

"Results of emulsified fuel test are excellent"… "The MSAR® commercial demonstration has confirmed to us that the technology offers a commercially viable alternative to fuel oil production, and has a suitable fit with future plans for our refinery."

General Director
Orlen Lietuva Refinery

MSAR® is commercially and operationally proven in both steam boilers and diesel engines. It can be supplied directly from candidate refineries and delivered to a power plant using conventional infrastructure designed for heavy fuel oil.

STEAM BOILERS

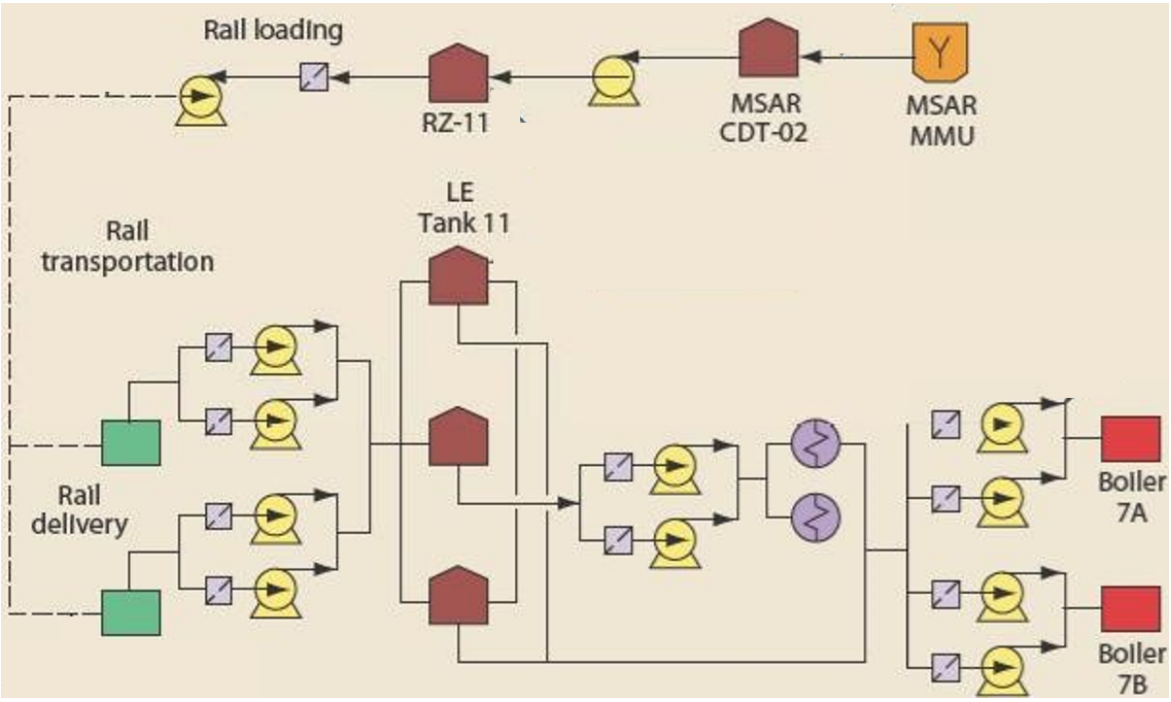
Over 60 million tonnes of oil-in-water (OIW) emulsion fuel, branded Orimulsion®, was manufactured from 8° API Orinoco bitumen in Venezuela, and was subsequently fired worldwide in base-load boilers of varying sizes (50MWth to 770MWe). MSAR® is an improved version of Orimulsion® and the latest generation OIW emulsion, with a key difference being the technology can now be

deployed in oil refineries and is applicable to refinery residue streams, as well as extra-heavy crudes. Key members of the Quadrise team worked in the original Orimulsion® business.

In 2008, a commercial demonstration of MSAR® as boiler fuel was successfully completed. MSAR® was produced at ORLEN Lietuva's 200,000 bpd refinery in Lithuania and combusted at the 1,800MWe Elektrenai power plant owned by Lietuvos Elektrinė (LE), a previous Orimulsion® customer.

The commercial demonstration involved:

- Manufacture of >22,000 tonnes of MSAR® at the refinery, from Urals crude-based visbreaker residues, confirming the economic benefits of producing MSAR® versus fuel oil.
- A 20 t/h MSAR® Manufacturing Unit, which operated on a continuous basis, using a plot of less than 250m2 was installed in under 6 months.
- MSAR® was exported to the power plant by rail (~300km), using the refinery HFO rail loading system alongside regular HFO (or "Mazut") loadings.



Schematic of MSAR® commercial demonstration



ORLEN Lietuva refinery (200,000 bpd)

- At the powerplant the same discharge system used for HFO offloading was deployed for MSAR® (without the need for steam heating due to MSAR®'s low viscosity).
- MSAR® was fired on the 2 x 150MWe Unit 7. The boilers were opposed wall-fired, each with six burners, supplying 950 t/h of 240 bar steam (540°C reheat) to a single LMZ turbine.
- The trial confirmed 600MWe base-load power & Alstom APC operational viability.
- Successful trial results were independently verified by European Bank (EBRD) consultants.

MSAR® firing proved extremely successful, achieving flame stability at both low and high load operations. LE undertook a visual inspection partway through the firing programme and concluded that the levels of fouling were acceptable and within expectations.

Overall, MSAR® fuel performance was deemed by LE to be similar to, or better than, Orimulsion®.



Elektrenai power plant

DIESEL ENGINES

In conjunction with Wärtsilä, more than 10,000 test hours were accumulated using similar Orimulsion® fuel in V32 and V46 engines, prior to the commencement of commercial operation at the IFC (World Bank) financed 150MW Planta Arizona in Guatemala:

Around 150,000 running hours were completed burning Orimulsion® in 10 x 18V46 engines.
The plant was equipped with, and operated, ESP/FGD to meet World Bank Standards.
The plant is currently using HFO intermittently, due to the halt in lower-cost Orimulsion® supply (a political decision made by the Venezuelan government which had nothing to do with the effectiveness of the fuel).



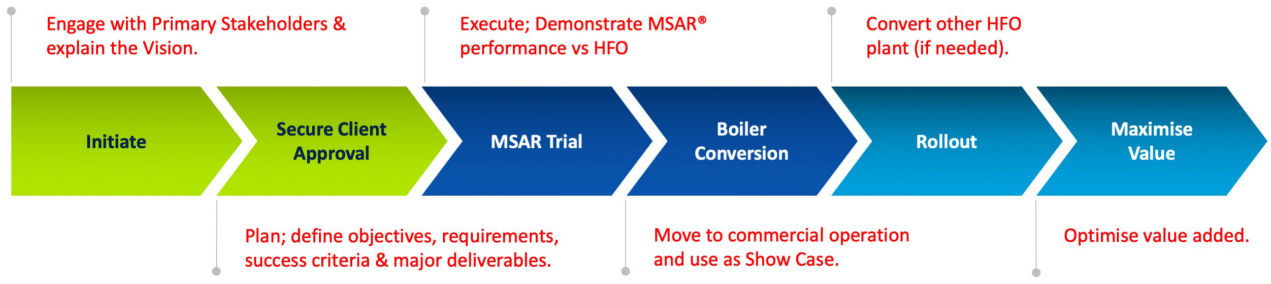
Planta Arizona in Guatemala was run on Orimulsion® commercially over three years (150,000 cumulative running hours).

MSAR® BOILER CASE STUDY

Example below using Mitsui Futures Prices for 2020 (as of February 2019), and assumptions of a 400MWe (Net) boiler, 75% engine load, at 37.5% efficiency.

Conversion to MSAR® for a 400MWe boiler:	$2.5m
Project margin share for boiler:	$30m/y = $11/MWh
Payback time:	1 month

As shown in the table, MSAR® CAPEX would be paid back in a matter of weeks and the fuel savings could be used to subsidise the cost of FGD if required. Pathway to achieving MSAR® savings:



As well as benefitting from a significantly lower cost fuel, power plants benefit from MSAR®'s numerous environmental benefits.

For 2-stroke diesel engine experience with MSAR® please see our Marine case study.

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