or 0.5-10 vol-% of the total weight of the blend.

The cashew nut shell liquid comprises at least 50 wt-% of cardanol. According to an embodiment, it comprises at least 80 wt-% of cardanol, or at least 90 wt-% of cardanol. The CNSL may thus comprise at least 50, 55, 60, 65, 70, 75, 80, 85 or 90 wt-%, up to 60, 65, 70, 75, 80, 85, 90 or 95 wt-% of cardanol. The amount of cardanol in the CNSL may be for
5 example 50-80 wt-% or 60-90 wt-%.

According to an embodiment, the cashew nut shell liquid has been refined by any of vacuum distillation, distillation, heat treatment, filtration, degumming or combinations thereof. For example, the CNSL may have been refined by vacuum distillation at 200 - 240 °C under a pressure of 2.5 - 3.5 mbar. It has been noticed that these distillation conditions lead to a high
10 yield of cardanol in the refined CNSL. The natural or raw CNSL may also be purified with supercritical CO₂ extraction, distillation, heat treatment, filtration, degumming, combination or filtration and degumming or any other suitable way, such as a combination of two or more of the above. One possible way of obtaining the refined cashew nut shell liquid is by pressing cashew shells in the absence of heating to obtain crude cashew nut shell liquid, bleaching
15 the crude cashew nut shell liquid followed by dehydration at 160 °C to obtain the refined cashew nut shell liquid.

The kinematic viscosity of the marine fuel blend is 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996. The kinematic viscosity may thus be for example from 1, 2, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100, 120, 140, 150, 170,
20 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650 or 675 mm²/s, up to 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100, 120, 140, 150, 170, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675 or 700 mm²/s as measured at 50 °C according to EN ISO 3104:1996.

25 According to an embodiment, the kinematic viscosity of the marine fuel blend is 1-30 mm²/s as measured at 50 °C according to EN ISO 3104:1996. The kinematic viscosity may thus be for example from 1, 2, 3, 4, 5, 7, 9, 10, 12, 14, 15, 17, 20, 22 or 25 mm²/s up to 3, 4, 5, 7, 9, 10, 12, 14, 15, 17, 20, 22, 25, 27 or 30 mm²/s as measured at 50 °C according to EN ISO 3104:1996.

Such marine fuel blends having a lower kinematic viscosity may comprise 0.5-20 vol-% of refined cashew nut shell liquid. The amount of refined CNSL in these blends may be 0.5, 1, 1.5, 2, 3, 4, 5, 7, 10, 12, 15 or 17 vol-%, up to 2, 3, 4, 5, 7, 10, 12, 15, 17 or 20 vol-%.

According to an embodiment, the marine fuel blend has a pour point of 5-30 °C as measured
5 by EN ISO 3016:2019. According to a preferred embodiment, the pour point is 15-30 °C, or more preferably, 20-30 °C as measured by EN ISO 3016:2019. The pour point may thus be for example from 5, 10, 15 or 20 °C up to 10, 15, 20, 25 or 30 °C as measured by EN ISO 3016:2019.

Marine fuel blends typically comprise or form some amounts of sediments, when the fuel
10 blend is heated and/or stored for a long period of time. For marine fuel blends in the category of RMB and RMG, these are measured according to ISO 10307-2A:2009, and are called Total sediment – Aged, or Potential Total Sediment, abbreviated TSP. In this description, the abbreviation TSP is used for RMB and RMG. For marine fuel blends in the category of DMB, the measurement method is described in ISO 10307-1:2009, and are called Total
15 sediment by hot filtration, or Existent Total Sediment, abbreviated TSE. In this description, the abbreviation TSE is used for DMB.

According to another embodiment, the marine fuel blend has an amount of aged sediment, TSP, of less than 0.10 wt-%, as measured by ISO 10307-2A:2009 or TSE, as measured by
20 ISO 10307-1:2009, is less than 0.10 wt-%. This amount fulfils the requirements of the standard for marine fuels. The amount of aged sediment may even be less than 0.08, 0.07, 0.06 or 0.05 wt-% or even lower.

The marine fuel blend may also have an ash content of less than 0.1 wt-%, as measured by ISO 6245:2002. This ash content fulfils the requirements of the standard for marine fuels.

The sulphur content of the marine fuel blend is preferably at most 0.1 wt-%, as measured by
25 ISO 8754:2003. This sulphur content fulfils the requirements of the standard for Sulphur Emission Control Area (SECA area). The sulphur content may even be less than 0.09, 0.08, 0.07, 0.06, 0.05, 0.04 or 0.03, wt-%, or even lower.

The Pensky-Martens flash point of the marine fuel blend is over 60 °C, preferably 100-150 °C as measured by EN ISO 2719:2016.

Indeed, despite its different chemistry, it was observed (as will be shown below in the Experimental section), that refined CNSL was found to fulfil both RMB and RMG categories (ISO 8217:2017) when blended with conventional fossil based RMB or RMG. Based on simulated distillation, behaviour of the CNSL containing blends resemble well the conventional RMB/RMG distillation behaviour and thus no obvious combustion issues can be seen. As RMB's/RMG's comprising or consisting of non-fossil based components need to fulfil the same requirements as fossil based RMB/RMG, it is believed that CNSL would be combinable with those RMB's/RMG's as well, without any difficulties.

According to another embodiment, the kinematic viscosity of the marine fuel blend is 31-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996. The kinematic viscosity may thus be for example from 31, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100, 120, 130, 140, 150, 170, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650 or 675 mm²/s, up to 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100, 120, 130, 140, 150, 170, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675 or 700 mm²/s as measured at 50 °C according to EN ISO 3104:1996. The kinematic viscosity is preferably 90-130 mm²/s as measured at 50 °C according to EN ISO 3104:1996.

Such marine fuel blends having a higher kinematic viscosity may comprise 0.5-20 vol-% of refined cashew nut shell liquid. The amount of refined CNSL in these blends may be 0.5, 1, 1.5, 2, 3, 4, 5, 7, 10, 12, 15 or 17 vol-%, up to 2, 3, 4, 5, 7, 10, 12, 15, 17 or 20 vol-%. The amount of refined CNSL is preferably 0.5-10 vol-%.

A person skilled in the art is readily able to make the present marine fuel blend, despite the vol-% and wt-%. Indeed, the CNSL is typically sold with an indication of its content of cardanol in wt-%. Further, a person skilled in the art knowing the density of the different components of the marine fuel blend is also able to calculate the corresponding values. For example, in a marine fuel blend comprising 95 vol% of RMB with a density of 880.8 kg/m³ and 5 vol-% of CNSL with a density of 939.5 kg/m³, would thus have 5.3 wt-% of CNSL. The amount of aged sediment of a marine fuel blend comprising refined CNSL is typically 0.01-0.11 wt-% lower than that of the other component(s) of the blend (i.e. the blend without refined CNSL), when measured with the same measurement method.

Typically, the use of refined CNSL allows lowering the amount of aged sediments by 0.05-0.10 wt-% compared to not using the refined CNSL.

The sulphur content of the marine fuel blend is preferably at most 0.5 wt-%, as measured by ISO 8754:2003. This sulphur content fulfils the requirements of the standard for marine fuels. The sulphur content may even be less than 0.45, 0.40, 0.35, 0.30, 0.25, 0.20, 0.15, 0.10 or 0.05 wt-%, or even lower.

Furthermore, these marine fuel blends are especially suitable for achieving the requirements of RMG grade with a maximum of 0.5 wt-% sulphur marine fuel. Indeed, these fuels comprise highly cracked asphaltenes of resid hydrocracker 560 °C + bottom oil, which need to be kept dispersed in the oil. It has now been observed (as will be shown in the Experimental section) that the stabilising cardanol component derived from cashew nut shell liquid keeps the asphaltenes in the solution and aged sediment limit in the bunker category of ISO 8217:2017 is fulfilled. Indeed, the laboratory test method for aged sediment (ISO 10307-2:2009) simulates ageing of a fuel and the marine fuel standard ISO 8217:2017 defines a limit for the aged sediment amount in marine fuels.

The fossil part of the marine fuel blend may comprise distillate marine fuel or fuels, residual marine fuel or fuels or mixtures thereof. For example, the marine fuel blend may comprise 10 vol-% of residual marine fuel, up to 50 vol-% of CNSL, the rest being distillate marine fuel.

The composition of the marine fuel blend may also be for example 90 vol-% of residual marine fuel and 10 vol-% of CNSL. Alternatively, the composition may be 80 vol-% of residual marine fuel and 20 vol-% of CNSL.

The present marine fuel blend may comprise any known marine fuel or mixtures thereof. For example, it may comprise marine fuels as defined by their properties in ISO 8217:2017(E), i.e. DMX, DMA, DFA, DMZ, DFZ, DMB, DFB, RMA, RMB, RMD, RME, RMG or RMK, such as RMG180, RMG380, RMG500 or RMG700 or RMK380, RMK500 or RMK700. Typically, RMG grades are the preferred ones.

For example, the marine fuel may be RMG, which is a residual fuel, which comprises hydrocracked residual oil, LCO (Light Cycle Oil, a diesel boiling range product, from fluid catalytic cracking units) and/or hydrocracked distillates. The fuel typically has a 50 °C

kinematic viscosity maximum of 700 mm²/s and density maximum of 991 kg/m³. The content of hydrocracked residual oil is typically in the range of 0-70 wt-%. The hydrocracked residual oil may also comprise from 0-100 wt-% hydrocracked deasphalted oil. According to another example, the marine fuel may be RMB, which is also a residual fuel, and may
5 comprise distilled gas oil containing (hydrocracked) vacuum distillates. It typically has a kinematic viscosity of 30 cSt at 50 °C, a density of max 960 kg/m³, a pour point of 30 °C or less and a boiling range of C6-C43.

The marine fuel blend may also comprise, in addition to the cashew nut shell oil, a low sulphur fuel oil bunker component as described in WO 2019/053323, which is incorporated
10 herein by reference.

The process for producing a low sulphur fuel oil bunker component from a vacuum residue may comprise

- solvent deasphalting (SDA) said vacuum residue and recovery of a deasphalted fraction,
- hydrocracking said deasphalted fraction at a hydrocracking unit, and
15 - recovering the low sulphur fuel oil bunker component as a residue of said hydrocracking unit.

Through this process, more efficient use of vacuum residue is obtained. The low sulphur fuel oil bunker component obtained is readily applicable as marine fuel and meets requirements set thereto. It may also be used as a blend component. It is even possible to use vacuum
20 residue which has sulphur content of about 3 wt-%.

Solvent deasphalting (SDA) refers here to a separation process, wherein asphaltenes are separated from lighter hydrocarbons by physical means, with solvent. Solvent deasphalting uses an aliphatic solvent to separate the typically more valuable oils and resins from the more aromatic and asphaltenic components of its vacuum residue feedstock. In the process, the
25 solvent is typically contacted countercurrent to the feed stream.

Solvent deasphalting is usually carried out under a temperature from 10 to 260 °C, such as from 50 to 180 °C, and a pressure from 3 to 100 atmospheres.

A suitable solvent is used to extract the desired fractions from vacuum residue. In solvent deasphalting, the solvent used is selected from the group consisting of low molecular
30 hydrocarbons such propane, butane, isobutane, pentane, isopentane, neopentane, hexane,

isohexane and any mixture thereof. Here the preferred solvent is selected from heavy solvents, such as pentane or hexane, preferably n-pentane or n-hexane. The use of heavy solvents provides good yield. Also lighter solvents, such as propane, may be used providing a purer product but poorer yield.

- 5 Heavy oil containing high amounts of metals is converted to high quality diesel in residue hydrocracking (RHC) system. The RHC system may contain several reactors, where the vacuum residue is converted via demetallisation, hydrocracking, desulphidation and denitrification reactions in the presence of a catalyst. RHC system comprises at least one reactor selected from an ebullated bed reactor, a slurry reactor, and mild hydrocracking
10 reactor preferably a combination thereof. Residue hydrocracking system may also comprise other unit operations.

According to a preferred embodiment, the residue hydrocracking comprises at least one ebullated bed reactor. An ebullated bed reactor is a hydrocracking process upgrading heavy feed using an ebullated or expanded catalyst bed. Feed enters the reactor at the bottom and
15 moves upward towards the reactor exit. In the presence of hydrogen and catalyst, the feed is converted into distillate products (vacuum gas oil, diesel, kerosene and naphtha). A constant catalyst activity is maintained throughout the run by continuous addition and removal from the reactor. This also has the advantage of no pressure drop buildup over the reactor as would be the case with fixed bed residuum hydrocracking units. Ebullated bed reactor reactor is
20 therefore especially suitable for continuous processes of heavy hydrocarbon feeds which contain high quantities of metals and solids.

As described above, the core of this process lies within a combination of solvent deasphalting and hydrocracking reactions producing the low sulphur fuel oil bunker component. However, when considering the vacuum residue as a stream obtainable from vacuum
25 distillation of atmospheric residue, the overall process from crude oil to low sulphur fuel oil bunker component, can be considered as follows.

- A process for producing low sulphur fuel oil bunker component, comprising
- crude oil atmospheric distillation and recovery of an atmospheric residue,
 - vacuum distilling said atmospheric residue and recovery of a vacuum residue,
 - 30 - solvent deasphalting said vacuum residue and recovery of deasphalted fraction,
 - hydrocracking said deasphalted fraction at a hydrocracking unit, and

- recovering the low sulphur fuel oil bunker component as residue of said hydrocracking unit.

In the above process, also a part of the obtained vacuum residue may be fed into the hydrocracking stage as a co-feed.

- 5 Atmospheric distillation and vacuum distillation are well known processes in oil refining. In a refinery crude oil is first distilled into fractions by atmospheric distillation. The residue from atmospheric distillation is further distilled by a vacuum distillation process using a reduced pressure to provide vacuum gas oil and bottom fraction called vacuum residue.

The marine fuel blend may also comprise co-processed components, i.e. components where
10 an oil of fossil origin has been co-processed with a feed of renewable origin in a conventional fossil fuel processing system.

The present marine fuel blend may naturally also comprise other non-fossil components, such as renewable components. It is also possible that the blend does not comprise any fossil component at all.

- 15 According to an embodiment, there is thus provided a marine fuel blend having a viscosity of 1-30 mm²/s as measured at 50 °C according to EN ISO 3104:1996, comprising 0.5 – 50 vol-% of refined cashew nut shell liquid, which cashew nut shell liquid comprises at least 50 wt-% of cardanol. According to another embodiment, there is provided a marine fuel blend
20 having a viscosity of 31-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, comprising 0.5 – 20 vol-% of refined cashew nut shell liquid, which cashew nut shell liquid comprises at least 50 wt-% of cardanol.

According to another aspect, there is provided a use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol as asphaltene stabiliser for marine bunker fuels having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO
25 3104:1996. A particularly advantageous use of the refined cashew nut shell liquid is as asphaltene stabiliser for residual marine fuels.

Another use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol is as a marine fuel component, the resulting marine fuel blend having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and fulfilling at least one

of the categories of ISO 8217:2017(E) for residual and distillate marine fuels. A still further use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol is for improving storage stability of marine bunker fuels. The efficiency of CNSL for these uses is shown below in the Experimental section.

- 5 Indeed, as will be demonstrated below in the Experimental part, it has been observed that use of the present CNSL in a marine fuel allows to stabilise asphaltenes in marine bunker fuels, leading to better stability of the fuels and less clogging problems for filters etc.

According to another aspect, there is provided use of a marine fuel blend for reducing the greenhouse gas emissions at least 4 % as CO_{2eq}/MJ calculated according to the directive
10 2018/2001 of the European Parliament and of the Council, of 11 December 2018 on the promotion of the use of energy from renewable sources. Indeed, a reduction of 4 % of the GHG emissions is obtained when using 5 vol-% of CNSL, while a reduction of 9 % is achieved when using 10 vol-% of CNSL. The use of the present marine fuel blend indeed allows to reduce the GHG emissions, as it comprises renewable material. The present marine
15 fuel blend thus fulfils at least partly the requirements of IMO, with respect to reductions of greenhouse gas emissions, as discussed above.

According to yet another aspect, there is provided a method for manufacturing a marine fuel having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, comprising mixing a residual fossil-based component with 0.5 – 50 vol-% of
20 refined cashew nut shell oil, which cashew nut shell oil comprises at least 50 wt-% of cardanol, the resulting marine fuel fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels. The base component may be fossil-based component and/or a renewable component. The base component may also have been obtained by co-processing one or more fossil feeds with one or more renewable feeds.
25 Additionally, recycled feeds may also be used. The various embodiments and alternatives described above in connection with the marine fuel blend apply *mutatis mutandis* to the method for manufacturing the marine fuel. The fossil based component may be any component suitable *per se* for marine fuels, such as any of those listed above. The mixing may take place according to known methods of blending marine fuels or fuels, for example
30 at the manufacturing facility of the marine fuel or at a point of distribution. Blending of fuel components is also possible on board.

It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of
5 describing particular embodiments only and is not intended to be limiting.

Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the description, numerous specific details are provided, to provide a thorough understanding of embodiments of the invention.

The verbs “to comprise” and “to include” are used in this document as open limitations that
10 neither exclude nor require the existence of also un-recited features. The features recited in dependent claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", i.e. a singular form, throughout this document does not exclude a plurality.

EXPERIMENTAL PART

15 The present marine fuel blends were tested with different compositions and the resulting blends were tested for their properties. The test results are given below in Tables 1 to 4.

The RMB used in the fuel blend was a typical fossil based RMB fulfilling ISO 8217-2017 standard except for pour point (marked with *).

20 The RMG 1 (or RMG test sample 1) grade with maximum of 0.5 wt-% sulphur used in the fuel blend was resid hydrocracker 560 °C+ bottom oil. The other two RMG's (RMG 2 and RMG 3, or RMG test sample 2 and RMG test sample 3, respectively) were two slightly different RMG grades.

The DMB was distillate based marine fuel according to ISO 8217:2014 with ultra low (i.e. below 0.1 wt-%) sulphur content.

25 The refined CNSL used comprised at least 50 wt-% cardanol. Three different grades of refined CNSL were used, namely CNSL 1, CNSL 2 and CNSL 3. The CNSL 2 was a purer grade than CNSL 3.

The measurement methods were as follows:

- Density at 15 °C: ISO 12185:1996
- Pour point for RMB: ASTM D5950-14(2020)
- Pour point for RMG: ISO 3016:2019
- Kinematic viscosity, at 50 °C: EN ISO 3104:1996
- 5 Sulphur content: ISO 8754:2003
- Flash point for RMB: ISO 2719:2016, method A
- Flash point for RMG: ISO 2719:2016, method B
- Hydrogen sulphide: IP570:2015
- Ash content: ISO 6245:2002
- 10 Carbon residue: ISO 10370:2014
- Total acid number (TAN) for RMB: ISO 6619:1988
- Total acid number (TAN) for RMG: ASTM D664-2018
- Potential Total Sediment (TSP) for RMB and RMG: ISO 10307-2A:2009
- Existent Total Sediment (TSE) for DMB and CNSL: ISO 10307-1:2009
- 15 Aged sediment for CNSL: ISO 10307-2:2009
- State of peptisation of asphaltenes (S-value): ASTM D7157:2012
- Intrinsic stability of the oily medium (So-value): ASTM D7157:2012
- Water content (vol-% or wt-%) by potentiometric Karl Fischer titration method: ISO 10336M:1997
- 20 Additionally, Table 1 gives the calculated carbon aromaticity index (CCAI), calculated using the following equation:

$$CCAI = D - 140.7 \log(\log(V + 0.85)) - 80.6 - 483.5 \log\left(\frac{t + 273}{323}\right)$$

wherein

- D= density at 15 °C (kg/m³)
- 25 V=kinematic viscosity (mm²/s)
- t = viscosity temperature (°C)

The amount of Al, Ca, Na, P, Si, V and Zn (in mg/kg) in the blends were determined using inductively coupled plasma (ICP).

- In Table 1, the column titled ISO 8217:2017(E) lists the requirements of said standard for
- 30 RMB marine fuels, with the exception of the pour point, where the maximum is indicated as 30.0 °C (marked with *). Tables 1 and 2 give some characteristics of the blends as well as

for the RMG 2. The requirements of ISO 8217:2017(E) for RMG marine fuels are the same as for RMB marine fuels, with the following exceptions: density maximum 991.0 kg/m³, viscosity at 50°C 700 mm²/s, sulphur maximum 0.5 wt-%, ash maximum 0.100 wt-% and carbon residue maximum 18 wt-%.

Property	Unit	ISO 8217:2017(E)	RMB + 5 vol-% CNSL 1	RMB + 10 vol-% CNSL 1	RMB + 20 vol-% CNSL 1
Density	kg/m ³	max 960.0	884.2	888.3	896.6
Pour point	°C	max 30 (*)	27	30	27
Viscosity at 50°C	mm ² /s	max 30	11.42	11.93	14.36
Sulphur	wt-%	max 0.10	0.09	0.08	0.07
Flash point	°C	min 60.0	122.0	125.0	126.5
Hydrogen sulphide	mg/kg	2.00			<0.40
Ash	wt-%	max 0.070	0.055	0.104	<0.001
Carbon residue	wt-%	max 10.00	0.44	0.83	1.75
TAN	mg KOH/g	max 2.5	<0.10	<0.10	<0.10
CCAI		max 860	798	801	805
TSP	wt-%	max 0.10	0.06	0.09	0.23
ICP-Al	mg/kg	Al+Si 40	4.8	9.7	
ICP-Ca	mg/kg	30	7.4	14	
ICP-Na	mg/kg	100	5.9	10	
ICP-P	mg/kg	15	5.5	11	
ICP-Si	mg/kg		7.2	14	
ICP-V	mg/kg	150	<0.5	<0.5	
ICP-Zn	mg/kg	15	<0.6	<0.6	
Water	vol-%	0.50	0.03	0.05	
Water	wt-%				0.06

5 Table 1

Property	Unit	RMG 2	RMG 2 + 5.2 vol-% CNSL 2	RMG 2 + 10.5 vol-% CNSL 2	RMG 2 + 5.1 vol-% CNSL 3
Density	kg/m ³	980.9	979.8	978.6	981.0
Pour point	°C	0	-3	-6	-6
Viscosity at 50°C	mm ² /s	193.5	228.1	266.4	254.2
Sulphur	wt-%	0.45	0.45	0.44	0.45
Flash point	°C	116.0	128.0	140.0	126.5
Hydrogen sulphide	mg/kg	<0.60	<0.60	<0.60	<0.60
Ash	wt-%	0.019	0.039	0.028	0.082
Carbon residue	wt-%	7.48	7.78	8.03	10.0
TAN	mg KOH/g	0.10	<0.10	<0.10	<0.10
TSP	wt-%	0.16	0.07	0.05	0.10
ICP-Al	mg/kg	24	20	19	19
ICP-Ca	mg/kg	< 3	< 3	< 3	6
ICP-Na	mg/kg	2	4	3	6
ICP-P	mg/kg	< 1	< 1	< 1	3
ICP-Si	mg/kg	13	13	14	8
ICP-V	mg/kg	17	17	17	16
ICP-Zn	mg/kg	< 1	< 1	< 1	< 1

Table 2

The refined CNSL was also blended with two further different RMG grades (RMG test sample 1, i.e. RMG 1 and RMG test sample 3, i.e. RMG 3) with max 0.5 wt-% sulphur marine fuel, and TSP was measured according to ISO 10307-2A:2009. Three different CNSL's were used, CNSL 1, CNSL 2 and CNSL 3 (also named CNSL test sample 1, CNSL test sample 2 and CNSL test sample 3, respectively). Tables 3 and 4 show the results, the column titled ISO 8217:2017(E) giving the requirement of said standard for RMG marine fuels.

Property	Unit	ISO 8217:2017(E)	RMG 1	RMG 1 + 0.5 vol-% CNSL 1	RMG 1 + 5 vol-% CNSL 1	RMG 1 + 10 vol-% CNSL 1
TSP	wt-%	max 0.10	0.12	0.12	0.05	0.04

Table 3

Property	Unit	ISO 8217:2017 (E)	RMG 3	RMG 3 + 10.3 vol-% CNSL 2	DMB	DMB + 9.4 vol-% CNSL 2	DMB + 9.2 vol-% CNSL 3
TSP	wt-%	max 0.10	0.10	0.04			
TSE	wt-%	max 0.10			< 0.01	< 0.01	< 0.01

Table 4

The used RMG test samples RMG 1 and RMG 2 alone did not fulfil the RMG marine fuel category ISO 8217 limit (0.10 wt-%) regarding TSP. Adding 0.5 vol-% of CNSL 1 to the RMG 1 kept the aged sediment concentration the same as without any addition. When 5 vol-% or 10 vol-% of any of the CNSL's were added to RMG 1, RMG 2 or RMG 3, TSP reduced from 0.12 wt-% to 0.05 wt-% and 0.04 wt-%, respectively for CNSL 1, from 0.16 wt-% to 0.07 wt-% and 0.05 wt-% respectively for CNSL 2, and from 0.16 wt-% to 0.10 wt-% for CNSL 3. The amount of TSP was finally well below the required limit, as the absolute reduction was from 0.07 to 0.09 wt-% when using 5 vol-% of CNSL and 0.08 to 0.11 wt-% when using 10 vol-% of CNSL.

The tested DMB had a very low amount of TSE, and this did not change when 10 wt-% of CNSL 2 or 3 was added.

Further storage tests were carried out with CNSL 2 and CNSL 3. CNSL 2 was a distilled, heated and fine filtered CNSL, while CNSL 3 was a degummed CNSL. Firstly, the two CNSL's were tested on their own, and the results given below in Table 5. As can be seen, the products behaved well during storage.

CNSL	CNSL 2				CNSL 3			
Months	0	1.5	3.5	6	0	1.5	3.5	6
Sediment (wt-%)	< 0.01	< 0.01	< 0.01	< 0.01	0.05	0.04	0.04	0.03
Aged sediment (wt-%)	< 0.01	< 0.01	< 0.01	< 0.01	0.06	0.03	0.04	0.03

Table 5

These two CNSL's were also tested in different marine fuel blends, as shown in Tables 6-9.

Table 6 gives the density (ISO 12185:1996) in kg/m³ in a top part of the sample and a bottom part of the sample, i.e. storage test results in room temperature for a DMB (alone) and DMB

with 10 wt-% of either CNSL 2 or CNSL 3. As can be seen, there is no separation of phases during the storage.

Sample	DMB			DMB+CNSL 2			DMB+CNSL 3		
Months	0	1.5	3.5	0	1.5	3.5	0	1.5	3.5
Top	872.2	878.14	878.17	883.40	883.37	883.40	885.40	885.43	885.47
Bottom		878.15	878.16		883.37	883.41		885.44	885.49

Table 6

Tables 7-9 give the storage test results at 70 °C for RMG05 alone (Table 7) and mixed with CNSL, where Table 8 has the results with CNSL 2, either 5 or 10 wt-%, and Table 9 has the same results for CNSL 3. The marine fuel blends are not regularly stored at 70 °C, but such temperature was used in these tests to simulate a storage time that is significantly longer than the tested maximum of 6 months.

	RMG05			
Months	0	1.5	3.5	6
Sediment (wt-%)	0.10	0.28	0.58	0.65
Aged sediment (wt-%)	0.16	0.32	0.59	0.64
S-value	0.97	1.42	1-39	
So-value	1.03			

Table 7

Sample	RMG05+CNSL 2 (5 wt-%)				RMG05+CNSL 2 (10 wt-%)			
Months	0	1.5	3.5	6	0	1.5	3.5	6
Sediment (wt-%)	0.05	0.08	0.39	0.70	0.05	0.04	0.06	0.35
Aged sediment (wt-%)	0.07	0.12	0.43	0.76	0.05	0.05	0.11	0.22
S-value	1.32	1.44	1.44		1.65	2.05	1.72	
So-value	1.37				1.97			

10 Table 8

Sample	RMG05+CNSL 3 (5 wt-%)				RMG05+CNSL 3 (10 wt-%)			
Months	0	1.5	3.5	6	0	1.5	3.5	6
Sediment (wt-%)	0.08	0.09	0.77	0.62	0.05	0.05	0.07	0.31
Aged sediment (wt-%)	0.10	0.15	0.83	0.66	0.06	0.05	0.17	0.28
S-value	1.27	1.34	1.30		2.55	2.45	1.82	
So-value	1.23				3.41			

Table 9

When measured according to ISO 10307-2:2009 (which refers to ISO 10307-1:2009 for filtration), the maximum total sediment covered by the precision evaluations of the method is 0.50 wt-% (w/w) for residual fuels and 0.40 wt-% (w/w) for distillate fuels containing residual components.

- The results show that both CNSL's have a positive effect on the storage properties of the marine fuel. CNSL 2 gives overall better results than CNSL 3, as it has less aged sediments than CNSL 3. It was also observed that a higher amount of CNSL in the marine fuel had a more positive effect on the storage properties.
- 10 The renewable component (CNSL) thus improves the sediment (i.e. decreases) and most importantly aged sediment (i.e. decreases), S-value (i.e. increases) and So-value (i.e. increases) of the RMG05 tested.

CLAIMS

1. A marine fuel blend having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and comprising 0.5 – 50 vol-% of refined cashew nut shell liquid, which cashew nut shell liquid comprises at least 50 wt-% of cardanol, the marine fuel
5 blend fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels.
2. The marine fuel blend according to claim 1, wherein the kinematic viscosity is 1-30 mm²/s as measured at 50 °C according to EN ISO 3104:1996.
3. The marine fuel blend according to claim 2, comprising 0.5-30 vol-% of refined cashew
10 nut shell liquid.
4. The marine fuel blend according to claim 2 or 3, having a pour point of 5-30 °C as measured by EN ISO 3016:2019.
5. The marine fuel blend according to any of the claims 2-4, having a sulphur content of at most 0.1 wt-%, as measured by ISO 8754:2003.
- 15 6. The marine fuel blend according to any one of the claims 2-5, having a Pensky-Martens flash point of over 60 °C, preferably 100-150 °C as measured by EN ISO 2719:2016.
7. The marine fuel blend according to claim 1, wherein the kinematic viscosity is 31-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and it comprises 0.5-20 vol-% of refined cashew nut shell liquid.
- 20 8. The marine fuel blend according to claim 7, wherein the kinematic viscosity is 90-130 mm²/s as measured at 50 °C according to EN ISO 3104:1996.
9. The marine fuel blend according to claim 7 or 8, comprising 0.5-10 vol-% of refined cashew nut shell liquid.
10. The marine fuel blend according to any of the claims 7-9, having an amount of aged
25 sediment of less than 0.10 wt-%, preferably 0.08 wt-% as measured by ISO 10307-2:2009.
11. The marine fuel blend according to any of the preceding claims, wherein the cashew nut shell liquid comprises at least 80 wt-% of cardanol.

12. The marine fuel blend according to any of the preceding claims, wherein the cashew nut shell liquid has been refined by any of vacuum distillation, distillation, heat treatment, filtration, degumming or combinations thereof.
13. The marine fuel blend according to any of the preceding claims, wherein the cashew nut shell oil has been refined by vacuum distillation at 200 - 240 °C under pressure of 2.5 - 3.5 mbar to obtain the refined cashew nut shell liquid.
14. The marine fuel blend according to any of the claims 1-12, where the refined cashew nut shell liquid has been obtained by pressing cashew shells in the absence of heating to obtain crude cashew nut shell liquid, bleaching the crude cashew nut shell liquid followed by dehydration at 160 °C to obtain the refined cashew nut shell liquid.
15. Use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol as asphaltene stabiliser for marine bunker fuels having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996.
16. Use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol as marine fuel component, the resulting marine fuel blend having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, and fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels.
17. Use according to claim 15 or 16, for reducing the greenhouse gas emissions at least 4 % as CO_{2eq}/MJ calculated according to the directive 2018/2001 of the European Parliament and of the Council.
18. Use of refined cashew nut shell liquid comprising at least 50 wt-% of cardanol for improving storage stability of marine bunker fuels.
19. A method for manufacturing a marine fuel having a kinematic viscosity of 1-700 mm²/s as measured at 50 °C according to EN ISO 3104:1996, comprising mixing a residual fossil-based component with 0.5 – 50 vol-% of refined cashew nut shell oil, which cashew nut shell oil comprises at least 50 wt-% of cardanol, the resulting marine fuel fulfilling at least one of the categories of ISO 8217:2017(E) for residual and distillate marine fuels.