



A clean solution to the Americas' heavy fuel oil problem

NOVEMBER 2020



Quadrise's MSAR® technology enables production of a proprietary oil-in-water emulsion fuel oil – MSAR®, that reduces energy costs for consumers and improves refinery profitability and yields.



The most cost effective and cleanest refinery residue upgrading technology.

Delivers significant environmental benefits with a 30% reduction in NOx emissions and 50% lower ash emissions, with further potential to reduce CO2 by 20% (same as LNG).



Oil-in-water emulsions have been used worldwide, with 100,000BPD commercial supply experience and over 60 million tons consumed in power generation and industrial facilities. The latest generation, MSAR®, is now on the verge of being implemented in the Americas, Africa, Europe and the Middle East.

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With over ten years of working in the region, Quadrise is now poised to progress regional commercial implementation.



Implementation of MSAR® in refineries and power generation facilities in key regions such as Ecuador and Mexico can deliver cost savings of ~US\$100 million per year per refinery to governments, whilst also benefiting the population and environment through lower emissions.



Strong synergies with metals recovery from ash - including vanadium, a critical component for the manufacture and deployment of renewable energy storage batteries.

Executive Summary

The Heavy Fuel Oil Problem

The oil industry has a problem. There are supply and demand imbalances from both quantity and quality perspectives; with crude oils and refined products invariably not where they are needed and not of the quality that the market wants.

Refineries are designed to address these imbalances, but refining requirements change over time due to market forces and legislation, resulting in suboptimal operations. As the world demands more cleaner oil products, the costs of producing them increase.

If energy industry participants are unable to economically configure their infrastructure to produce lighter, cleaner products, whilst efficiently transitioning to renewables, then they stand to lose billions of dollars of revenue, thousands of jobs, and they will be left behind by their peers and competitors.

Despite being one of the world's leading producers of oil and gas products, the Americas are witnessing a transformation to renewables, with substantial investments and advancements being made in the region and globally. During this transition, which will last generations, it is vital that fossil fuel resources are used as efficiently as possible to maximize revenues and minimize emissions.

In parallel with the transition to renewables there is also an underlying shift in demand from heavy, sour to lighter, sweet oil products, accelerated by new International Maritime Organisation ("IMO") regulations on marine fuel that became effective on January 1, 2020.

Conventional Solutions are not always the Answer

Conventional methods of shifting oil production and refining to match new regulations and market demands are expensive, time consuming and energy intensive - leading to increased greenhouse gas emissions. In a low oil price environment where permanent shifts in demand have already taken place, these methods are typically not a viable solution and risk being outmoded before they are commissioned.

Regions which require substantial imports of distillates to meet local energy demands (due to upstream production and or refinery configurations) have felt this shift harder than most. The Americas is one such region; with Mexico and Ecuador both being heavily impacted in upstream and downstream operations. Whilst the costs of these imports have reduced in the short-term, this still represents a significant balance of trade issue for the affected countries.

The MSAR® Solution

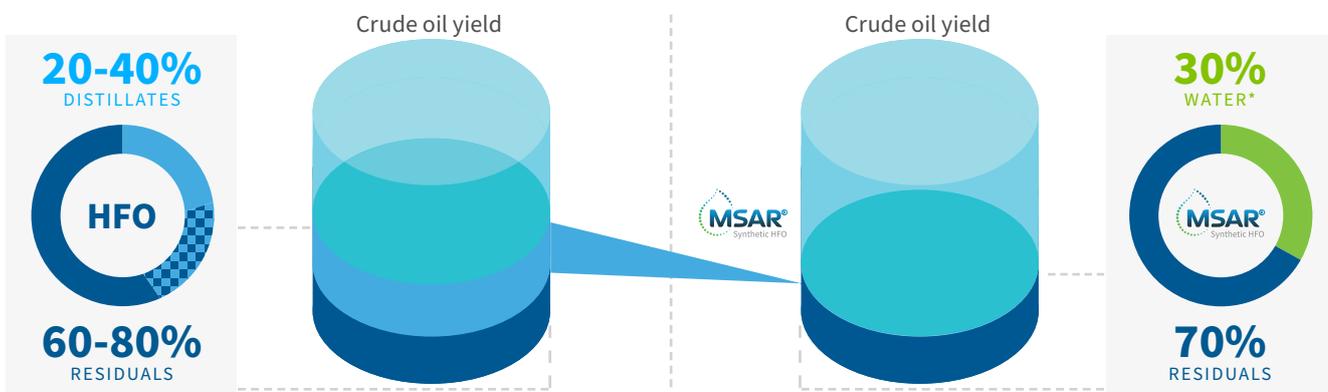
Quadrise's MSAR® technology offers a unique, proven solution to these problems.

For refineries producing fuel oil, MSAR® technology creates value by improving refinery yields and margins by reducing manufacturing costs.

Economic value is delivered for MSAR® fuel consumers through lower fuel costs enabled by the increased refinery efficiency. At the same time, environmental benefits of significantly reduced NOx and particulate emissions are realised due to the composition of the fuel.

High value "premium" distillate fuel used to blend HFO is lost margin to the refinery

With MSAR®, an additional yield of 10-20% higher value premium products can be sold



● High value fuel \$/bbl > crude oil

● High value fuel sold as HFO \$/bbl < crude oil

● Low value Residue \$/bbl < crude oil

● Water & <1% chemicals \$/bbl < crude oil

* including <1% additives

MSAR[®] technology comprises a low-cost, modular process to create an oil-in-water emulsion fuel oil (MSAR[®] fuel) that controls the viscosity of the oil without distillate diluents. It uses low value, treated water-streams to dilute the heavy oil residues as micro-droplets, with the resultant emulsion stabilised by proprietary surfactant additives. This approach frees up valuable distillates, which can be sold as premium transport fuels, or reduces expensive imports. Due to its lower viscosity, MSAR[®] also reduces energy costs associated with transportation and storage for producers and consumers.

MSAR[®] systems can be operational in under one year, which significantly and rapidly increases refinery profits whilst producing a cheaper, cleaner fuel that uses existing fuel oil infrastructure. This is in stark contrast to the expensive, conventional refinery upgrading solutions, that take many years to implement.

For upstream companies producing heavy oil, MSAR[®] technology's viscosity control can provide solutions for reducing in field steam and power costs and or mobilising stranded assets, alongside environmental advantages.

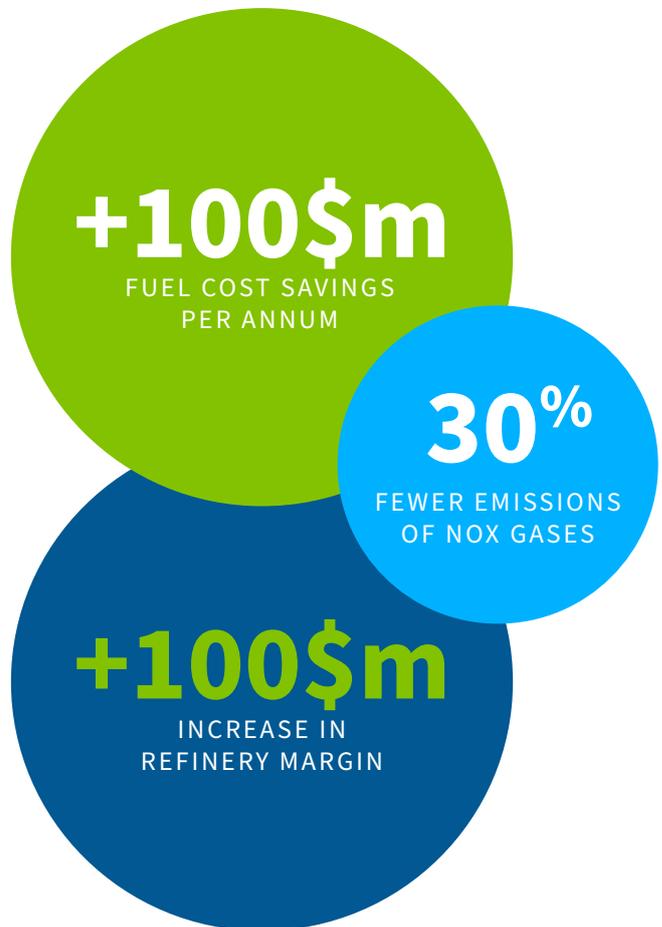
MSAR[®] technology and fuel also embeds improved environmental and societal benefits for refiners and utilities. It is the cleanest way of upgrading heavy oil value in a refinery, delivering significant savings and lower CO₂ emissions vs alternatives. MSAR[®] fuel:

- Generates 30% fewer emissions of NO_x gases.
- Reduces particulates, with no black carbon/soot, lowering global warming potential.
- Lowers ash disposal costs, improving metals recovery economics, and enabling local vanadium redox battery manufacture for sustainable renewable energy growth.

In markets where volatile pricing, shifting regulatory regimes and unpredictable demand are creating existential challenges, MSAR[®] offers a unique, economic and environmentally superior solution.

The Americas are ideally placed to benefit – with adoption of MSAR[®] fuel by refineries and utilities able to deliver savings of US\$100 million per annum per candidate refinery¹, together with significant domestic and export opportunities from new specialised industries.

MSAR[®] technology enables existing oil resources and assets to be used efficiently and economically, addressing the heavy fuel oil problem, hence smoothing the path to a sustainable future.



¹Savings stated are for 100-200KBPD semi-complex refineries in Ecuador and Mexico.

Introduction

There is increasing momentum to move to renewable energy in virtually all regions of the world. Whilst being one of the world's leading producers and exporters of oil and gas products, the Americas region is at the vanguard in several areas relating to renewable energy. However, there will be a long transition and during this time, it will be vital to ensure that fossil fuel resources are used as efficiently as possible, to maximise revenues and to further improve environmental performance.

There is a “quality” issue for oil markets as well as a “quantity” issue – with both producers and refiners worldwide producing too much heavy, sour crude and products. Recent IMO regulations, implemented on 1st January 2020, have further reduced demand for heavy, sour, oil products and shifted demand to lighter and sweeter distillate products such as diesel.

Whilst shifting production to match the new demand profile is a well-trodden path, making this change using traditional technology is both expensive and time consuming. Neither of these are attractive when oil prices are low, with reduced revenues, when product demand has already shifted. This situation is further accentuated in regions where current production and refinery configurations require substantial imports of heavy oil products and/or distillates to meet local demand. There are several regions in the world where this is the case, including South and Central America, the Middle East and Russia. In the Americas, Ecuador and Mexico are heavily impacted.

The Shift from Heavy to Light Oil Could Prove to be a Game Changer in The Global Energy Transition

The dual shock of the onset of the Covid-19 pandemic and associated plunge in oil prices to a 20-year low is hitting the world's economy hard. For illustration, the drop in the value of the region's exports is estimated to be around 30 percent year-on-year in April and the downward trend will continue for several more months at least, according to Inter-American Development Bank (“IDB”) estimates. These dramatic events have brought the importance of the energy transition into ever sharper focus and increased the urgency for oil producing regions to expedite an energy transition to more sustainable sources. But the reality is that this transition cannot and will not happen overnight.

Whilst the world will remain reliant on oil and gas for many years to come, the pandemic has shone a spotlight on the importance of a sustainable and therefore green recovery, during which it will be vital to ensure that fossil fuel resources are used as efficiently as possible in order to both maximise revenues and radically improve environmental performance.

As the global energy transition gains traction, the Americas will not only need to grapple with the “quantity” issue pertaining to oil markets but also the “quality” issue in light of the current shift in demand underway from heavy to lighter, distillate products such as diesel.



Typical Heavy Oil Product Processing

The production of fuel oil is expensive. In a typical semi-complex refinery that produces fuel oil, the very thick residue streams that come out of the bottom of the process units would be solid at room temperature and so are not suitable to sell as fuel without further processing. The distillate products that come out of the top of the process units are the valuable transportation fuels such as jet, diesel and gasoline, which sell at a significant premium to the crude oil being refined.

In order to enable the thick viscous residue streams to be sold as fuel oil, they must be diluted or “cut” with some of the valuable distillate products. The fuel oil is sold at a discount to the crude oil processed, resulting in a significant reduction

in the yield of premium products and associated revenues for the refiners; around 10-20% of the valuable distillates are downgraded or “lost” by the refinery and are not sold at a premium, but at a discount.

10-20%

VALUABLE DISTILLATES ARE
DOWNGRADED TO FUEL OIL

Upgrading Solutions are Energy & Capital Intensive, Slow to Implement, and Increase Emissions

The common solution to this issue is to “upgrade” the refinery to get more value out of the bottom, or heavy part of each barrel refined. This is undertaken by much more intensive processing of the oil in new process units, which break down the heavier parts of the crude – creating more valuable distillate products and either lower quantities of very thick residues (which need even more distillate to dilute them to enable their use as fuels), or, in the most extreme cases, no liquid residue streams at all but a solid coke by-product.

Such large multi-billion-dollar projects typically take 5 -7 years to implement and are prone to cost and timing overruns.

In the current oil price environment, capital investment in the downstream sector remains under pressure and the traditional solutions are very energy intensive and create additional CO2 emissions which further hampers the implementation of these traditional schemes.

Is There an Alternative Solution?

If producers and refiners are looking for a proven alternative solution, there is one available that can be implemented rapidly to deliver significant savings at low capital cost whilst also delivering enhanced environmental performance.

Quadrise’s technology replaces the need to dilute heavy residues with higher value diesel, producing a high-quality synthetic fuel oil.

Surprisingly, it relies on something that is commonly thought to be impossible – mixing oil and water - creating an emulsion fuel – MSAR®.

The use of water and a small amount of proprietary stabilising additives to dilute the thick residues as micron-sized oil droplets in suspension, is similar in concept to the production of water-based paints. For the heavy oil or refinery producer

it frees up the valuable distillates to be sold as premium fuels, significantly increasing profits whilst creating a cheaper, cleaner fuel that uses existing fuel oil infrastructure.

“ *Quadrise’s technology replaces the need to dilute heavy residues with higher value diesel, producing a high-quality synthetic fuel oil.* ”

What is MSAR® Technology and Fuel?

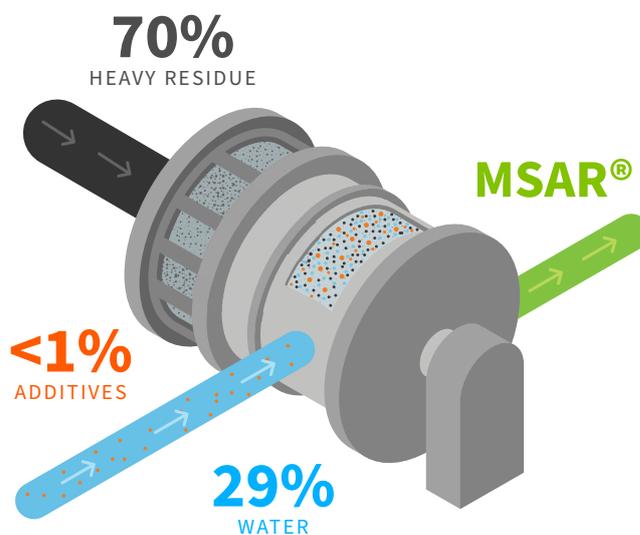
MSAR® technology is founded on the experience of supplying more than 60 million tons of Orimulsion® fuel to the base-load thermal utility market worldwide, including the cleanest modern utilities in Canada, Italy, Denmark and Singapore.

With this proven foundation, MSAR® technology has developed significantly and can be used to create MSAR® emulsion fuels from a variety of refinery heavy residue and low-value water streams (Orimulsion® was produced from a single source of heavy crude oil in Venezuela) for use in power, marine and industrial applications.

MSAR® technology is based on standard equipment that is used worldwide to produce asphalt emulsions for road surfacing applications, with patented additive and upgraded production technology that has been jointly developed by Quadrise with Nouryon; one of the world's leading speciality chemicals business. Both Quadrise and Nouryon have invested heavily in the development of MSAR® technology to enable its use with a very wide variety of refinery residue streams and to meet demanding end-user requirements.

The hot residue (or crude) streams are fed directly to the MSAR® unit (called an “MMU” or MSAR® Manufacturing Unit) where it is colloidally-milled into very small droplets (around 5-10 microns in diameter – human hair is around 50 microns in diameter) immediately mixed with treated refinery (or associated) water (sourced from a variety of water streams that would otherwise be disposed of) containing a very small amount of additives. The MSAR® fuel is then cooled and transferred to storage tanks. Existing fuel oil infrastructure can be used for the storage and transportation of MSAR® alongside conventional fuels.

MSAR® fuel comprises (70%) heavy residue, dispersed as small droplets, in water (29%) which contains a proprietary additive package (<1%). As water is the continuous phase, this determines the viscosity of the fuel – enabling MSAR® to flow at ambient temperatures, where conventional fuel oils would require heating for storage and transportation.



Implementing MSAR® Technology

Business Benefits

Unlike other refinery upgrading solutions, MSAR® technology is based on the use of modules that can be housed in ISO shipping containers. This significantly reduces both design and equipment lead times and offers “plug and play” upgrading within 12 months. This modular approach also enables users to undertake a phased approach, if desired, by simply adding further modules to increase capacity as required. This low capex solution delivers the refinery with rapid increases in profitability – with typical cash payback in around a year.

The users of the fuel are provided with two primary benefits – an oil-based fuel that is around 10% cheaper on a unit-energy basis (i.e. per GJ or BTU of energy – excluding the water) and which burns more like a gas, delivering significant reductions in emissions.

Quadrise's Experience in the Region

Quadrise has undertaken extensive work with global power companies, marine operators and boiler/diesel OEM's to demonstrate that MSAR® fuel can be used effectively, with limited changes to the fuel handling systems that enable online changeover to conventional fuels if required.

Quadrise is proud to have been active in the region, and in the Americas in particular, for over 10 years. In this time Quadrise has formed excellent relationships with key companies in the refining and power/utility sectors supported by GE Steam Power and Wärtsilä. Members of the Quadrise team were also involved for over a decade in the 100,000BPD Orimulsion® business, including supply to 150MWe Planta Arizona (Guatemala) and Arawak Cement (Barbados).

A commercial scale trial is generally the precursor to commercial deployment, demonstrating the proven economic and environmental performance of MSAR® technology and fuel in the Americas. Within 12 months of completing such a trial, commercial deployment could be underway, delivering significant and enduring benefits to the host country and the region.

ACTIVE IN REGION FOR
>10 years

What is the Scale of the Potential Value Add?

By deploying MSAR® technology to oil refineries in the region, significant value can be rapidly unlocked that has the additional benefit of improving the profitability of NOC downstream assets and of the national utilities' oil-fired generating assets.

To provide some context for the scale of the savings, the impact of substituting the current HFO production of 45,000 – 150,000 BPD in the Americas with MSAR® today could equate to:

- Fuel cost savings equating to \$100-500 Million at refineries and utilities.
- Reduced import requirements for diesel-type products by 12,000 – 45,000 BPD.
- Swift implementation at refineries and power plants at low cost, within 12 months.
- Reduced maintenance and operating costs for utilities.
- Production of MSAR® fuel and blending systems in the region.
- Potential production of MSAR® additives in the region, a \$50-120 million investment leading to new sales of \$100-500 million per year and jobs in the petrochemical sector.
- Reduced NOx emissions, typically by 30%, and SOx emissions when combined with exhaust gas cleaning “scrubbers” for both marine and land-based applications.

- Reduced PM / ash emissions (by 50% or more), due to more efficient fuel combustion.
- Significantly reduced ash carbon content leading to lower disposal costs or economic recovery of valuable metals from waste by-products, including vanadium, which is needed for the manufacture and deployment of renewable energy storage batteries.

+100\$m

+US\$100 MILLION INCREASE IN REFINERY MARGIN AND +US\$100 MILLION FUEL COST SAVINGS PER CANDIDATE REFINERY PER ANNUM

Future Activities

Quadrise continues to work with key stakeholders to deliver the significant value opportunity, both regionally and globally. Quadrise plans to present at regional events to highlight the opportunities for investment in progressing to a sustainable future whilst maximising the value of its fossil fuel resources, reducing emissions and attracting inward investment. As part of our commitment to the region, Quadrise is in the process of ensuring that its website and other key materials will be available in both Spanish and English.

In other markets, Quadrise has already secured an international chemicals and mining group client headquartered in Morocco, for whom it will be undertaking a pilot trial as well as delivering paid engineering studies for larger commercial scale trials at the client's facilities in

Morocco. Quadrise's equipment and MSAR® fuel for the first phase trial in Morocco are now on site and the joint project team remains in regular contact to progress the second phase activities for the trials on the client's larger commercial units.

In the Americas, Quadrise is working with a number of upstream companies to use MSAR® technology to enhance development of heavy sweet, sour or paraffinic crude oil assets.

Quadrise is also very active in the Middle East, with focus on reducing fuel oil costs and emissions in Saudi Arabia, Kuwait and Iraq.

Quadrise Global Partners and Activity



Summary

The Americas are planning a major shift to the use of renewables. However, in the medium-term, oil will continue to be of significant value to the economy as a source of revenue generation and job retention. During this transition, it will be important to manage the use of existing oil-based facilities to minimise costs, maximise asset values and drive further improvements in environmental performance. There are several ways in which the region's oil and power industries can respond to the challenges, although most solutions are complex, multi-billion-dollar projects that take many costly years to implement.

The region is poised to be an early beneficiary of the use of simple, low-cost, modular MSAR® technology that can be implemented within one year and delivers rapid returns alongside significant improvements in environmental

performance, creating a sustainable pathway to renewables – optimising the use of existing fossil-fuel resources.

The Americas are ideally placed to benefit – with adoption of MSAR® fuel by refineries and utilities able to deliver significant savings of US\$100 million per annum per candidate refinery², together with significant emissions reductions as well as domestic and export opportunities from new specialised industries.

² Savings stated are for 100-200KBPD semi-complex refineries in Ecuador and Mexico.

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