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Executive Summary

The overall objective of REDIFUEL is to enable the utilization of various biomass feedstocks for an ultimate renewable EN590 diesel biofuel (drop-in capable at any ratio) in a sustainable manner. The proposed drop-in biofuel contains high-cetane C11+ bio-hydrocarbons and C6-C11 bio-alcohols.

In this deliverable, as a part of the investigation of the drop-in compatibility of REDIFUEL, the properties of REDIFUEL are analysed from a perspective of handling, storage, and logistics. For this, the logistics chain of diesel is identified, and the practices related to safety, storage and handling are discussed. Furthermore, the different parameters of REDIFUEL that are relevant to fuel handling, storage and distribution are summarized and benchmarked with diesel standards.

The safety related parameters of REDIFUEL such as flash point lie within the EN 590 norm and are similar to diesel. In addition to flash point, REDIFUEL has very good electrical conductivity and hence does not need a conductivity improver additive. The safety regulations and precautions for REDIFUEL therefore will be similar to those of diesel. Similarly, the fuel component interaction results show that REDIFUEL is compatible with all the components of a typical automotive fuel injection system. However, there are some aspects of REDIFUEL which differ from conventional diesel, and which need to be kept in mind when handling diesel.

With the aspect to density, the loading of pipes and tanks must be calculated due to the low density of REDIFUEL. Otherwise, overfilling may happen during transportation and storage. For the parameter HFRR, too large HFRR indicates poor lubricity of REDIFUEL, which can only be solved by adding additives. Regarding the increase of water content during the aging process, it did not affect the compatibility of REDIFUEL with components. Based the experiment results, additives can be a good solution to mitigate fuel oxidation. The storage stability can be improved by addition of commercially available additives that commonly used for diesel, like BHT. Nevertheless, water content for renewable REDIFUEL like other biofuels is still a potential risk during usage and must be constantly inspected.

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1 Introduction

This deliverable is a part of work package 3 and related to task 3.2.5. The task's main objective is to detect potential bottlenecks for REDIFUEL during its distribution and handling from production to the end user from a technical standpoint and to identify the consequent infrastructural adaptations that need to be carried out for the application of REDIFUEL. The regulatory aspects such as norms related to the transport of hazardous substances are beyond the scope of this deliverable. The deliverable summarizes the results for stakeholders of the fuel logistics chain, e.g., distributing companies, end users and (local) authorities. All objectives of the tasks have been reached.

In chapter 2, logistics chain of Diesel is identified and presented. Furthermore, the practices related to safety, storage and handling are discussed. In chapter 3 the different parameters, methods and norms that are relevant to fuel handling, storage and distribution are summarized.

In chapter 4, the results for REDIFUEL for the various analyses described in chapter 3 are presented and compared to Diesel. Based on these results, possible issues of REDIFUEL with the existing logistic chain and handling practices are determined. Recommendations for the adjustment of the infrastructure and handling practices from conventional diesel fuel to REDIFUEL are proposed at the end of the document in Chapter 5.

2 Logistics and handling for conventional diesel fuel

2.1 IDENTIFICATION OF THE LOGISTICS CHAIN

To evaluate REDIFUEL's compatibility with the existing infrastructure and logistics chain of fossil liquid fuels, firstly the logistics chain and handling practices are identified.

2.1.1 SCOPE

There are three major sectors in the oil and gas industry supply chain namely the Upstream, Midstream and Downstream (Figure 1).

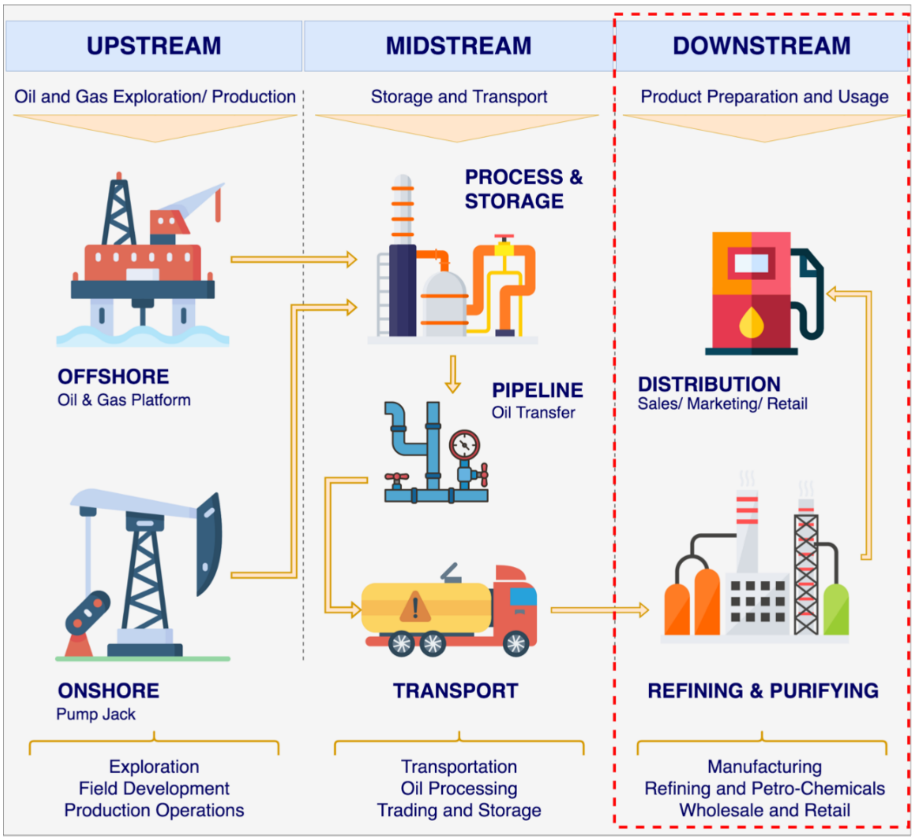

Figure 1: Overview of Diesel supply chain [2]

The upstream sector includes both exploration and production activities, while the midstream sector covers the transportation, trading and storage of crude oil and natural gas. The downstream sector is the final step in the journey of crude oil and natural gas from ground (after processing) to consumers. It involves the refining and purifying as well as the marketing and distribution of petroleum products. This deliverable will focus on the downstream sector and its individual steps.

2.1.2 LOGISTICS CHAIN

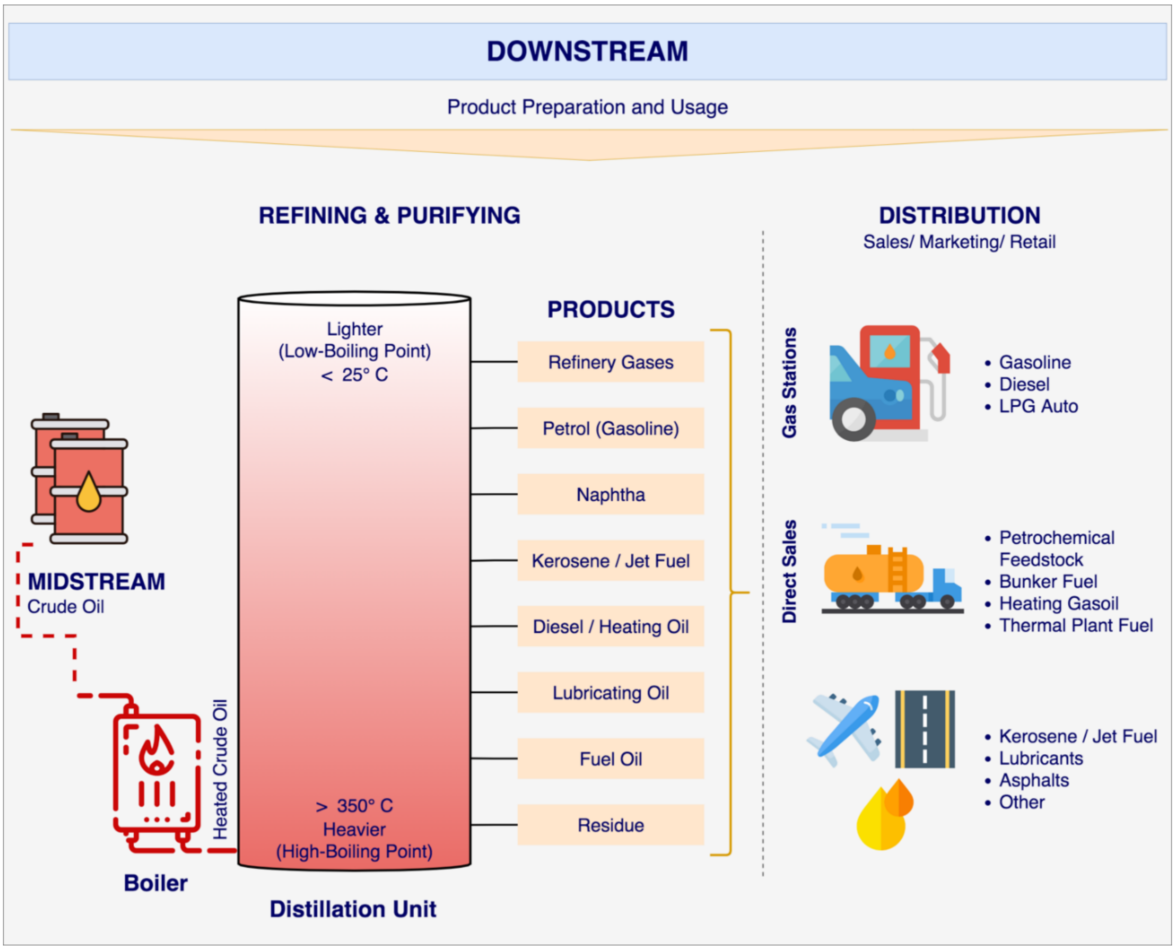

Figure 2: Downstream process chain [3]

Downstream operations are the processes involved in converting oil and gas into the finished product as seen in Figure 2. The first stage is therefore refining. Crude oil is fractionally distilled to produce a variety of refined products, including gasoline, kerosene, fuel oil and diesel. The fractional distillation functions because these various products all have different boiling points. Heavy and light fractions are respectively on the bottom and on the top of the distillation unit. The crude oil is heated with the help of a boiler until all the components turn into gases that rise in the chamber of the distillation unit. These gases cool as they rise in the chamber, and an equipment is placed to collect the various products while they condense from a vapor to a liquid [2].

Once all the petroleum products have been processed and purified, they are then supplied to consumers in different ways. There are several ways to transport oil in large quantities around the world. These includes pipelines, rail transport, oil tankers and trucks.

Pipelines are the most common form of oil transportation. They are large transportation lines used to transport crude oil and natural gas in expanded distribution systems. These pipes vary in diameter depending on their intended use and usually run underground. In areas without pipelines, oil can also be transported on long freight trains with special tanker cars. Although more railcars are required to transport larger quantities of oil, rail transport is considered a reasonably cost-efficient transportation method. Trucks are most used for transporting refined petroleum like gasoline to distribution points like gas stations. Despite having the lowest storage capacity, they offer the most flexibility in terms of possible destinations. When the land transportation is impractical, oil is transported by oil tankers. The sizes of oil tankers can vary widely, smaller ships are generally used for transporting refined petroleum products, while much bigger tankers are used for transporting crude oil [4].

2.1.3 STORAGE & HANDLING OF DIESEL

Diesel is a highly flammable petroleum product used as a burning fuel for diesel engines. To avoid the risks of serious health issues, environmental contamination and the exposure to flames and sparks, this chemical must be carefully stored, handled and transported.

2.1.4 INSTRUCTIONS FOR HANDLING OF DIESEL

There are many negative effects of diesel fuel on the environment both during and after its consumption. Diesel fuel in liquid form tends to be toxic when spilled or leaked outdoors. It threatens not only animal and plant species, but it also contaminates ground and potable water supplies [5]. Through contact with human skin, diesel fuel is a skin and eye irritant that can cause rashes and reactions. Furthermore, the exposure to diesel fuel exhaust for extended periods of time has also been linked to cancer and central nervous system disorders. Moreover, these fumes can cause dizziness and drowsiness if accumulated. And that is due to the microscopic size of the toxic particles found in diesel fuel, which can easily enter the lungs while breathing [6]. Therefore, many safety precautions should be adopted when handling diesel fuel to prevent any accidents or damages as shown in an example in **Figure 3**.

Figure 3: Safety tips in fuel (Diesel) handling Error! Reference source not found.

Diesel is sensitive to heat, fire and static discharge hence it should be kept away from flame, sparks and excessive temperatures. Smoking is then prohibited, and fire extinguishers must be in proximity from the areas where the fuel is being handled. Protective gloves, clothes and safety glasses must always be worn when working with this fuel. Additionally, adequate ventilation should also be provided and prolonged exposure to the fuel vapours should be avoided. Besides, fuel tanks and containers should be tightly closed and not overfilled. Any leakage should be cleaned immediately. Lastly, it is also important to provide training to all personals working with diesel fuel to minimise the risks and damages that can be caused if handled in a wrong way.

To store diesel for longer periods, appropriate measures are required to be taken to keep it safe and contamination free. For this purpose, tanks of various sizes can be used to store it. Considering the safety and longevity of the fuel, the choice of the appropriate size, material and location of storage tanks is critical. The selection of the appropriate size of the storage tanks depends on individual purposes as illustrated in the **Figure 4**.

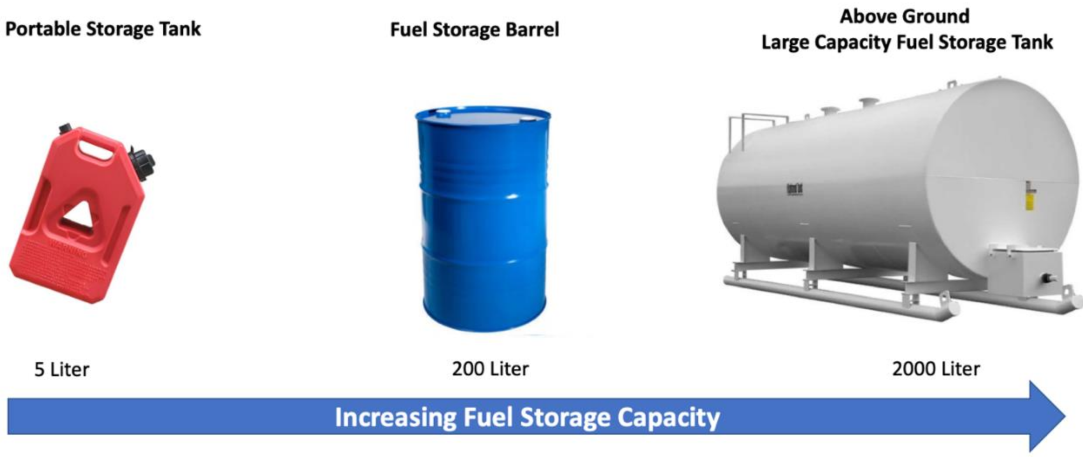

Figure 4: Fuel storage tanks with various storage capacity

For storing small amounts of diesel fuel, portable 5 litre tanks can be used. For relatively larger amounts of fuel, 200 litre storage drums (plastic or steel) can be used. And finally, for the industrial scale or at refineries, diesel fuel is usually stored in large metal storage tanks with a capacity of more than 2000 litres depending on the required storage capacity [8][8]. The long storage life of the diesel fuel depends on the conditions in which the fuel is stored and maintained. Ideally, the diesel fuel should be kept at isolated, dry and cool areas (temperature below 20°C) away from residences. With such conditions, the fuel storage life can last between 6 to 12 months. However, it can be extended further with the use of fuel stabilizers [9][9].

If the fuel is stored for a longer time, it may react with the oxygen in the tank which could lead to deteriorate the diesel quality and would make it unsuitable for the desired application and cause engine troubles. In the case of above ground fuel storage tanks, the water from the rain can contaminate the stored fuel and can lead to the growth of fungus. This fungus would break down the diesel molecules by releasing organic components. Therefore, it is important to restrict the water being pooled on top of the tanks. Otherwise, pooled water can also rust the metal containers. There are two possible solutions which can be used to avoid water contamination i.e., draining off the water and using biocide additives to prevent microbiological contamination. It is also important to place fuel storage tanks (exceptions can be in industrial storage where electricity is needed) away from electrical outlets to avoid undesired accidents [8][8].

Fuel storage tanks are made of materials which are adhered to the requirements of the specific fuel storage depending on the application and location. They are typically made of steel but also available in plastic and hybrid form [10][10]. Steel storage tanks are known for their strength whether they are manufactured as single or double walled tanks. Since the nature of steel is non-porous, it does not absorb fuel. As the steel tanks are heavier in weight hence, the tank installation is complicated along with costly and challenging transportation. Furthermore, steel containers must be painted and repainted periodically for protection against corrosion. Steels tanks are usually used in industrial applications and at oil refineries [11][11].

On the other hand, plastic material-based storage tanks or containers are made of polyethylene. Polyethylene based storage containers are easier to install and transport. The insulating properties of polyethylene can slow the heat transfer to the fuel in the tank. However, long exposure to direct sunlight can still weaken the material which is usually countered by adding ultraviolet stabilising agents to protect against the adverse effects of the sunlight. Unlike steel-based containers they do not rust. However, the storage of diesel fuel in plastic containers must be adhered to container specifications since it cannot be stored for longer periods (< 6 months) due to the reaction of diesel with plastic polymers. This can cause fuel contamination or undesired leakages by breaking down the plastic. Therefore, the plastic-based containers must be changed at regular intervals. The major benefits of plastic containers include low maintenance costs since leakages can be easily repaired and plastic can be recycled, decontaminated, and reused [12][12].

Currently, hybrid storage tanks are also found on construction sites and in other specialist environments. They are made of multi-material i.e., plastic and steel. The inside wall of the tank is made of plastic, while the outer wall is made of steel. They offer the combined advantages of both steel and plastic containers [10][10].

Furthermore, there are certain handling practices for the storage of diesel to prevents accidents such as fuel spills and leakages which could in turn cause pollution and lead to dangerous accidents at workplaces. To prevent this, the following safety regulations (**Figure 5**) should be complied.

Figure 5: Safety tips in fuel (Diesel) storage Error! Reference source not found.

Since diesel fuel is flammable and combustible, it must be kept or stored far from any source of ignition. Smoking must always be prohibited in the fuel storage area. Furthermore, fire extinguishers must be placed at adequate places or in proximity of the storage area to ensure that in case of a fire breaking out, the fire can be brought under control at the right moment and abruptly. The access route to the storage area should remain clear of any obstacles to prevent accidents such as falling. Moreover, storage containers should never be placed in passageways, stairwells, and accessible corridors [13][13].

Diesel fuel should be stored in certified storage containers made of approved materials such as polyethylene, and reference labels must be properly placed on each one. The overfilling of a fuel container poses a significant safety risk as the spilling of the flammable fuel can cause serious consequences on both humans and the environment. Furthermore, it can also have a negative impact on the mechanical integrity of the storage tanks [14][14]. Therefore, fuel storage containers must always be filled to the reference level marking to avoid overfilling. Storage tanks inspection must be made compulsory at least once a week and in case damaged containers are found, these must be replaced or repaired immediately. Additionally, if any leakage is found then it must be cleaned up immediately. It is also necessary to provide an adequate ventilation in the fuel storage area to avoid the working employees from the exposure to the fuel fumes which can put their lives at risk.

3 Analysis methods

To identify the potential bottlenecks in the logistics chain, it is essential to determine the differences in physical-chemical properties between conventional liquid fuels and renewable REDIFUEL. For example, the difference of flash point must be paid attention to since it is a security related property. Based on these differences between conventional liquid fuels (e.g., EN 590 diesel) and REDIFUEL, an assessment can be performed to identify the compatibility between fuels and infrastructure.

3.1 EN 590 STANDARD AND TEST PARAMETERS

In terms of the project's objectives, a renewable fuel is developed as a supplement of road fuel. Diesel, as the most used conventional fuel, was chosen as the reference fuel. EN 590 standard describes the properties of the diesel fuel and defines uniform conditions in all EU countries. According to EN 590 standard, parameters to be tested can be divided into three different categories – parameters that indicate combustion performance of fuels include viscosity, cetane number, polycyclic aromatic hydrocarbons, etc., parameters indicating the composition of combustion products contain sulphur content, ash content, total contamination, carbon residue value, etc. and parameters indicating fuel management like transport and storage, compose of flash point, density, cloud point (for arctic grades), water content and so on. However, for the scope of this task and report, only the parameters related to fuel handling and storage are relevant. The important relevant parameters for testing and evaluation are interpreted in the following paragraphs.

Density is related to the chemical composition and distillate composition of fuels. In general, fuels with higher density have a relatively low mass calorific value. Density must be considered to calculate loading capacity and perform trade volume transfer conversions. Density at 15°C is tested following the test-method EN ISO 12185 [15][15].

Viscosity directly affects the conveying performance and the spray atomization effect of diesel engines. If the viscosity is too high, it will increase the resistance along the pumping path, affect the shape of the fuel injection jet, and cause poor atomization, which cannot be evenly mixed with air, resulting in poor combustion. If the viscosity is too low, the angle of the oil jet is too large, and it cannot be injected to the designed position to mix well with the air, which will also cause incomplete combustion and lower power. Viscosity at 40°C is tested according to standard EN ISO 3104 [16][16].

The flash point is an indicator to identify the fire hazard of fuels. Fuels with lower flash point have greater fire risk, which must be considered in the transportation and storage of fuels. Flash point is tested following the test-method EN ISO 2719 [17][17].

Water content is a crucial factor that must be considered to store the fuels. Water will corrode equipment parts and bring salt dissolved in the water into the cylinder to cause carbon formation and increase cylinder wear. Excessive moisture in fuels can easily cause flameout. The presence of water will also accelerate the oxidation and gelation of oil. At the same time, as the water absorbs heat when it evaporates, the calorific value of the oil is reduced. Water content is tested by the test-method EN ISO 12937 [18].

Electrical conductivity is another very important safety related parameter, which should be paid attention especially during transportation and storage. During the transportation of diesel products, electrostatic discharge may result in serious safety problems. Diesel is flammable and it is impossible to eliminate flammable vapours completely. Diesel as hydrocarbon chemicals is poor conductor of electricity and are usually prevented from accumulating charges by adding a conductive improver. [19]

3.2 STORAGE STABILITY

The storage stability of the fuels was investigated using the PetroOxy method according to standard DIN EN 16091, which is with a 5 ml reactor holder shown in the **Figure 6** (left). The fuel sample is heated together with oxygen in a small hermetically sealed test chamber. This initiates a very fast artificial aging process, that is displayed by a pressure drop in the system. It was found that the time consumption of the pressure drop is directly related to the oxidation stability. Based on the same principle, the reactor was scaled up to the reactor with a volume of 0.5 l, in the **Figure 6** (right).

Figure 6: Standard test method "PetroOxy" and reactor in "BigOxy" test rig

The test rig at the end is composed of 4 pressure reactors. The Big Oxy test rig is utilized to investigate the artificial aging process by increasing pressure and temperature of fuels. The pressure and temperature can be set and measured in the aging process. At high pressure and high temperature, the fuel is accelerated aged. When the fuel is not stable, it can be oxidized during the aging process, which is observed from the pressure drop. The pressure in reactors of Big Oxy test rig is tested for 64 hours, which shows the stability of the fuels. All the parameters, such as density, viscosity, water content of the aged fuels can also be analysed, which are crucial to store and handle renewable REDIFUEL.

3.3 FUEL COMPATIBILITY TO ENGINE COMPONENTS

Drop-in compatibility is a crucial factor to various biofuels. In general, not all the properties of renewable fuel can meet the requirement and standard of road fuel without any modification. A more realistic approach is to blend renewable and conventional fuels. Thereby, the compatibility of the fuel and fuel blend to the components in the diesel engine need to be investigated.

The drop-in compatibility of REDIFUEL was tested by Tec4Fuels, by a hardware in the loop (HiL) in a complete common rail system (CoCoS). The CoCoS testing bench includes in-tank pump, fuel filter, high pressure pump, rail, and fuel injector like a genuine diesel engine, as shown in the piping and instrumentation (P&ID) diagram in **Figure 7**.

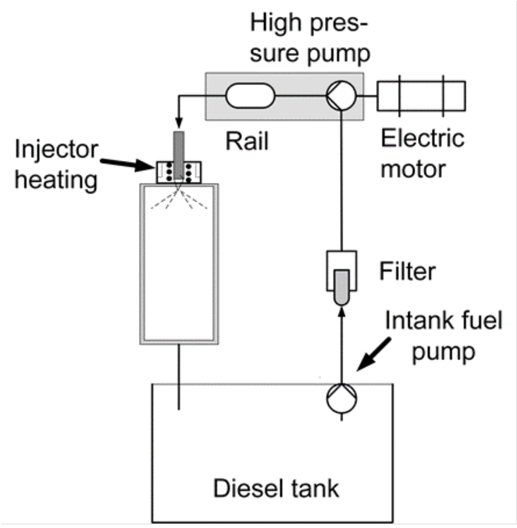

Figure 7: P&ID diagram of the CoCoS test bench.

In the testing process, fuels are circulated in the loop system contacting all conventional automotive components without combustion. The interaction with components is diagnosed from two parts, the high-pressure pump and the injector. When the fuel is not compatible to the engine components, at the testing condition (1300 bar and 230°C), the high-pressure pump will be completely disassembled. For the injector, the factors like mass flow during the CoCoS testing and mass flow measurement in the injector testbench are measured to describe the compatibility of REDIFUEL to components of diesel engine.

4 Handling relevant properties of REDIFUEL and blends

To determine the infrastructure adaptation of REDIFUEL, a comparison of REDIFUEL's properties with the relevant properties from the standard of fossil diesel fuel EN 590 is conducted. As stated before, EN 590 is the standard for the test.

4.1 FUEL CHARACTERISTICS

The fuel compositions, characterization, and fuel properties of REDIFUEL and its various blends are described in detail in Deliverable 3.3. For this task, the physical and chemical properties relevant to handling are interesting and are summarized in **Error! Not a valid bookmark self-reference.**.

Table 1: Physical and chemical properties of REDIFUEL and its blends in comparison with EN 590 standard and reference diesel [from Deliverable D3.3]

Property	Unit	Value			
		EN 590 limit	EN 590 reference diesel	REDIFUEL	EN590 diesel /REDIFUEL blend (50:50) vol % (D50RF50)
Density (15 °C)	**kg/m³**	**820 - 845**	**839**	**791.7**	**815.2**
Viscosity (40 °C)	mm2/s	2-4.5	3.24	3.01	3.019
Cloud point	°C		-5	-21.3	-8.4
Flash point	°C	≥55	66.5	63.5	64.5
Electrical conductivity	(pS/m)		188	219	155
HFRR	**µm**	**460**	**348**	**516**	**477**
Water	mg/kg	≤200	48	200	150
Copper strip corrosion at 50 °C	-	Class 1	-	1a	-

Most of the parameters of REDIFUEL comply with the limits of standard EN 590. However, there are a few exceptions. One of the important measured parameters is density. The density of REDIFUEL at 15°C is 791.7 kg/m³, which is obviously lower than the EN 590 limit 820 kg/m³. On the other hand, the density of the benchmarked fuel EN 590 diesel is 839 kg/m³, which could be blended with REDIFUEL to achieve the required density with an appropriate blending ratio.
The second parameter which is not compliant to EN 590 standard is high-frequency reciprocating rig (HFRR). In **Table 1**, the HFRR of EN 590 diesel as reference shown is 348 µm at 60°C, while HFRR of REDIFUEL is 516 µm at 60°C, which is over 460 µm at 60°C, the limit of EN 590 standard. Even blending with diesel, this parameter of D50RF50 still does not comply to the EN 590 standard. It should be noted that, the EN 590 reference fuel already contains lubricity improver additive, while the REDIFUEL is not additivated. The tested HFRR parameter indicates that lubricity additive must be mixed in the REDIFUEL, similar to commercial diesel for the HFRR value of REDIFUEL to be within specification.
Another parameter electrical conductivity in table 1 shows a crucial safety related property. The electrical conductivity of EN 590 refence diesel is 188 pS/m, which is with conductivity improver additive for the commercial usage. However,

the REDIFUEL and the blend of REDIFUEL and diesel show good electrical conductivity. That means, from the perspective of electrical conductivity, the renewable REDIFUEL is safer than the commercial fossil fuel.
The last parameter that needs to be considered is water content, which shown in table 1 is 200 mg/kg, which is exactly the water content limit value specified by the EN 590 standard. Based on the analysis of fresh fuels, D50RF50 comply with the EN 590 standard with some margin. Compared to the water content of diesel, the higher water content can cause the faster oxidation during storage, which must be paid attention to as well. Furthermore, high water content could increase the risk for metal corrosion. According to the results reported by Neste in Deliverable D 3.3., the copper strip corrosion test of the pure REDIFUEL showed adequate results. However, further investigations and severe steel corrosion tests indicated that REDIFUEL can cause corrosion. The corrosive nature of REDIFUEL could degrade the metals and component that it comes in contact with during its stage and application and has to be looked into further detail. Therefore, in the next section, the differences between REDIFUEL and Diesel in handling relevant properties such as storage stability (fuel oxidation) and fuel – component interaction (corrosion) will be discussed.

4.2 DIFFERENCES IN HANDLING RELEVANT PROPERTIES OF DIESEL AND REDIFUEL

Two handling relevant properties which can be influenced by the high water content of REDIFUEL were investigated, storage stability tested by OWI and the interaction with components tested by TEC4FUELS.

4.2.1 STORAGE STABILITY

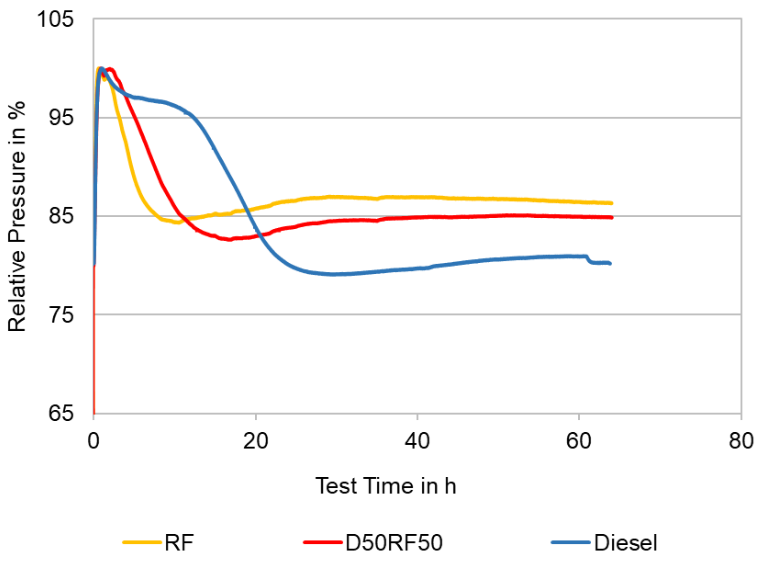

Figure 8: Ageing behaviour of REDIFUEL, Diesel and their blend

The storage stability investigations were carried out using the accelerated ageing test rig BigOxy. In Figure 8 the ageing behaviour of REDIFUEL, Diesel and a 50 % blend of REDIFUEL and Diesel are compared. The drop in pressure indicates oxidation of fuel. The pressure drop in Diesel is slower in compared to REDIFUEL and its blend which indicates that REDIFUEL has a poor oxidation stability compared to Diesel and would age faster. However, in terms of long-term stability, the final oxidation stability of REDIFUEL is better in comparison to EN 590 diesel, as REDIFUEL shows higher relative pressure compared to fossil diesel. It is additionally emphasized that, the baseline Diesel used in the experiments are commercially available and contain storage stability additives. Hence, trials were carried out to treat REDIFUEL with commercially available additives. One such additive used was butylated hydroxytoluene (BHT). BHT (butylated hydroxytoluene) is an oil-soluble organic compound, which is mainly used as an antioxidant in biodiesel.

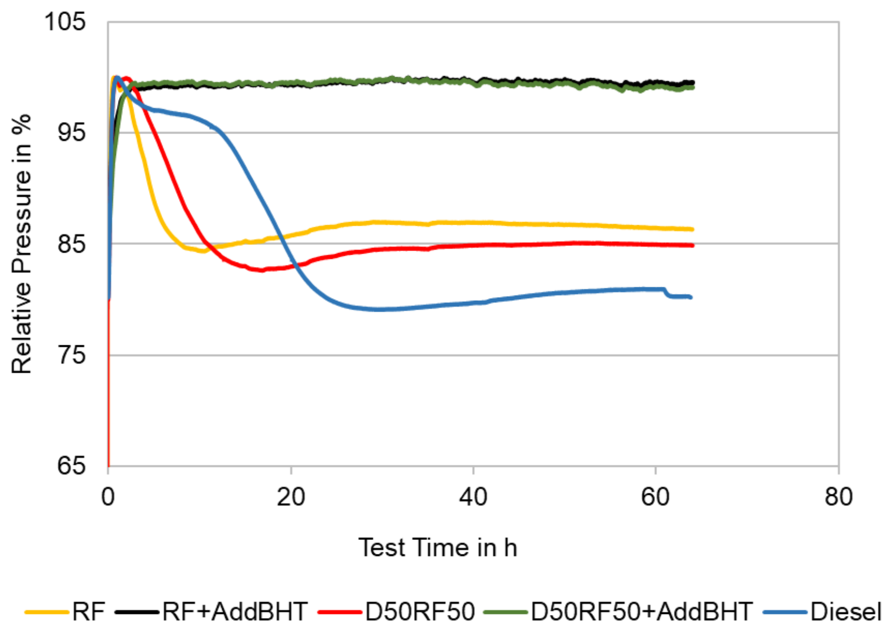

Figure 9: Ageing behaviour of REDIFUEL and REDIFUEL blend with additive BHT (200 ppm)

Figure 9 shows the ageing behaviour of REDIFUEL (200 ppm) and the blend (200 ppm) with BHT type antioxidant. It can be seen that the commercially available BHT which is used to enhance the storage stability of Diesel can be successfully used for REDIFUEL as well.

4.2.2 INTERACTION TO ENGINE COMPONENTS

As previously described the interaction between the components, in particular diesel engine was surveyed by CoCoS testing bench. The results of mass flow measurement of injector for all the tested fuels have shown constant values. It implies the compatibility of REDIFUEL to components is acceptable in applying as a drop-in fuel for the road transport. Because the testing condition in the HiL is high pressure and temperature, during the testing process, the tested fuel goes through an accelerated aging process. The tested fuel before and after the CoCoS test bench can also be analysed to verify the results of fuel stability tested by Big oxy accelerated ageing test. The water content of REDIFUEL after the CoCoS turned out much higher than the fuel before the CoCoS. However, from the CoCoS testing results, water content had no effect on the emulated diesel engine. Therefore, REDIFUEL can be used as a drop-in fuel to be mixed with diesel directly with respect to the component compatibility. Further details of these investigation are described in detail in Deliverable D.3.12. From the point of higher water content after CoCoS testing, to avoid the degradation of REDIFUEL, attention must be paid to store REDIFUEL for a long time. Adding additives would be a favourable solution for the enhancement of storage stability of renewable fuels as shown in the previous section.

Although no negative impact of the water content on the engine performance was observed, the interaction of REDIFUEL needs to be further investigated from a perspective of storage and transportation. For e.g., the compatibility of REDIFUEL with the materials used in the drums and containers for storing Diesel as described in Section 2.1.4 needs further investigation since this was out of the scope of the activities in the REDIFUEL project.

5 Recommendations for handling of REDIFUEL and further work

As a part of the investigation of the drop-in compatibility of REDIFUEL, the properties of REDIFUEL were analysed from a perspective of handling, storage, and logistics. The results provide an understanding of the infrastructural adaptions required for the application of REDIFUEL. For safety related properties such as flashpoint and electrical conductivity, REDIFUEL exhibits performance which are well within the standard in terms of flash point. With regard to electrical conductivity, based on the results in the deliverable 3.3, REDIFUEL has a good electrical conductivity. It could be directly used without adding a conductivity improver. Hence, the safety tips for handling of REDIFUEL are similar to those for Diesel. Similarly, the fuel component interaction results show that REDIFUEL is compatible with all the components of a typical automotive fuel injection system. However, there are some aspects of REDIFUEL which differ from conventional diesel and which need to be kept in mind when handling and transporting diesel. These points are summarized below:

For transport and loading of fuels, density is an index used to calculate loading capacity and perform trade volume transfer conversion. Because of density difference of the REDIFUEL and diesel, to transport and load REDIFUEL properly, the capacity of the transport and storage tanks must be recalculated to avoid overfill. Compared to diesel, with lower density of REDIFUEL, the same weight of REDIFUEL requires a large volume of tank to transport and store.

In addition, although water content of REDIFUEL is compliant to EN 590 standard, it is much higher than diesel. Higher water content can cause REDIFUEL to deteriorate faster than diesel. The growth of microorganisms could also be a serious problem, which must be considered. From the perspective of chemical composition of REDIFUEL, it is a mixture of alcohol (C6 - C11) and paraffinic compounds. Owing to hygroscopicity nature of the alcohols, the water content may increase with the storage time, which has been confirmed by the CoCoS results investigated by Tec4Fuels. Therefore, the storage time should be as short as possible. Like other biofuels normally REDIFUEL should be used within 6 months. The exact allowable storage time needs to be investigated further.

Additives play an integral role in many fuel properties. At present, there are basically no fuels without additives anymore. Additives can improve the lubricity of the fuels. The performance of vehicle in cold weather can also be improved by adding additives in the fuel. To store fuels properly, adding additives is also a good solution. Based on the results of big oxy test rig, fuel stability of REDIFUEL can be enhanced by adding commercially available additives such as BHT which are commonly used for biodiesel. Furthermore, additives for improving the lubricity of REDIFUEL are also recommended.

Corrosion is a big issue that must be addressed for automotive metal components. The water content in REDIFUEL is significantly higher than conventional diesel. It leads to the accumulation of salts, which can cause serious corrosion compared to the conventional road fuels. Additives such as film-forming corrosion inhibitor can be applied to prevent corrosion in the components of automotive. These additive inhibitors form a barrier layer that protects the metal surface even under extreme conditions. As described in the introduction of diesel logistics chain, it is common to transport and store diesel with plastic or steel drums or tanks. From the safety perspective, the materials compatibility of REDIFUEL with metals and polymers is very crucial for the transportation, storage and handling. In the future, the corrosion property of renewable REDIFUEL and its compatibility to materials, namely metals and polymers used in storage containers and drums, need to be investigated.

6 Deviations from Annex 1

There are no deviations with respect to the description of work.

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