Permanente's Sustainable Green Fuel Family — GRC88®

Patented Liquid and Solid Green Fuels from Cellulosic Biomass

GRC88® Fast Fuel Facts — The Marine Fuel Market Today

- Global marine petroleum-hydrocarbon fuel consumption is approximately 330 million metric tons per year and increasing.[1] Approximately 100,000 commercial vessels worldwide — including more than 35,000 oceangoing ships that account for the majority of global bunker-fuel demand — burn this fuel today.[2]
- The proposed marine-sector alternatives — methanol, ammonia, and LNG — are not energy-dense by volume and typically require newbuild vessels, allowing shipowners to defer meaningful emissions action.
- No cost-competitive marine biofuels exist today at scale with global availability.
- Global marine biofuel production from vegetable oils amounts to approximately 0.7 million tons of oil equivalent — less than 0.3% of the marine sector's total energy use.[3] Bio-oil fuels derived from vegetable oils, blended at 24% to 30% with marine fuels, have yet to exceed 1.3 million tons per year. There will never be enough vegetable oil to provide the needed green-fuel feedstock.
- The average price of Bunker C, historically the lowest-cost and most energy-dense conventional marine fuel, is just over $450 per metric ton. Existing non-cellulosic bio-oil-blended marine fuels typically exceed $900 per metric ton.[4]
- GRC88® liquid green-energy fuel from cellulosic biomass can be made and distributed at approximately 30% less than the cost of conventional marine fuels — *without subsidy of any kind*.

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[1]U.S. Department of Transportation Maritime Administration (MARAD), Techno-Economic Analysis and Life Cycle Assessment of Greenhouse Gas and Criteria Air Pollutant Emissions for Biobased Marine Fuels, reporting annual global marine fuel consumption of approximately 330 million metric tons (87 billion gallons). See also International Maritime Organization data via Safety4Sea, IMO: Over 200 million tons of fuel used during 2023. Global maritime trade volumes continue to grow, sustaining ongoing increases in marine fuel demand.

[2]IMO Ship Fuel Oil Consumption Data Collection System (DCS) reports for 2023 covered 28,620 ships of 5,000 GT and above; commercial fleet databases indicate approximately 37,500 vessels in that size category globally. Including smaller commercial vessels, fishing fleets, and domestic traffic, the total worldwide commercial fleet is commonly estimated at approximately 100,000 vessels. See Ship & Bunker orderbook analysis (Clarksons Research).

[3]Global marine biofuel volumes remain marginal relative to total bunker demand, with vegetable-oil-derived bio-oil fuels representing less than 0.3% of marine sector energy use. See S&P Global Platts Global Bunker Fuel Cost Calculator, documenting the Platts UCOME–VLSFO biobunker price indicator and blending ranges.

[4]High Sulfur Fuel Oil (HSFO, the modern successor to conventional Bunker C for scrubber-equipped vessels) averaged approximately $450–$550 per metric ton in 2024–2025; Very Low Sulfur Fuel Oil (VLSFO) averaged approximately $535–$665 per metric ton; vegetable-oil-based marine biofuel blends (UCOME-VLSFO, B24, B30) have historically priced at $900 per metric ton and above. See Ship & Bunker, Average VLSFO Bunker Prices Analysis (2025).

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- The U.S. Department of Energy's 2023 Billion-Ton Report finds that the United States has the potential to sustainably produce more than one billion tons of cellulosic biomass per year.[5]
- GRC88® solid fuels can be made cost-effectively without subsidy of any kind, in massive bulk volumes, from every form of abundant low-cost cellulosic biomass — including forest-products waste, logging slash, sawmill hog fuel, shavings and fabrication residues, wildfire and bug-killed trees, and agribusiness by-products such as shells, pits, hulls, straw, stover, gin trash, orchard pruning, and ground orchard wood.
- If all the annually manufactured forest products in the United States were placed on one side of a scale, balancing that weight would require only 5% of the waste agribusiness biomass generated in the same year on the other side. Twenty times the forest-waste volume goes unused in cellulosic biomass every year. There is no shortage of feedstock — there has been only an absence of technology to process it.

The Opportunity Has Been Open For a Reason

The legacy U.S. forest-products industry and its international counterparts have operated for decades under narrow margins, high capital and operating costs, and cyclical demand dependent on lumber, pulp, and paper markets. Interest rates and financing cycles have repeatedly stymied the creative vision that would otherwise redirect waste forest feedstocks toward higher-value energy applications. Juvenile fiber, logging slash, and waste agribusiness by-products have gone unused at industrial scale because the technology to convert them economically did not exist — and because the organizations best positioned to change that chose not to. Permanente created GRC88® because the forest-products industry lacked vision and could not, and the legacy bunker-fuel industry lacked motivation and would not.

What Permanente Has Created

By bringing to bear the entrepreneurial expertise of three generations of global forest-products value-added fabrication, the Seidner family turned its focus to ecologically and environmentally protective means of creating decarbonizing, sustainable green fuels at industrial scale. After more than a decade of focused engineering, testing, and validation of prototype designs and product outputs across every class of cellulosic biomass feedstock, Permanente's principals invented a family of continuous processing methods capable of yielding millions of tons per year of biofuel, biochar, and co-processing outputs.

The scalability of the PIPE™ technology platform matters because its implementation obsoletes every other cellulosic-biomass-derived fuel-processing method in both cost and output volume. The generation of energy-dense biocoal nanoparticles blended in a colloidal suspension of high-quality pyrolysis bio-oil produces a biofuel that equals or improves on the energy output of conventional Bunker C and No. 6 Residual Fuel Oil — and it is the centerpiece of the GRC88® product family. GRC88® is protected under U.S. Patent No. 9,758,738 B2, *Green Renewable*

[5]U.S. Department of Energy, Bioenergy Technologies Office, *2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources* (March 2024), finding that the United States could sustainably produce 1.1–1.5 billion tons of biomass annually in a mature market. Available at https://www.energy.gov/articles/doe-releases-report-outlining-how-america-can-sustainably-produce-more-one-billion-tons.

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Liquid Fuel, together with additional U.S. patents, Canadian patents, and European Patent EP3841184.[6]

GRC88® PIPE™ Reactor Processing Technologies

Multiple heat-transfer fluids are recycled as they move feedstocks through the pipe-in-pipe reactor configuration, employing very few moving parts and managing key operating functions at very low pressure and high-volume throughput — then allowing a selection of purpose for all processed outputs. The reactor operates as a horizontal equivalent of a hydrocarbon cracking tower, allowing control of time, temperature, and flow rate so that the desired cellulosic biomass output products are extracted in serial fashion as they move through the reactor.

Torrefaction by Permanente

Torrefaction by Permanente is a ten- to twenty-minute, lower-temperature (approximately 300°C to 350°C) pre-pyrolysis process that "cooks" cellulosic biomass in the PIPE™ reactor under controlled time and temperature to yield high-energy-dense biocoal, biocoke, biochar, wood vinegar, and biocarbon — all through a continuous process in an oxygen-free environment.[7] The reactor's serpentine horizontal radiator configuration allows a wide range of cellulosic feedstocks to be processed to yield a variety of outputs at industrial volumes that exceed 400,000 tons per year per reactor.

Pyrolysis by Permanente

Pyrolysis by Permanente is the gasification of cellulosic biomass and torrefied biocarbon in the second stage of the PIPE™ oxygen-free reactor environment at higher temperatures (approximately 500°C to 850°C) under controlled time and temperature. The process produces syngas, biochar, and a pyrolysis bio-oil condensed from a major portion of the syngas. A portion of the syngas is used as a self-generating recycled heating fuel to perpetuate both torrefaction and pyrolysis, so that once the process begins, no other fuels are required. The excess syngas generated beyond process heat, together with the condensed bio-oil, becomes the liquid-fuel feedstock. The excess heat can be used to generate further heat and power.

Biochar for Carbon Sequestration

Biochar is well-established and world-recognized as a superior soil amendment, capable of reconditioning depleted soils and helping create new soils by holding nutrients and moisture in the root zones of plants, while providing a home for microbes that support ecological soil and plant function. One ton of biochar used as a soil amendment sequesters approximately 2.8 tons

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[6] GRC88® is a patented green fuel product of Permanente Corporation made under U.S. Patent No. 9,758,738 B2, *Green Renewable Liquid Fuel* (available at https://patents.google.com/patent/US9758738B2/en), together with additional Permanente patents, including U.S. Patent Nos. 10,961,459, 11,345,860, 11,674,086, and 12,595,340 B1; Canadian Patent No. 309645 and Canadian application 3,280,527 (pending); and European Patent EP3841184, *Method for Production of a Renewable Liquid Fuel* (EPO Register record available at https://register.epo.org/espacenet/regviewer?AP=19851455&CY=EP&LG=en&DB=REG), together with additional U.S. and foreign patents pending.

[7] Conventional torrefaction is conducted at 200°C to 300°C and conventional pyrolysis at 500°C to 850°C. See Ohio State University Extension, *Torrefaction: Upgrading Biomass to "Green Coal"*, available at https://ohioline.osu.edu/factsheet/fabe-6603. Permanente's PIPE™ reactor operates torrefaction at an approximately ten- to twenty-minute cycle at 300°C to 350°C and pyrolysis in a second stage at 500°C to 850°C, with per-reactor throughput exceeding 400,000 tons per year.

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of CO_2 — effectively forever.[8] The life of biochar in soil extends well into millennia. Biochar can also increase crop yields by as much as 20% simply by the way it holds moisture and nutrients and enables beneficial microbes.[9] Conventional biochar has historically been too expensive and too scarce to realize its potential; Permanente's PIPE™ reactor outputs make biochar available in massive bulk quantities at sharply reduced cost.

GRC88® Solid and Liquid Green-Energy Products at Industrial Scale

Permanente's patented cellulosic-biomass processing technologies obsolete every other method of cellulosic-biomass conversion and enable the scalable production of tens of millions of tons per facility annually of biocoal, biochar, biocoke, and bio-oil from readily available and abundant forest biomass and agribusiness by-products. Over 40 million tons per year of waste agribusiness and forest-industry feedstocks are sustainably generated in the region tributary to Permanente's Houston hub alone; similar volumes are available nationwide, and Permanente's decades of multi-continent experience in value-added forest products provide ready access to many multiples of that volume.

GRC88® Biocoal and Biocoke — Lower in Cost Than Fossil Alternatives

Permanente biocarbon products exceed the energy output specifications and fixed-carbon levels of fossil alternatives — with biocoal at approximately 12,500 BTU/lb delivering roughly 33% to 62% greater energy density than Powder River Basin (PRB) coal, and fixed-carbon levels up to approximately 40% higher than typical coked metallurgical coal — while eliminating the emissions and pollutants associated with fossil-fuel use.[10] The solid green-energy products of the PIPE™ reactor are hydrophobic and non-toxic, with no mercury, no lead, no other heavy metals, and no sulfur; they are carbon-neutral, low-moisture, low-ash, non-slagging in boilers, and burn cleanly. They substitute seamlessly into existing coal-fired boilers, dual-fuel industrial diesel engines, and steam-heating boilers — requiring no special machinery or equipment. Biocoal can be stored without special handling. In most power plants, the ash from combustion is non-toxic and can itself be used as a soil amendment.

GRC88® Marine Fuel — A Blue-Sky Solution for a 330-Million-Ton Market

Permanente's patented liquid green fuel is produced by slow pyrolysis for use in marine transportation, power and thermal production, and gasification for higher-grade fuel refining. It is not the emulsified, low-energy, fast-pyrolysis unstable liquid produced by other technologies. GRC88® is the opposite: a drop-in, carbon-neutral marine fuel engineered as a viscous, energy-dense colloidal suspension of bio-oil, pyrolysis oil, and nano-sized particles of torrefied biocarbon — a combination protected under U.S. Patent No. 9,758,738 B2 and companion

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[8] International Biochar Initiative, Why Biochar. Industry consensus places carbon sequestration at approximately 2–3 tons CO_2 per ton of biochar applied; biochar is recognized by IPCC AR6 (2022) as a carbon-dioxide-removal pathway with global potential of approximately 2.6 $GtCO_2$ per year.

[9] K. Schmidt et al., *Biochar in Agriculture — A Systematic Review of 26 Global Meta-Analyses*, GCB Bioenergy (2021). Meta-analyses of global biochar field trials report average crop-yield increases of approximately 13–25%, with higher responses in acidic and tropical soils. Available at https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12889.

[10] Permanente biocoal at approximately 12,500 BTU/lb is supported by Permanente Corporation internal product testing. Wyoming State Geological Survey reports Powder River Basin subbituminous coals ranging from 7,710 to 9,410 BTU/lb (averaging 8,580). At 12,500 BTU/lb, Permanente biocoal delivers approximately 33% greater energy density than PRB coal at its high end, and approximately 62% greater than PRB coal at its low end. Permanente biocarbon products can also exceed typical coked metallurgical coal on fixed-carbon content by up to approximately 40%, as supported by Permanente internal product specification. See Wyoming State Geological Survey, Wyoming's Coal Geology.

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patents. This formulation is the technical basis of GRC88®'s energy density, which meets or exceeds that of No. 6 Residual Fuel Oil and Bunker C.[11]

GRC88® blends with heavy marine fuels, Bunker C and No. 6 RFO, at approximately 30% less cost on a BTU-for-BTU basis — and it meets or exceeds the no-sulfur, non-polluting marine-fuel regulations of the International Maritime Organization.[12] It contains no heavy metals, burns cleanly, and is equally suitable for many land-based energy-generating operations. Combustion is carbon-neutral; the process of manufacturing is both carbon-neutral and carbon-negative.

[11] Energy density of No. 6 Residual Fuel Oil (Bunker C) is approximately 17,400 BTU/lb (lower heating value) and approximately 124,000–150,000 BTU per gallon. See U.S. Forest Products Laboratory, Fuel Value Calculator.

[12] IMO Resolution MEPC.305(73) (2018) established the IMO 2020 sulfur cap, limiting marine fuel sulfur content to 0.50% m/m outside Emission Control Areas (0.10% inside ECAs). The EU FuelEU Maritime regulation (Regulation (EU) 2023/1805) took effect January 1, 2025, establishing declining GHG-intensity limits for energy used on board ships and phasing shipping into the EU Emissions Trading System. See Ship Universe, Marine Diesel and Alt Fuel Prices.

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