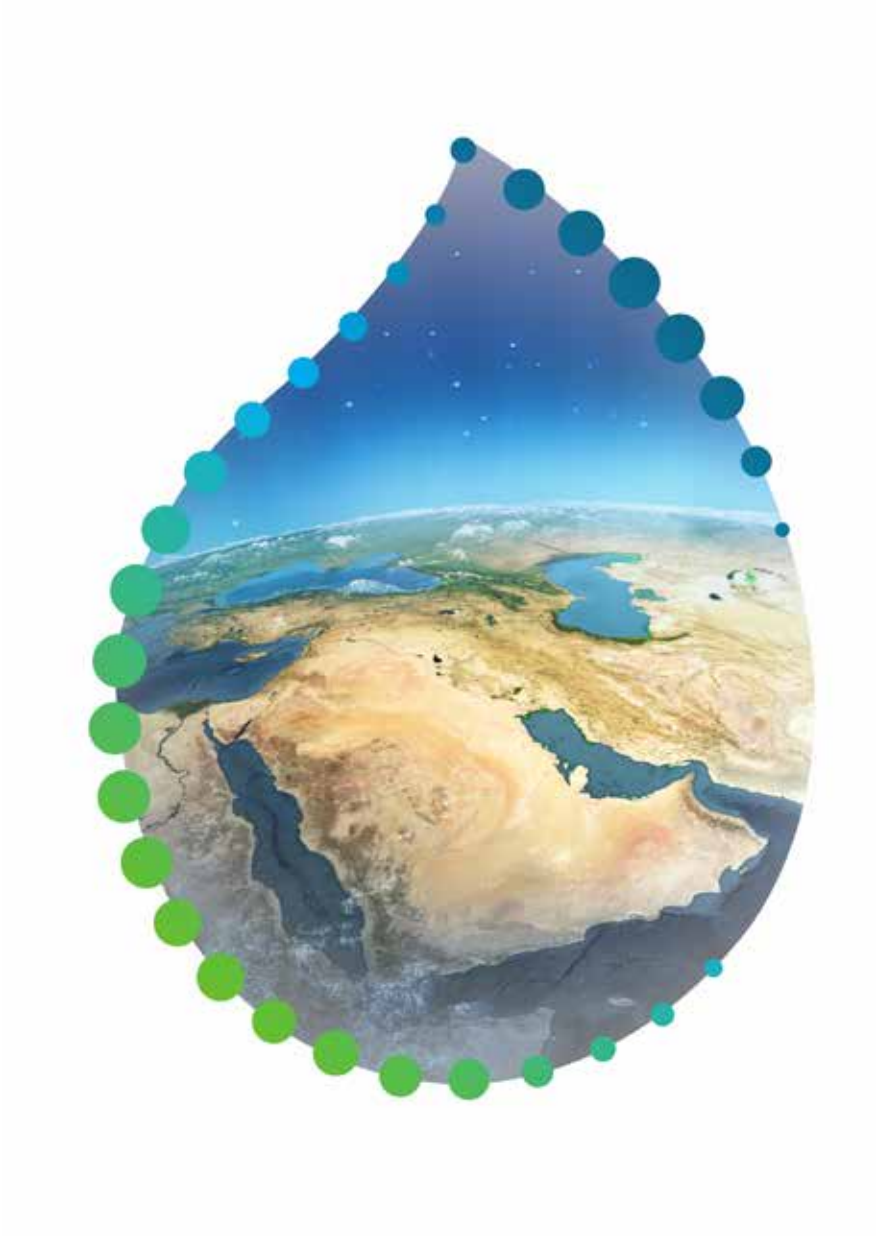
Quadrise



A clean solution to the Middle East's heavy fuel oil problem

AUGUST 2020

Highlights



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 yield.

Implementation in power generation in the KSA can deliver annual fuel cost savings of ~$0.8 Billion.

Refinery margins where MSAR® is being produced would increase by a comparable amount.

Delivers significant environmental benefits to consumers, 30% reduction in NOx emissions and 50% lower ash emissions - and is the most cost effective and cleanest upgrading technology for refiners.

Oil in water emulsions have been used worldwide, with over 60m tons consumed in power generation. The latest generation, MSAR®, is now on the verge of being implemented in the Americas, Africa, Europe and the Middle East.

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

10+

With over 10 years of working in the KSA, Quadrise is now poised to progress its first regional commercial implementation.

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 their 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 Middle East is driving a transformation to renewables, with substantial investments and advancements being made across the region. During this transition, which will last generations, it is vital that fossil fuel resources are used as efficiently as possible in order to maximise revenues and minimise 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.

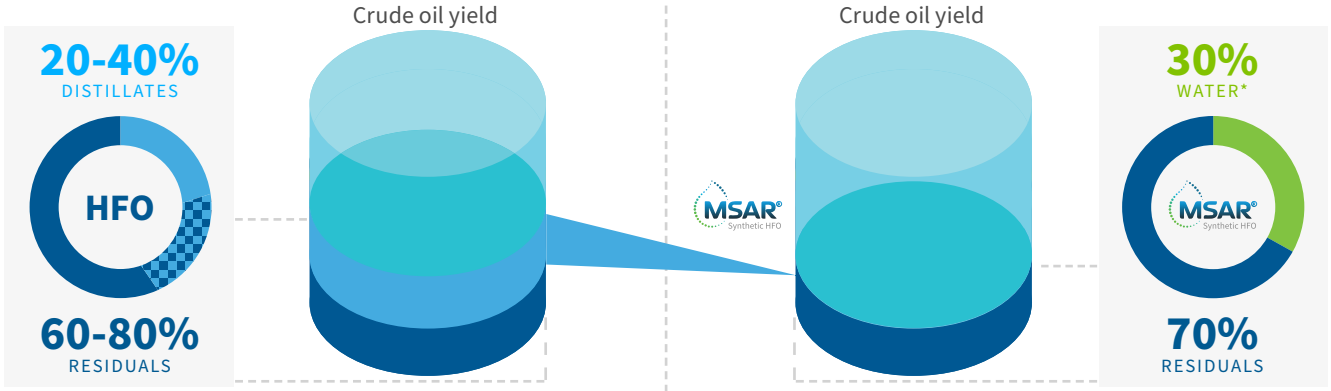
Regions which require substantial imports of heavy oil products and/or distillates to meet local energy demands (due to production and refinery configurations) have felt this shift harder than most. The Middle East is one such region; with the Kingdom of Saudi Arabia ('KSA') and Iraq being heavily impacted. 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, including the KSA.

The MSAR® Solution

Quadrise's MSAR® technology offers a unique, proven solution to these problems. For refineries producing fuel oil, MSAR® technology adds value by improving refinery yields and margins by reducing manufacturing costs. Economic value is delivered for the 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 reduces energy costs for producers and consumers. It uses refinery water-streams to dilute the heavy oil residues as micro-droplets, which frees up valuable distillates to be sold as premium fuels by refiners.

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.

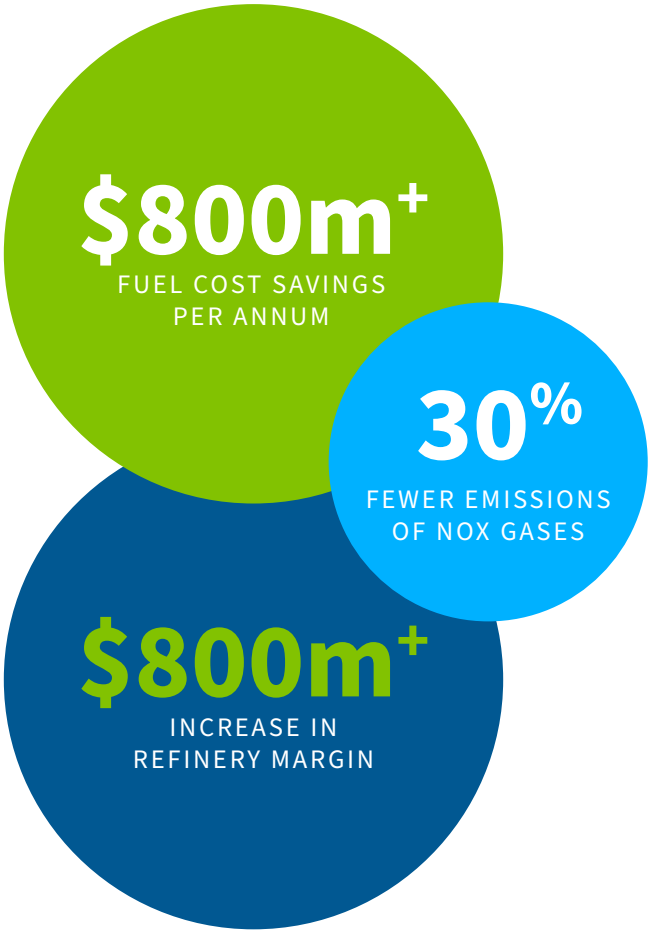
MSAR® technology and fuel also embeds improved environmental and societal benefits for refiners and utilities. It is the cleanest way of upgrading heavy oil value in a refinery, delivering significant savings and lower CO2 emissions vs alternatives. MSAR® fuel:

- Generates 30% fewer emissions of NOx 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 Middle East and the KSA in particular are ideally placed to benefit – with adoption of MSAR® fuel by KSA utilities able to deliver savings of c$0.8 billion per annum, together with significant IKTVA and export opportunities from new specialised industries. The increase in refinery margin associated with MSAR® production, through the increase in high value premium fuels is of the same order of magnitude as the fuel cost savings or c$0.8 billion per annum.

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.



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 Middle East 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 a 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 Russia, South and Central America and the Middle East. In the latter, the KSA and Iraq are the markets most impacted.

The Middle East's Shift from Heavy to Light Oil Could Prove to be a Game Changer in the Global Energy Transition

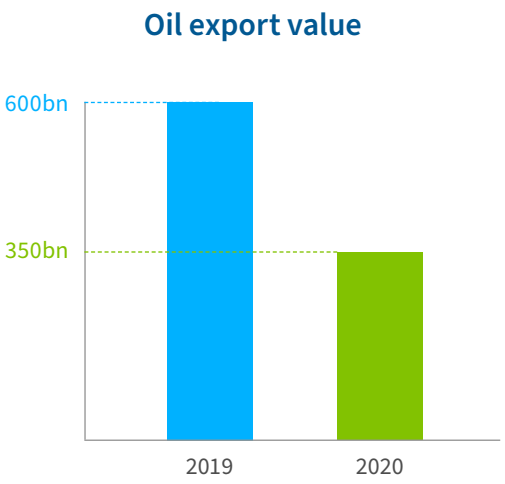
The dual shock of the onset of the Covid-19 pandemic and associated plunge in oil prices to a 20-year low has hit the region's economies harder than most. Middle Eastern oil exports are expected to decline by more than $250 billion in 2020, representing a fall of over 40% on 2019 values when the region's oil revenues stood at around $600 billion. These dramatic events have brought the importance of the energy transition into ever sharper focus and increased the urgency for the region to expedite this transition. 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.

The KSA, as current president of the G20 group of industrialised nations, recognises that it has an important role to play in the global recovery effort. Its national oil company, Saudi Aramco, has already started investing heavily in sub-surface management of its oil production, which has yielded significant reductions in carbon emissions. Across the Gulf Cooperation Council region, the national oil companies and their respective international partners have also begun developing new technologies to reduce the carbon footprint of oil and gas production.

The World Energy Council's Trilemma Index which assesses countries' performance with regards to the key energy challenges of energy equity, energy security and environmental sustainability has noted that the Middle East region, and particularly the Gulf States, performs well on energy equity and security but there is notable room to improve their credentials with regard to environmental sustainability – the significance of which has been accentuated further as the global economy looks to 'build back better'.

As the global energy transition gains traction, the Middle East 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. The Middle East's current heavy oil reserves are estimated at 1 trillion barrels, equivalent to 28% of total world reserves.



Typical Heavy Fuel 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. Several such schemes are in construction or are being contemplated in the region such as Bapco's Oil Refinery Modernisation Programme, KNPC's Clean Fuel Project and Saudi Aramco's Jubail and Jizan refineries. Such large multi-billion-dollar projects typically take 5 -7 years to implement, and can be 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 CO_2 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, this creates 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.

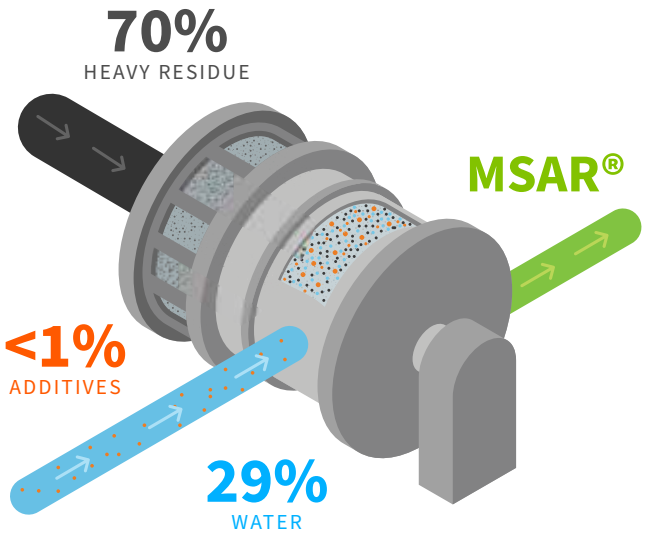
With this proven foundation, MSAR® technology has developed significantly and can be used to create MSAR® emulsion fuels from a variety of refinery heavy residue and low-value water streams (Orimulsion® was produced from a single source of heavy crude oil in Venezuela) for use in power, marine and industrial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

The refinery's 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.

Environmental benefits

MSAR® technology and fuel 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 CO_2 emissions vs alternatives.

MSAR® fuel:

- Generates 30% fewer emissions of NOx gases.
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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 KSA in particular, for over 10 years. In this time Quadrise has formed excellent relationships with key companies in the refining and power/utility sectors in the KSA, Kuwait and Bahrain, supported by GE Steam Power.

In the KSA, Quadrise has worked with the NOC's Power Systems Planning division for several years, to plan for and implement the use of MSAR® in the KSA. Whilst the fuel is proven in commercial use in large thermal boilers, a commercial-scale boiler trial project was planned in 2018 to demonstrate comprehensively to the stakeholders the effectiveness in a 400MWe boiler based on MSAR® fuel imported from Cepsa in Spain, where an MSAR® production facility was installed for the successful Maersk marine trial.

Significant progress made by the teams at the NOC, the electricity utility and Quadrise would enable the project to be restarted rapidly:

- All the technical and logistical preparations were completed to initiate fuel production at the refinery for delivery to the KSA;
- All commercial agreements were in final form;
- The Boiler OEM had undertaken work to define the baseline HFO performance of the boiler against which performance on MSAR® would be calibrated; and
- MSAR® fuel was listed as an opportunity fuel in the KSA's long-term plan.

Quadrise has been working diligently with the Al Khafrah Holding Group since 2018 to enable a project to produce the trial MSAR® fuel in the KSA, that the companies believe will reduce the original trial costs by $20m. In parallel, the utility has accepted that emulsion technology reduces fuel costs and emissions.

In Kuwait, Quadrise are working with Aleph Commodities and Hawazin Regional Trading Company (Ahmad Al-Otaibi and Faisal Al-Kharafi) to develop MSAR® projects to long-term commercial agreements for the production and supply of MSAR® technology.

A commercial scale boiler trial is the key to progressing commercial deployment based on the proven economic and environmental performance of MSAR® technology and fuel in the KSA. Within 12 months of completing such a trial, commercial deployment could be underway, delivering significant and enduring benefits to the KSA.

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 consumption of ~540,000 BPD in the KSA with MSAR® today could equate to:

- Fuel cost savings to the KSA of at least 10%, equating to ~$0.8 Billion per year based on fuels costs of $40/BBL.
- Increased refinery margins of a similar magnitude to the above from MSAR® production.
- Swift implementation at refineries and power plants at low cost, within 12 months.
- Reduced maintenance and operating costs for utilities (SEC and SWEC).
- Production of MSAR® fuel and blending systems in the KSA (IKTVA employment).
- Production of MSAR® additives in the KSA (IKTVA project), a $200 million investment leading to new sales of $0.8 billion per year and jobs in the petrochemical sector.
- Reduced NOx emissions, typically by 30%.
- Reduced 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 in the KSA for the manufacture and deployment of renewable energy storage batteries.
- Potential future supply to the national tanker fleets, reducing fuel costs and emissions.

$800m+

YEARLY KSA FUEL SAVINGS

Future Activities

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 Arabic and English. 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.

Quadrise has global reach, with a business development pipeline covering five continents. Ongoing projects outside the Middle East include the following:

In Morocco, Quadrise has secured an international chemicals and mining group client for whom it will be undertaking a pilot trial as well as providing paid engineering studies for larger commercial scale trials at one of the client's facilities in Morocco. Quadrise's equipment and MSAR® fuel for the first phase of this 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 South America, Quadrise is working with a national oil company and power utility on the deployment of MSAR® technology to deliver significant savings to both parties and potentially completely removing the need to import expensive distillates.

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

Quadrise Global Partners and Activity



Summary

The KSA and the wider region 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, multibillion dollar projects that take many years to implement.

The KSA is poised to be at the vanguard of the transition to renewable energy with the use of Quadrise's MSAR® technology; a simple, low-cost, modular technology that can be implemented within one year. MSAR®_technology delivers rapid returns alongside significant improvements in environmental performance, creating a sustainable pathway to renewables – optimising the use of existing fossil-fuel resources.

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