BRAZILIAN BIOCOMBUSTÍVEIS LTDA

TECHNICAL MEMORANDUM

APPLICATION OF BBL DX IN MARINE FUELS BLENDS AT 10% AND 20%

BBL DX Technology – Advanced Renewable Diesel and SAF
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Brazilian Biocombustíveis Ltda – 2025
Preliminary document

PREAMBLE

1. Purpose of the document

The purpose of this **Technical Descriptive Memorandum** is:

- Describe, on a strictly technical basis, the application of advanced biofuel **BBL DX** as a blending component in distillate marine fuels (mainly MGO and VLSFO), in proportions of **10%** and **20%** by volume;
- Assess the potential for **reducing greenhouse gas (GHG) emissions**, especially CO_2, as well as the mitigation of other air pollutants relevant to the maritime sector (SOx, particulate matter, black carbon);
- Establish a methodological basis for the **quantification of carbon credits** associated with the use of BBL DX on medium and large ships, considering life cycle metrics (*Well-to-Wake*).

The document is aimed at shipowners, fleet operators, shipyards, regulators and financial institutions interested in technological decarbonization solutions that are **immediately integrated into the existing fleet**, without the need to replace engines or supply infrastructure.

2. Scope and technical-regulatory framework

The study presented here is framed in the context of:

- The **carbon intensity reduction targets** established by the International Maritime Organization (IMO), with a horizon of 2030 and 2050;
- The increasing internalization of carbon costs in the maritime sector, through instruments such as **EU ETS**, **FuelEU Maritime** and potential global taxes on GHG emissions;
- The need for **low-carbon liquid fuels**, of the *drop-in* type, capable of being used in marine diesel cycle engines with **minimal or no technical modification**.

Within the framework of this Memorial:

- BBL **DX** is treated as an **advanced drop-in biofuel**, formulated to be miscible with distillate and/or residual fossil fuels, with physicochemical properties compatible with the operational requirements of the maritime sector;
- Emissions analyses are conducted according to the **Well-to-Wake (WtW)** logic, that is, contemplating both the **well-to-tank (WTT)** and the **tank-to-wheel**

(TTW) phases, in line with the most recent international guidelines on Life Cycle Assessment (LCA) for marine fuels;

- The quantification of the potential of **carbon credits** is discussed in conceptual and methodological terms, in order to allow subsequent framing in recognized certification standards (e.g., VCS, Gold Standard or specific schemes for maritime transport), once the definitive emission factors and concrete logistics routes are available.

3. General assumptions

For the formulation of the subsequent analyses, the following assumptions are adopted, in general:

1. BBL DX is produced according to the technological route already described in its own memorandum, with **the absence of glycerin as a by-product** and stability superior to that of conventional biodiesels;
2. The product is **compatible with high blends in Diesel engines** (in road applications, tested up to 50%), a premise that is explored here conservatively in marine blends of **10% and 20%;**
3. The reference fossil fuels considered are **Marine Gas Oil (MGO)** and/or **Very Low Sulphur Fuel Oil (VLSFO),** in accordance with current sulphur limits;
4. The emission factors and performance parameters of the BBL DX, when required for calculations, will be obtained from:
   - laboratory and field tests of BBL itself;
   - LCA methodologies aligned with the international guidelines applicable to the maritime sector.

1. MARINE FUELS MARKET

1.1 Global overview of marine energy consumption

The commercial shipping sector accounts for approximately **80% of international trade volume**, operating with one of the highest continuous energy demands among all modes of transport. Currently, the world consumption of marine fuels is estimated at around **250 to 300 million tons per year**, mainly distributed between:

- **Heavy Fuel Oil (HFO/IFO)** – heavy residual fuel, traditionally dominant in large ships;

- **Very Low Sulphur Fuel Oil (VLSFO)** – blend formulated to meet the global sulfur limit of 0.5% (IMO 2020);
- **Marine Gas Oil (MGO) and Marine Diesel Oil (MDO)** – light distillates used in shunts, auxiliary engines and emission control zones (ECAs).

Offshore energy consumption is equivalent to approximately **4.0 to 4.5 million barrel equivalents per day**, which represents a significant fraction of the global demand for liquid fuels.

1.2 Maritime sector's share of global emissions

According to recent international studies, maritime transport emits:

- **2.8% to 3.0% of global CO_2e emissions**,
- with annual emissions ranging between **850 and 1,100 million tons of CO_2e**, depending on the base year and the methodology adopted.

These emissions come mostly from the combustion of heavy, carbon-intensive fossil fuels. Climate impact is compounded by emissions from:

- **SOx** (sulphur oxides),
- **NOx** (nitrogen oxides),
- **Particulate matter (PM),** including **black carbon**,
- Unburned hydrocarbons.

Such pollutants have direct effects on human health, port air quality, and regional climatic phenomena (such as the acceleration of melting in polar areas by the deposit of black carbon).

1.3 Regulatory Pressures and Decarbonization Trends

The International Maritime Organization (IMO) has adopted long-term targets for reducing emissions, including:

- Reduction of **the carbon intensity of maritime transport by 40% by 2030** (compared to 2008);
- Absolute reduction of total emissions by 2050;
- Implementation of indexes and metrics such as:

- **EEXI (Energy Efficiency Existing Ship Index)** – technical efficiency of the vessel;
- **CII (Carbon Intensity Indicator)** – annual carbon intensity score of the ship;
- Well-to-Wake **Rules** for Low-Emission Fuel Analysis.

In addition:

- The **European Union** incorporated the maritime sector into the **EU ETS**, creating a direct cost per ton of CO_2 emitted;
- The **FuelEU Maritime regulation** imposes progressive limits on the GHG intensity of the energy used on board;
- The implementation of a **global tax on maritime emissions** is under discussion, starting between 2026–2027.

This regulatory set creates **increasing financial and operational pressure** on shipowners and operators, stimulating the adoption of renewable fuels and lower carbon intensity blends.

1.4 Demand for Low-Emission Drop-in Fuels

Despite the growing interest in alternative fuels such as methanol, ammonia and hydrogen, the technical and economic reality of the sector shows:

- **Low global availability** of these fuels;
- Limited supply infrastructure;
- High costs of adapting engines, tanks and safety systems;
- Operational risk on long ocean routes.

Therefore, there is an immediate and growing demand for **drop-in fuels**, capable of:

1. Be used with minimal modification to existing engines;
2. Be available on an industrial scale;
3. Reduce Well-to-Wake emissions intensity;
4. Generate verifiable gains in the CII and cost savings in the EU ETS.

Advanced renewable blends, such as the one involving the use of **10% and 20% BBL DX**, fall precisely into this category: solutions **that are quickly implemented**, with a measurable environmental impact and taking advantage of the existing logistics infrastructure.

1.5 Strategic Market Relevance for BBL DX

The maritime market represents:

- One of the segments with the highest energy volume in the world;
- A rapidly changing regulatory environment;
- An opportunity to insert renewable fuels with **very high potential for scaling**.

Thus, the sector presents itself as a strategic area for the application of **BBL DX,** both from a technological point of view (drop-in compatible with marine diesel) and economically (reduction of regulatory costs and generation of carbon credits).

2. EMISSIONS PROBLEMS TO BE SOLVED

2.1 CO_2 emissions and carbon intensity

Maritime transport predominantly uses carbon-intensive fossil fuels (HFO, VLSFO, MGO). These fuels have typical emission factors of the order of:

- **3.10 to 3.20 tCO_2 per tonne of fuel consumed**, corresponding to values between **73 and 77 gCO_2/MJ** in the **Tank-to-Wake (TTW) cycle**.

When considering **Well-to-Wake (WtW) analysis**, including upstream emissions (extraction, refining, transportation):

- carbon intensity increases by approximately **15% to 20%,** resulting in average values of **88 to 95 gCO_2e/MJ.**

This high intensity limits the ability of shipowners to meet regulatory targets such as CII, FuelEU Maritime and directly generates costs in the EU ETS.

The reduction of WtW intensity depends **exclusively** on the introduction of lower emission fuels, since operational and efficiency measures (EEXI, route optimization, slow steaming) do not eliminate dependence on fossil fuels.

2.2 SOx (sulphur oxides) emissions

Traditional marine fuels are naturally high in sulphur. Although the global limit is now **0.5% m/m**, and in ECAs it is **0.1%,** the impact of SOx remains significant:

- Forms sulfates and acid mist;
- It directly affects respiratory systems of port populations;
- Contributes to corrosion of engines and exhaust systems;
- Increases the formation of secondary particles.

The SOx reduction is directly proportional to the sulfur content of the fuel. **Renewable blends such as BBL DX, containing significantly lower sulfur contents**, reduce this emission immediately and linearly, without the need for scrubbers.

2.3 NOx (nitrogen oxides) emissions

Diesel cycle marine engines operate under high pressures and temperatures, favoring the formation of NOx. Typical levels vary by engine type (Tier II, Tier III), but globally represent:

- A major contributor to the formation of tropospheric ozone;
- A relevant factor in the calculation of indirect climate impacts;
- An important indicator in the environmental assessment of ports and coastal areas.

Although NOx reduction depends in part on engine technology, fuels with higher combustion stability, lower aromatic content, and better atomization—as occurs in renewable blends—can contribute to marginal but measurable reductions, especially in auxiliary engines.

2.4 Particulate Matter (PM) and Black Carbon

The use of heavy fossil fuels, especially HFO, generates fine and ultrafine particles that:

- Increased mortality and morbidity in urban port centers;
- They increase the deposition of soot in polar regions, reducing albedo and accelerating melting;
- They affect the thermal efficiency of the engine and the durability of internal components.

Renewable fuels that burn cleaner and are free of waste, such as BBL DX, contribute to:

- Significant reduction of **PM and black carbon**;
- Decreased deposit formation in combustion chambers;
- More stable operation of auxiliary engines (hotel load), which are critical on cruise ships and container ships.

2.5 Fuel aging and instability

VLSFO, despite having a lower sulfur content, is chemically unstable and suffers:

- **phase separation**,
- viscosity increase,
- formation of sediments incompatible with certain diluents,
- stability problems along long ocean voyages.

These factors affect:

- filters, injectors and pumps;
- thermal stability of the fuel system;
- operational risk during tank transition.

Stable renewable blends — such as BBL DX, which has no polymerization-prone compounds — reduce the likelihood of chemical degradation of the fuel during prolonged use.

2.6 Conflict between operational goals and environmental constraints

Shipowners face a technical-regulatory dilemma:

1. **To meet CII and ETS**, they need to reduce CO_2 emissions.
2. **To maintain operational performance**, they need fuels with stability, adequate flash point, and predictable behavior in engines.
3. **In order not to immobilize vessels**, they need solutions that do not require retrofit or infrastructure changes.

Alternative solutions (methanol, ammonia, LNG) do not simultaneously meet all three needs, due to:

- global logistical unavailability,
- high costs,
- operational risks,
- need to change engines or complete systems.

In this context, the **only short-term solution with real impact** is the adoption of **low-carbon intensity drop-in liquid fuels**, a category in which **BBL DX** falls.

3. INTRODUCING THE BBL DX SOLUTION FOR THE MARITIME INDUSTRY

3.1 BBL DX Technical Description

BBL **DX** is an advanced biofuel, formulated from vegetable oils, fatty residues and anhydrous ethyl alcohol, combined through a **proprietary process without glycerin generation** and using a stabilizing catalytic additive. Its technological route — distinct from traditional biodiesel (FAME) — results in a fuel:

- **Stable**, with no tendency to polymerization or phase separation;
- **Miscible** with distilled and residual fossil fuels;
- **Low acidity**, facilitating its use in extended storage systems;
- **Low hygroscopicity**, reducing water absorption;
- **High calorific value comparable to mineral diesel**, with clean burning;
- **Very low sulfur content** (close to zero), allowing direct SOx reductions in emissions.

The absence of glycerin and soaps eliminates the risk of filter clogging, gummy deposits and thermal instability — common problems in conventional biodiesel. This makes the BBL DX particularly suitable for marine use, where operational robustness is critical.

3.2 Physicochemical properties relevant to marine application

The properties below are considered fundamental for the evaluation of compatibility with marine fuels (ISO 8217) and with large engines:

Parameter	Operational Relevance	BBL DX Expected Behavior
Density at 15°C	Influences atomization and injection	MGO range compatible
Kinematic viscosity	Crucial for pumping/injection	Within the operating range of marine engines
Flash Point	Navigation safety (≥ 60°C)	Adjustable via blend with VLSFO/MGO
Oxidative stability	Prevents sediment formation	High stability due to glycerin-free route
Water content	Prevents corrosion and microorganisms	Low
Sulphur content	Controls SOx emissions	Close to zero
Calorific Value (PCI)	Direct impact on autonomy	No significant losses vs. MGO
Chemical Compatibility	Elastomers, pipes, pumps	High, due to low polar compound content

Laboratory and field tests indicate that BBL DX can be used in a blend with diesel at **up to 50%** in automotive applications without engine changes, which provides technical support for the conservative adoption of **10% and 20% blends in the maritime sector**.

3.3 Regulatory framework and ISO 8217 compatibility

For marine use, BBL DX must be evaluated against the requirements of **the ISO 8217** standard, which defines the specifications for marine engine fuels (categories DMA, DMB, DMZ, DMC, RMA–RMK, among others).

The practical application of BBL DX tends to fall under the auspices of:

a) Renewable blend compatible with distillate fuels (DMA/DMZ)

Using MGO as a baseline, the critical parameters are:

- minimum and maximum viscosity,
- flash point,
- stability

- total acidity (TAN),
- sulfur content.

BBL DX, due to its low acidity, low sulfur and good stability, tends to **contribute positively** to keeping the blend within the normative ranges.

(b) Low GHG intensity fuel according to IMO MEPC methodology.391(81)

The IMO has defined the formal Life Cycle Assessment (LCA) guidelines for marine fuels. The BBL DX can be classified as:

- **Renewable fuel with low carbon intensity**, provided that the producer presents:

1. Well-to-Wake emission factors;
2. Documentation of the production route;
3. Certification of renewable content;
4. Traceability of raw material supply.

This framework allows the shipowner to account for the GHG reduction in the CII and FuelEU Maritime indicators.

3.4 Operational Compatibility in Marine Engines

Large marine engines (MAN, Wärtsilä, Caterpillar/MaK, Yanmar, etc.) are designed to tolerate significant variation in fuel physical properties. The main points that support the use of BBL DX in blends are:

- **High lubricity**, reducing wear of pumps and injectors;
- **Efficient atomization**, resulting in more complete combustion;
- **Reduced soot formation**, essential for engines operating long hours at constant load;
- **Less tendency to fouling** in combustion chambers and valves;
- **Suitability for use in auxiliary engines**, responsible for hotel load and port operations — critical points for reducing emissions in urban areas.

The behavior of BBL DX in mixing with MGO/VLSFO does not require changes in:

- filtration systems;
- transfer pumps;
- Guns;

- storage tanks;
- fuel circulation circuits.

This qualifies it as a **real drop-in** solution, with very low implementation costs.

3.5 Immediate technical benefits for navigation

The use of BBL DX in 10% and 20% blends contributes to:

1. **Proportional reduction of SOx**, due to the low sulfur content;
2. **Significant reduction of PM and black carbon**, by cleaner burning;
3. **Superior thermal stability**, reducing the risk of deposits on lines and pumps;
4. **Improvement in CII,** given reduced Well-to-Wake carbon intensity;
5. **Decreased need for scrubbers**, especially in blends with MGO;
6. **Potential for generating carbon credits**, thanks to the measurable WtW emissions gap.

4. APPLICATION OF BBL DX IN MARINE BLENDS (10% and 20%)

4.1 Technical definition of mixing scenarios

For marine application purposes, two base scenarios are defined, both using **Marine Gas Oil (MGO)** or, alternatively, **Very Low Sulphur Fuel Oil (VLSFO) as a reference fossil fuel** – depending on the operational profile of the vessel.

Scenario A – BBL DX Blend 10% (v/v)

- Composition: **10% BBL DX + 90% MGO/VLSFO**
- Recommended application: auxiliary engines, maneuvers in port, coastal operations, hotel load.
- Technical rationale: initial emission reduction with full operational compatibility and no noticeable impact on fuel density or viscosity.

Scenario B – BBL DX Blend 20% (v/v)

- Composition: **20% BBL DX + 80% MGO/VLSFO**

- Recommended application: auxiliary engines and, after validation, main engines in medium and large vessels.
- Technical rationale: delivers an extended reduction of CO_2e and pollutants while keeping safety and combustion parameters within the operating ranges of most marine engines.

These two levels of mixing were chosen because they represent **conservative solutions, with rapid acceptance and high environmental impact**, allowing immediate scalability without the need for retrofit.

4.2 Technical methodology for the analysis of blends

The technical evaluation of the blends considers:

1. **Energy equivalence (MJ/kg and MJ/L)**
   - BBL DX has a calorific value close to that of mineral diesel, allowing the blend to be evaluated without the need for complex energy correction factors.
2. **Physicochemical properties resulting from the mixture**
   - The critical parameters evaluated are:
     - kinematic viscosity,
     - density
     - flash point (≥ 60°C),
     - water content,
     - oxidative stability,
     - acidity (TAN),
     - sulfur content.
3. **Combustion behavior in marine engines**
   - Atomization, ignition, soot formation, thermal efficiency and operational stability.
4. **Emissions analysis – Well-to-Wake (WtW) approach**
   - Use of fossil fuel emission factors and BBL DX.
   - Emissions reduction calculations based on volumetric proportion and energy equivalence.
5. **Regulatory compliance criteria (IMO and ISO)**
   - The blend must meet the minimum requirements of ISO 8217 for the base fuel.

4.3 Expected physicochemical properties of blends

Viscosity

BBL DX, being a light distillate renewable fuel, tends to **slightly reduce the viscosity of MGO/VLSFO,** improving atomization, without compromising pumping.

- In the 10% and 20% blends, the resulting viscosity remains within the typical marine engine range.

Density

The density of BBL DX is close to that of mineral diesel, ensuring:

- stability in injection curves,
- predictability in the energy mass delivered to the engine.

Flash Point

- Marine fuel must have **a flash point ≥ 60°C**.
- In the 10% and 20% blends, the predominance of MGO ensures that this requirement is maintained; in case of VLSFO, batch-by-batch laboratory verification is recommended.

Total Acidity (TAN)

- BBL DX has low acidity, contributing positively to keeping the blend within ISO 8217 specifications.

Oxidative and thermal stability

Thanks to its production route (without glycerin or soaps), BBL DX gives the blends:

- less tendency to deposit formation,
- increased heating stability,
- lower risk of aging during long ocean voyages.

4.4 Operational behavior of blends in marine engines

Blends with BBL DX demonstrate:

- **Better atomization** and more complete burning;
- **Reduction of soot formation** and carbon deposits;
- **Less wear and tear** of injection systems due to greater lubricity;
- **Stable burning in engines under continuous load** (typical of long-haul ships);
- **Full compatibility** with filtration systems, pumps and piping.

The behavior of the 10% and 20% blends does not require:

- modification of injector nozzles,
- injection pressure modification,
- software tweaks,
- requalification of tanks or lines.

This reinforces that BBL DX is a **drop-in** fuel, ready for immediate use.

4.5 Energy comparison and practical implications

As the difference in calorific value between BBL DX and MGO/VLSFO is small, the autonomy of the vessel remains practically unchanged:

- Expected variation: **< 1.5%** in 10% blends and **< 3%** in 20% blends.
- For actual operations, such variations are considered **operationally irrelevant**.

The environmental and regulatory benefits far outweigh this energy margin.

4.6 Technical synthesis of the benefits of blends (10% and 20%)

Aspect Evaluated	Blend 10%	Blend 20%	Technical Result
CO_2 Reduction WtW	Moderate	Significant	Proportional to the mix
SOx Reduction	Substantial	Very substantial	BBL DX Low S
Reduction of PM and black carbon	White	High	Cleaner burning
Fuel stability	Increases	Increases	Glycerin-free
Engine compatibility	Total	Total	Drop-in
Energy impact	Irrelevant	Very low	No practical losses
Generation of carbon credits	Feasible	Discharge	Provable reduction

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5. EMISSIONS REDUCTION STUDY – BBL DX (10% and 20%)

5.1 Technical assumptions of the study

To estimate the emission abatement resulting from the use of BBL DX on large ships, the following general assumptions are adopted:

- The reference fuel is **MGO/VLSFO,** which is widely used in main and auxiliary engines;
- The typical annual consumption of a large container ship is in the order of **30,000 tons of fuel per year**;
- The Well-to-Wake emission factors of fossil fuel and BBL DX are taken from the technical literature and will be replaced by the official BBL values in the definitive study;
- The blends analyzed are:
  - **Blend 10% BBL DX + 90% MGO/VLSFO**
  - **Blend 20% BBL DX + 80% MGO/VLSFO**
- The range and performance of the ship remain equivalent, as the difference in calorific value between BBL DX and fossil fuel is operationally irrelevant.

5.2 Consolidated result of emission reductions

Considering a large ship with an annual fuel consumption of ~30,000 tons, the following approximate results are obtained:

Blend 10% BBL DX

- **Estimated annual reduction: ≈ 8,000 tons of CO_2e/year**
- **Approximate percentage reduction: 7%**

Blend 20% BBL DX

- **Estimated annual reduction: ≈ 16,000 tons of CO_2e/year**
- **Approximate percentage reduction: 14%**

(Note: Final values will depend on the official BBL DX emission factors, and may be even higher if the LCA confirms significantly reduced carbon intensity.)

5.3 Technical interpretation of the results

The results show that:

- Even with a **modest 10% blend**, BBL DX reduces CO_2e emissions by **several thousand tonnes per vessel per year**, representing direct gains in IIC, FuelEU Maritime and EU ETS;
- The **20%** blend nearly **doubles environmental efficiency** while maintaining full operational compatibility — requiring no changes to engines, filters, lines, or tanks;
- In a fleet with 10 ships, the potential reduction amounts to:
  - **80,000 tCO_2e/year** (10% blend)
  - **160,000 tCO_2e/year** (20% blend)
- These volumes are high enough to justify:
  - carbon credit projects,
  - green financing,
  - sustainable fuel supply trade agreements,
  - and prioritization of regulated routes (Europe, North America, Japan).

5.4 Robustness of the analysis

- The methodology follows the **Well-to-Wake standard** recommended by the IMO.
- The results are **linearly proportional** to the percentage of the blend, which facilitates projections for other levels of blending.
- The values presented are **conservative**, as they do not incorporate:
  - additional reductions in PM and black carbon,
  - improvement of thermal efficiency of the motor,
  - reduction of SOx, which also contribute to environmental impact metrics, although not directly accounted for in CO_2e.

5.5 Economic return per ship – Carbon Credits

The emission reduction provided by the use of BBL DX can be converted into **carbon credits**, as long as the project is properly structured according to a recognized standard (e.g., VCS, Gold Standard or marine equivalent), with auditable MRV.

5.5.1 Assumptions used

- Estimated annual reduction per vessel:
  - **≈ 8,000 tCO_2e/year** with 10% blend
  - **≈ 16,000 tCO_2e/year** with 20% blend
- International price range of carbon credits:
  - **US$ 10 to US$ 50 per ton,** depending on the market (voluntary, compliance, maritime sector, credit quality).

*(Note: sectors related to transportation and renewable fuels usually achieve **values above average**, due to the "hard-to-abate" attribute).*

5.5.2 Estimated Annual Economic Value Per Vessel

10% BBL DX Blend – 8,000 tCO_2e avoided/year

Price per credit	Annual value per ship
US$ 10/t	**$80,000 / year**
US$ 20/t	**$160,000 / year**
US$ 30/t	**$240,000 / year**
US$ 50/t	**$400,000 / year**

20% BBL DX Blend – 16,000 tCO_2e avoided/year

Price per credit	Annual value per ship
US$ 10/t	**$160,000 / year**
US$ 20/t	**$320,000 / year**
US$ 30/t	**$480,000 / year**
US$ 50/t	**$800,000 / year**

5.5.3 Interpretation for shipowners and investors

1. **Even in the most conservative scenario**, with credits at US$ 10/t:
   - The shipowner obtains between **US$ 80 thousand and US$ 160 thousand per ship/year**, depending on the blend.
2. **In realistic scenarios**, where premium marine credits can reach US$25–40/t:
   - The return rises to **US$ 200 thousand to US$ 600 thousand per ship/year**.
3. **In high-valuation ESG markets** (Japan, EU, green funds):

- High-quality credits associated with the decarbonization of shipping can exceed **US$ 50/t**, generating up to **US$ 800 thousand per ship/year**.

4. For commercial fleets, the impact is huge:
   - **Fleet of 10 ships (20% blend)** → up to **US$ 8 million/year** in credits alone.
   - **Fleet of 50 ships** → up to **US$ 40 million/year**.
   - **Global fleet of 100 ships** → up to **US$ 80 million/year**.
5. This turns the use of BBL DX into a **financial asset**, not just an environmental one:
   - reduces costs in EU ETS,
   - improves CII rating,
   - generates annual recurring revenue,
   - strengthens the shipowner's ESG rating,
   - attracts green financing.

5.6 Technical/economic conclusion.

The use of BBL DX in 10% and 20% blends:

- **generates new revenue**, with no change in the ship's operation;
- transforms decarbonization into **competitive advantage**;
- it enables partnership models where BBL and the shipowner share the financial value of reducing emissions;
- It is an immediate and scalable solution with strong economic attractiveness.

The use of BBL DX in 10% and 20% blends represents an **immediate decarbonization solution**, with high effectiveness and global scalability, reducing emissions in a measurable way and compatible with independent audits, without requiring technical adaptations on ships.

6. QUANTIFICATION AND CERTIFICATION OF CARBON CREDITS

The reduction in emissions obtained by BBL DX blends (10% and 20%) can be converted into tradable carbon credits, as long as the project is structured in accordance with international certification standards and strictly follows MRV (Monitoring, Reporting and Verification) processes. This point describes **how the reduction calculated in Point 5 is transformed into credits effectively issued** and accepted in the voluntary or compliance market.

6.1 Eligibility for carbon credit generation

In order for the credits associated with the use of BBL DX to be recognized, the project must meet three fundamental requirements:

(a) Additionality

It is necessary to demonstrate that:

- the shipowner **would not adopt BBL DX without the incentive of the carbon project**;
- there is no prior legal obligation that imposes the use of this fuel;
- The reduction in emissions is **additional** to the reference scenario (100% fossil use).

(b) Measurable and permanent reduction

The reduction should be:

- **quantified** according to international methodology;
- **monitored and audited** annually;
- **permanent** in the sense of not being reversible.

c) Absence of double counting

The avoided emission:

- it cannot be claimed simultaneously by two agents (shipowner and fuel supplier);
- It must be included in a single registry to ensure environmental integrity.

6.2 Applicable methodology (technical framework)

For marine fuels, the three most appropriate methodologies are:

1. VCS – Verra (Verified Carbon Standard)

- It has methodologies for replacing fossil fuels with renewable ones;
- Accepts shipping and alternative fuels projects;
- Allows **Well-to-Wake approach**, aligned with IMO.

2. Gold Standard

- Focused on projects with high environmental and social impact;
- Suitable for routes where port impact (PM/black carbon) is relevant.

3. Standards derived from the IMO (LCA – MEPC. 391(81))

- Basis of future regulation of low-carbon fuels;
- It will be a reference for compliance schemes.

The BBL DX project can be structured to meet one of these standards or a combination that maximizes global acceptance.

6.3 MRV Process – Monitoring, Reporting and Verification

The creditworthiness of the credit depends on the accuracy and transparency of MRV. The process involves:

Step 1 - Monitoring

- Record of the volume of fuel consumed by each vessel (MGO, VLSFO, Blend 10%, Blend 20%);
- Record of energy content (MJ) and fuel density;
- Record of the route, hour meter and cargo transported, when necessary.

Step 2 — Reporting

- Annual consolidation of calculated reductions;
- Technical documentation provided by BBL:
    - BBL DX WtW emission factor;
    - certifications of origin of the raw material;
    - production traceability.

Step 3 - Independent verification

- Audit carried out by an accredited entity (DNV, SGS, TÜV, Bureau Veritas, LRQA, etc.);
- Conference of the volumes consumed, emission factors and final calculations.

At the end of the verification, the credits are **officially issued in an electronic registry** and can be negotiated.

6.4 Carbon Project Framework (BBL Maritime Decarbonization Project)

A typical BBL DX-based carbon credit project will include:

1. **Description of BBL DX technology**
   – production process, emission factors, LCA compliance.
2. **Definition of the reference scenario**
   – exclusive use of MGO/VLSFO.
3. **Definition of the project scenario**
   – use of BBL DX 10% and/or 20% blends.
4. **Annual calculation of the net reduction of emissions**
   – according to the simplified methodology presented in Point 5.
5. **Fleet scope**
   – number of participating ships, types of navigation, routes.
6. **Monitoring plan**
   – continuous collection of operational data.
7. **Verification plan and periodicity**
   – usually annual, and can be semiannual.
8. **Emission of credits**
   – each ton of CO_2e avoided = 1 certified credit.

6.5 Risks, mitigators and integrity guarantees

Possible risks

- Variation in fuel consumption;
- Errors in the volumetric declaration;
- Differences between the actual and estimated emission factor;
- Risk of double counting between shipowner and supplier.

Applicable mitigations

- Electronic measurement and digital consumption record;
- Auditable and centralized MRV;
- Single Registration of Credits (Verra Registry, Gold Standard Registry);

- Clear contracts defining the ownership of the credits (shipowner, BBL, or division model).

6.6 Technical conclusion of Point 6

The emission reduction resulting from the use of BBL DX:

- **is certifiable**,
- **is eligible**,
- **is monetizable**,
- and **has high added value** due to the maritime sector being classified as *hard-to-slaughter*.

The combination between:

- high annual reduction (8,000–16,000 tCO_2e/ship);
- significant potential revenue for the shipowner,
- and operational simplicity of BBL DX (drop-in),

makes this solution one of the most efficient alternatives on the market to transform decarbonization into **immediate economic return**.

7. TECHNICAL CONCLUSIONS

The technical analysis presented throughout this memorial demonstrates that **BBL DX,** when applied in blends of **10% and 20%** with distillate marine fuels (MGO/VLSFO), represents an **immediate, scalable and economically advantageous** solution for the decarbonization of the maritime shipping sector.

The main conclusions are as follows:

7.1 Operational feasibility and compatibility

- The BBL DX is fully **compatible with Diesel cycle marine engines**, both main and auxiliary, **without the need for technical adaptations**, such as changing nozzles, injection adjustments or changes to tanks and lines.
- The fuel has **excellent thermal and oxidative stability**, not forming gums or sediments, which positively differentiates it from traditional biodiesel (FAME).
- The 10% and 20% blends keep all physicochemical parameters within safe operating ranges, respecting the essential guidelines of ISO 8217.

7.2 Measurable emission reductions

The consolidated results show significant reductions:

- **Blend 10% BBL DX** → Reduction of approximately **8,000 tCO_2e/year** per vessel
- **Blend 20% BBL DX** → Reduction of approximately **16,000 tCO_2e/year** per vessel

In addition to CO_2e reduction, immediate gains are observed in:

- **SOx** (reduction proportional to sulfur content, almost zero in BBL DX);
- **Particulate matter (PM) and black carbon**, with significant improvement in air quality in ports and coastal areas;
- **Engine operation**, due to cleaner burning and superior lubricity.

These reductions directly contribute to meeting IMO targets (IIC, EEXI) and European regulations (FuelEU Maritime and EU ETS).

7.3 Direct economic benefit – Carbon Credits

The use of BBL DX allows you to transform decarbonization into real financial income, with an estimated annual generation of:

- **≈ \$80,000 to \$400,000 per vessel/year** (10% blend)
- **≈ \$160,000 to \$800,000 per vessel/year** (20% blend)

depending on the international price of the carbon credit (US\$10–50/t).

For medium or large fleets, the economic impact is extremely significant:

- **Fleet of 10 ships** → up to **US$ 8 million/year**
- **Fleet of 50 ships** → up to **US$ 40 million/year**
- **Fleet of 100 ships** → up to **$80 million/year**

This financial differential completely alters the shipowner's economic rationale, making BBL DX **not only environmentally advantageous**, but also **financially strategic**.

7.4 International Regulatory Alignment

The BBL DX meets the main requirements of maritime decarbonization:

- **Well-to-Wake methodology**, as per IMO MEPC.391(81);
- Eligibility for certification by VCS/Verra, Gold Standard and future shipping-specific standards;
- Direct contribution to IIC compliance, **FuelEU Maritime** and reduction of obligations in the **EU ETS**.

This positions BBL DX as a solution that is fully aligned with the 2030–2050 climate goals.

7.5 Scalability and Technological Readiness

Unlike emerging fuels (methanol, ammonia, hydrogen), which require structural changes, BBL DX:

- it's **drop-in**,
- requires **zero investment in retrofit**,
- uses **existing infrastructure in ports**,
- can be implemented immediately,
- It has a proven technological route.

This scalability gives BBL DX a decisive strategic advantage as a short- and medium-term solution for global fleet decarbonization.

7.6 Final Conclusion

The **BBL DX** brings together the essential elements sought by the maritime sector:

- **environmental effectiveness**,
- **technical feasibility**,
- **economic attractiveness**,
- **regulatory compliance**,
- **and immediate operational applicability**.

It is a mature solution, with high potential for global adoption, capable of reducing emissions, generating revenue for shipowners, improving regulatory indices and positioning operators at the forefront of the maritime energy transition.

The BBL DX is not only an alternative fuel, **it is a technical and cost-effective platform for the accelerated decarbonization of international shipping.**