



MSAR® Technology Overview

November 2017



Introduction to Quadrise

- Quadrise is the supplier of MSAR® technology that produces a lower cost, cleaner synthetic HFO.
- MSAR® is proven, proprietary oil refinery technology offering material economic and environmental benefits to producers and consumers.
- IP is protected jointly with AkzoNobel and projects are being developed with major global companies.
- QFI plc is listed on the London Stock Exchange under AIM companies (\$50M market cap).
- MSAR® applications include Marine (developed with Maersk) and Power (KSA NOC & Electricity Co).

Industry participants

AkzoNobel 



Lloyd's Register



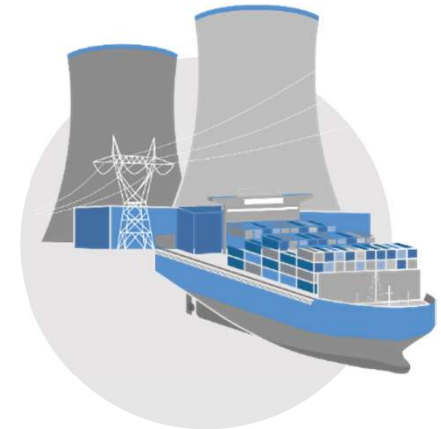
CIMAC



= Multiphase Superfine Atomised Residue



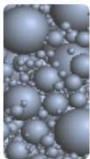
Technology Introduction



Quadrise licenses and supplies MSAR® technology, additives and services to produce a stable 'Oil-in-Water' emulsion fuel

MSAR® provides refiners with low-cost, rapidly deployed upgrading solutions for HFO pool

Delivers HFO consumers tangible cost savings and environmental benefits



How it works:

Tiny droplets of extra-viscous heavy hydrocarbons are dispersed in water using proprietary processes and additives

Key benefits:

- ✓ Water & chemicals replace premium fuels
- ✓ Significant value is added
- ✓ MSAR® viscosity is lower

Key benefits:

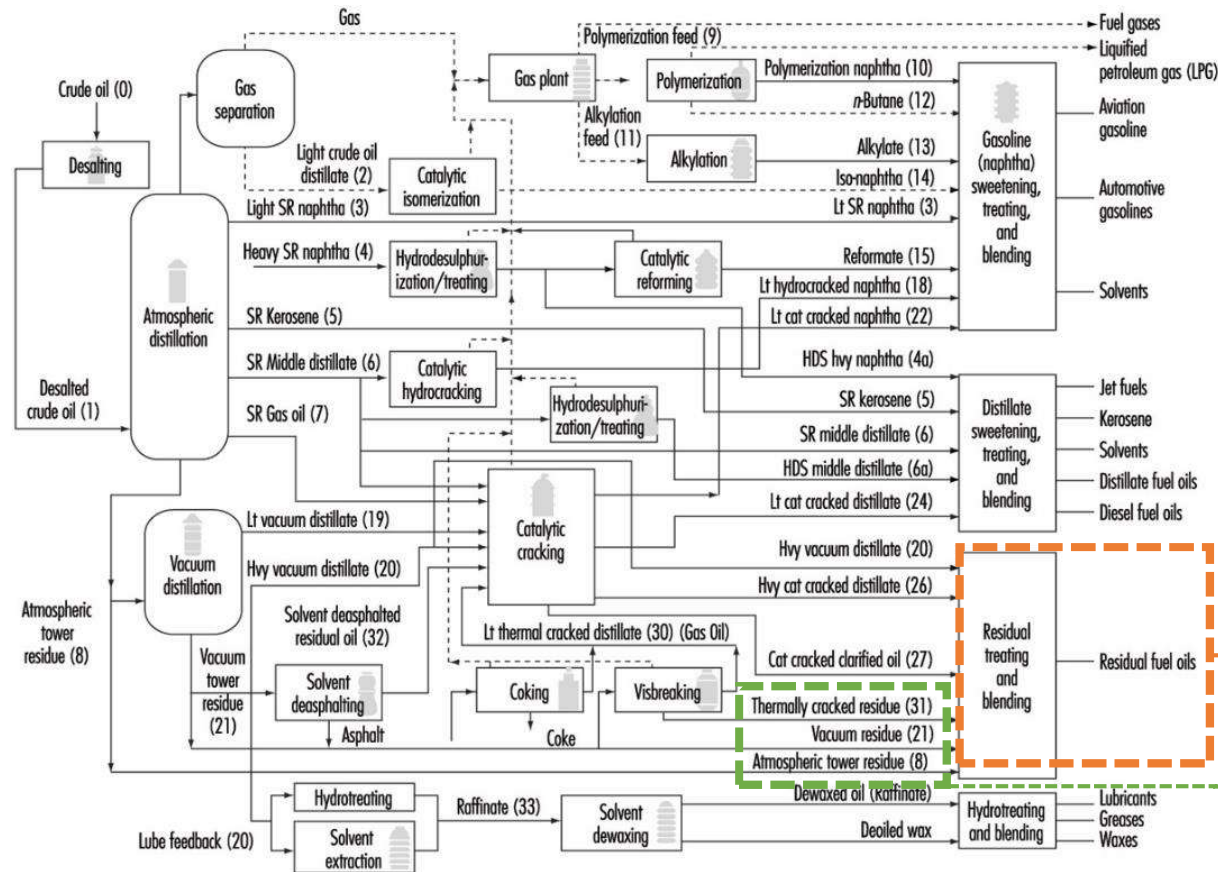
- ✓ Stable, lower cost synthetic HFO
- ✓ Enhanced combustion & lower emissions (NOx, PM)

Pioneering Research, Development & Innovation

- UK Research Facility (QRF)
 - Product development to enhance economics & efficiency
 - Fuel emulsion testing from laboratory to industrial scale
 - Central service centre for operations support
- University of Surrey – Research Collaboration
 - Formerly the BP Centre for Petroleum & Surface Chemistry
 - Pioneering research with Professor Spence Taylor
- Protection of Intellectual Property to create competitive entry barriers
 - JDA patent protection and joint IP with **AkzoNobel** 



Where does MSAR® fit in an oil refinery?



Note: Numbers in parentheses refer to typical product process flow routes.
Source: OSHA 1996.

Liquids _____ Gases - - - - -

The HFO “pool” where...

- The viscosity of the heavy hydrocarbons are reduced by blending with higher value distillate products*



- *A novel process blends these heavy hydrocarbons directly with water and additives = synthetic HFO*



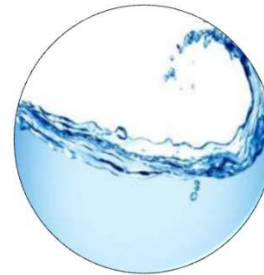
Refinery Blending Process



Solid, viscous residues ~70%

- ✓ Vacuum column
- ✓ Visbreaker
- ✓ Hydrocracker
- ✓ SDA
- ✓ Thermally cracked
- ✓ Unstable/incompatible residues

AkzoNobel Additives <1%



Water ~29%

- ✓ Can be derived from several utility or wastewater sources

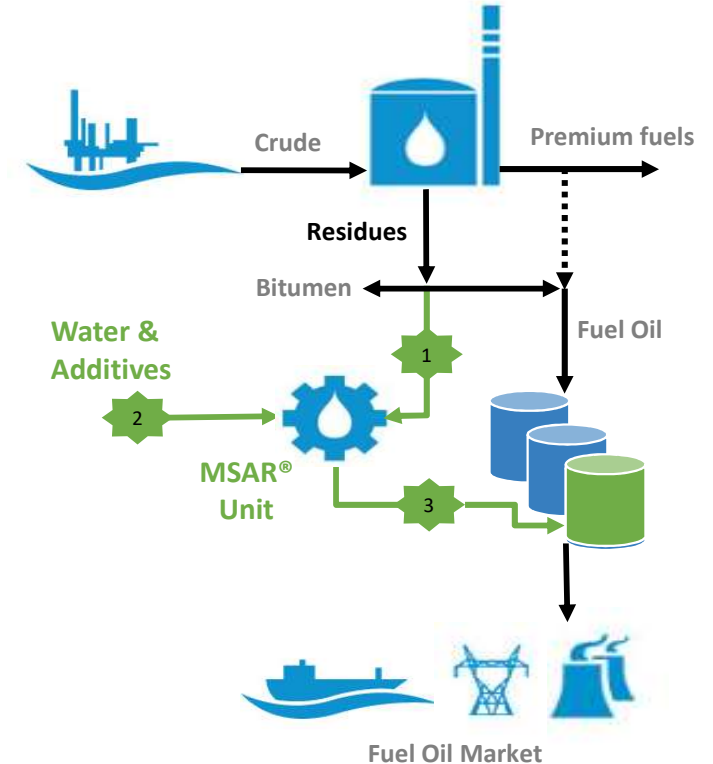


1 Oil residues are taken direct from refinery rundown lines and cooled to achieve the required viscosity (~200-1000cSt @ 100-200°C typically) for the colloid mill.

2 Water, together with proprietary additives, is added to the residue in a high-speed colloid mill under pressure.

"Plug & Play" Refinery Technology

"Semi-complex" Refinery

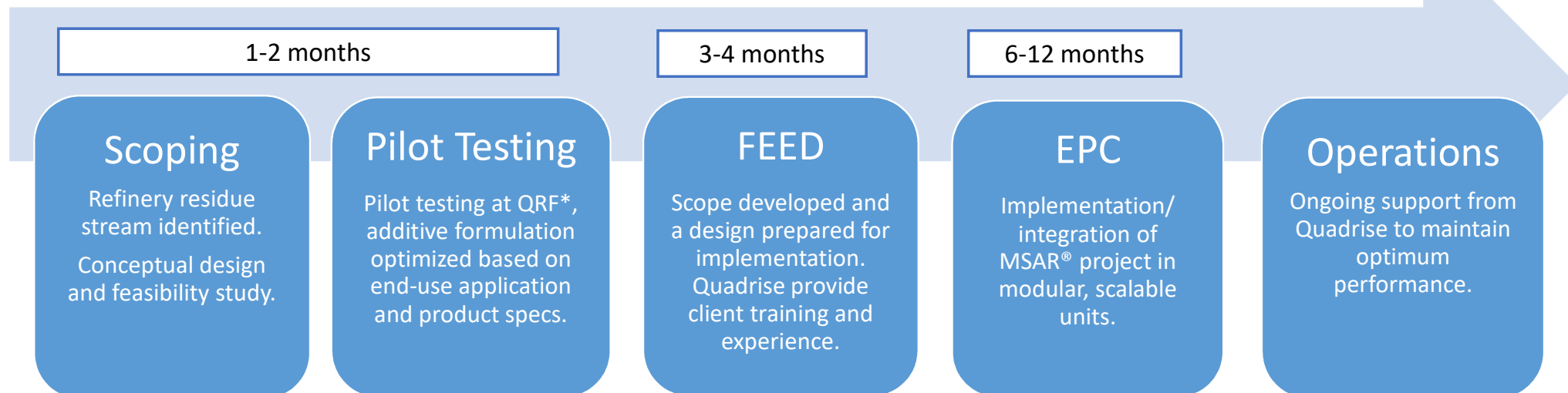


3 The mixture is processed in the mill and cooled to provide a **highly stable** oil-in-water fuel oil equivalent (~200cSt at 50°C) that can be run down to existing fuel oil tanks.





Fast-track Project Implementation



A typical MSAR® project costs around \$10m and is implemented within 12 months.



*QRF = Quadrise Research Facility



MSAR® installation at Cepsa San Roque Refinery



MSAR® vs. HFO (RMG)

Summary Differences:

Water

- MSAR® contains ~30% water, resulting in a reduced calorific value compared to HFO.
- Typically 50% more fuel required (factored into supply economics).

Density

- MSAR® density is higher as residue based.



Viscosity

- MSAR® Viscosity is lower as a function of the water in the bulk phase.

Sulphur

- Like HFO, MSAR® contains sulphur as a feature of the residue.

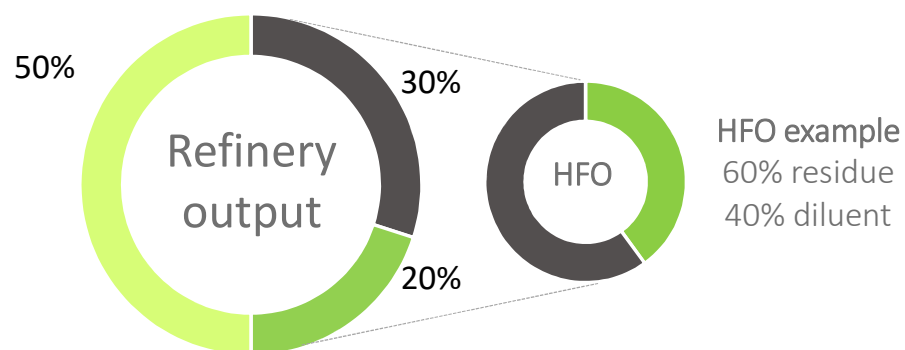
Comparison of ISO8217:2010 marine residual fuel (RMG) versus MSAR®

Characteristic	Limit	Category ISO-F-	ISO Test Method	
		RMG 380	Reference	Power Grade
Density at 15°C, kg/m³	max.	991,0	ISO 3675 / ISO 12185	1050,0
Kinematic Viscosity at 50°C, mm²	max.	380,0	ISO 3104	200,0*
Flash Point °C	min.	60	ISO 2719	60
Pour Point (upper)				
Winter Quality °C	max.	30	ISO 3016	30
Summer Quality °C	max.	30	ISO 3016	30
Carbon Residue, % (m/m)	max.	18	ISO 10370	20
Ash, % (m/m)	max.	0,15	ISO 6245	0,3
Water, % (v/v)	max.	0,5	ISO 3733	33,0
Sulfur, % (m/m)	max.	3,5	ISO 14597 / 8754	3,5
Acid number, mg KOH/g	max.	2,5		2,5
Hydrogen Sulfide, mg/kg	max.	2,0	IP 570 Part A	2,0
Vanadium, mg/kg	max.	350	ISO 14597 / IP 501	350
Sodium, mg/kg	max.	100	ISO 14597 / IP 501	100
Total Sediment Potential, % (m/m)	max.	0,10	ISO 10307-2	N/A
Aluminium plus Silicon, mg/kg	max.	80	ISO 10478	80
Used lubricating oil (ULO)	max*			
Zinc, mg/kg		15	IP 501/IP 470	N/A
Phosphorus, mg/kg		15	IP 501/IP 470	N/A
Calcium, mg/kg		30	IP 501/IP 470	N/A
	* The fuel shall be considered free of ULO if one or more elements Zn, P and Ca are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.			* = at 100s ⁻¹ N/A = Not relevant for emulsion fuel

Economic drivers for MSAR®

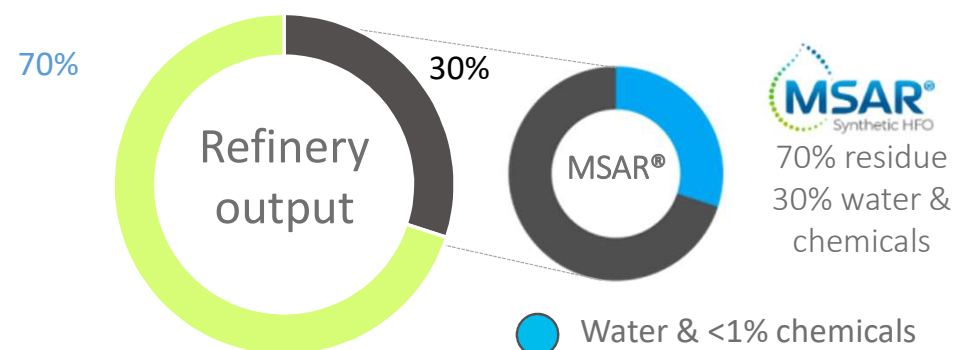
Value is created at the refinery by saving distillate fuels – to be shared with consumer*

Traditional refinery process



Every barrel of high value premium fuel used to create HFO is lost margin to the refinery

An MSAR® refinery



An additional 20% of higher value fuel can be sold by the refinery at the market rate vs HFO value

* Price of MSAR® < HFO on a per unit of energy basis

Low Capital Cost & Rapid Implementation → Rapid Payback
~\$10m < 12 months



Refinery economics (2018 example)

$$\text{MSAR vs HFO} = [\text{HFO value} - \text{distillate savings} + \text{additive costs}] \times \text{Net Calorific Value Adjustment}$$

Generic Case Study; Vacuum residue cut with LCO for 380cSt HFO versus MSAR®					
Number of MMUs	1	MSAR production rate		1000 mt/d	
Percentage of Resid in MSAR	70%			350,000 mt/yr	
Resid used by MSAR production	245,000 mt/yr				
Stream Values & Properties	\$/mt	Viscosity cSt @ 50°C	Viscosity cSt @ 100°C	NCV GJ/mt	Comments
Heavy Fuel Oil, 3.5wt% S	265	380	35.7	40.8	CAL 18 (Mitsui 28/03/17)
Gasoil, 0.1wt% S	475	4.8	2.0	43.0	CAL 18 (Mitsui 28/03/17)
Gasoil / Fuel Oil spread	210				See associated graph for historical spread
Cutter Stock (LCO)	404	6.5	2.5	42.0	85% of Gasoil
Refinery Residue	146	890,001	4,000	39.5	Netback fn(HFO & LCO \$/t and blend ratio)
Refinery Fuel Oil at gate	258	380	35.7	40.5	less \$7/mt Freight to market
Refinery Fuel Oil Blend Today	wt %	mt/yr			
Cutter Stock (LCO)	43.4%	187,544			Blend ratio needed to make viscosity spec
Refinery Residue	56.6%	245,000			Blend ratio needed to make viscosity spec
Refinery Fuel Oil blend	100.0%	432,544			
MSAR Blend Economics	\$/mt	Ratio (wt %)	\$/mt MSAR		
Refinery Residue	146	70.0%	103		
OPEX (Water 29%, chems 1%, etc)	35	30.0%	35		
MSAR Cost of Production			138		
MSAR NCV (GJ/mt)	27.1		\$/mt HFO eq.		MSAR has a lower NCV due to the water %
Value of MSAR versus HFO =	1.50	x \$138/mt =	207		MSAR cost is normalised for NCV (HFO equiv.)
Margin created by MSAR vs Market HFO		20% Disc.	\$51/mt	HFO - Normalised MSAR cost (to be shared)	

MSAR® Economics 101:

Step 1...

Derive the value of the residue per ton, based on value of HFO less the cost of distillates (LCO)

Step 2...

Calculate the cost of MSAR® (residue + water + additives)

Step 3...

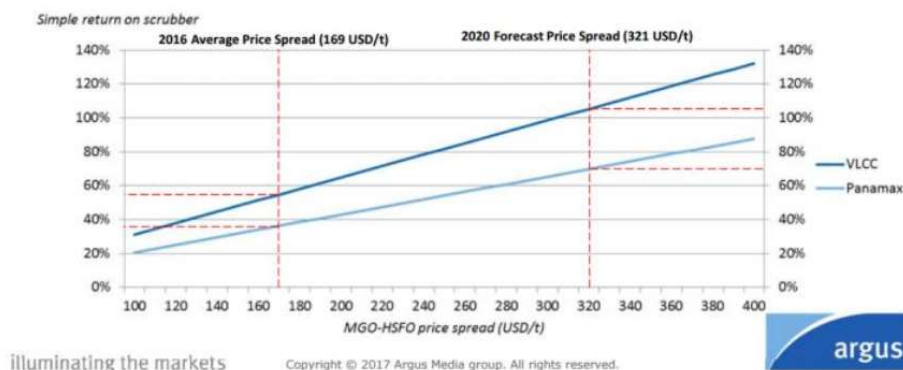
Adjust for lower calorific value and compare savings "like for like" vs HFO.
MSAR® value to be shared...

Impact of IMO MEPC 2020+ 0.5% Sulphur Limit

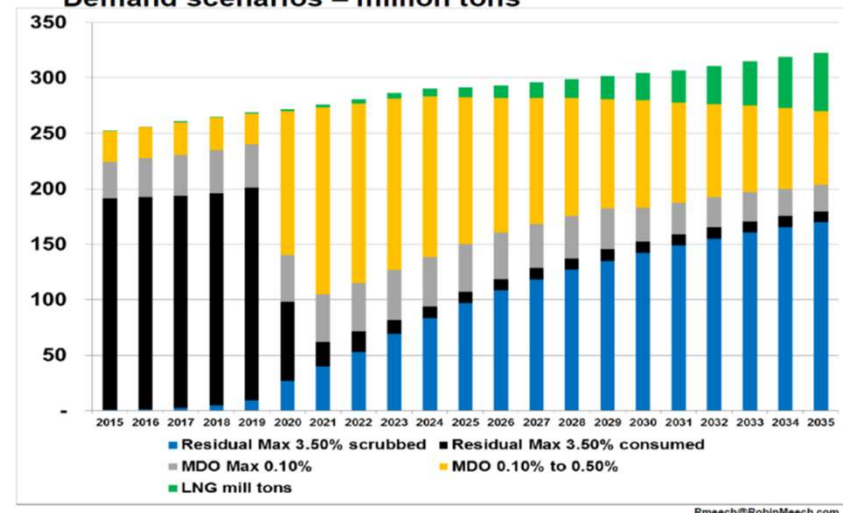
ROBIN MEECH
Marine and Energy Consulting Limited

Scrubbing economics

- Forecast gasoil-fuel oil differential ~\$321/mt
- Scrubber investment cost \$3-8mn, payback 1 year
- Scrubbing is in direct competition to residue destruction projects post 2020



Demand scenarios – million tons



• Positive for QFI and the MSAR® fuel solution:

- Higher distillate spreads = even better economics
- Low capex and quick implementation = <2 year payback by stakeholders
- Good fit with EGCS solutions, + lower NOx & PM

• Also positive for End Users with EGCS (“scrubber”)

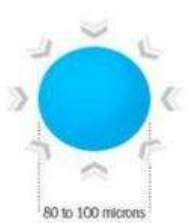
< 12 months to implement at refineries

MSAR® can be used as a permanent solution to residue streams as a result of new upgrading projects or as an interim solution to take advantage of high distillate spreads in 2020 and beyond.

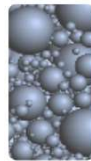
Economic & Environmental Benefits



BURNING HFO:

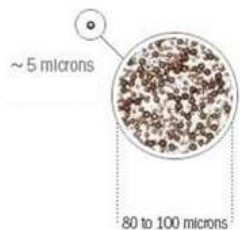


With MSAR®:
Tiny droplets of
residue are
dispersed in water



5-10 micron
droplets

MSAR®:



1. Energy Savings

- ✓ MSAR® is stored & transported at ambient temperatures (>25°C)

2. Efficient Combustion

- ✓ Complete Carbon burnout
= lower PM* emissions
= less Black Carbon (BC)

3. Lower NOx Emissions

- ✓ Water reduces the combustion temperature
= >20% lower NOx emitted

* PM = Particulate Matter
NOx = Oxides of Nitrogen

MSAR® is compatible with EGCS which enables affordable compliance with environmental standards

4. CO₂ Impact

- To provide 0.5%S by 2020 results in 17 Mt/y (11.6%) increase in EU refinery CO₂ emissions and \$19bn CAPEX.
- Partially offset by 8 Mt/y (5.5%) increase CO₂ emissions from scrubber energy requirements on vessel.
- ✓ Considerable CO₂ emission savings of 9 Mt/y (6.1%) CO₂ using EGCS vs. use of refined distillates.

Source: Concawe Report 1/13R (EU Refineries)

MSAR® Projects Update



Cepsa MSAR® Project (2016)



- 6 KBD MSAR® system installed at the CEPSA 240 KBPD* Gibraltar San Roque Refinery, initially to supply Maersk
- Quadrise responsible for MSAR® system installation, commissioning, operations, quality control
- MSAR® system designed to supply Marine or Power end users, installed in 9 months for <\$5m
- Processing visbreaker residue from LS or HS opportunity crudes
- Proven, reliable, 24/7, continuous operation



Cepsa Project: Scope



- Tie-ins and lines for residue supply/return to the Visbreaker
- New buffer tanks for VB residue & MSAR®
- New MSAR® unit & support infrastructure
- New tie-ins to existing pipework
- Cleaning & preparation of 14,000m³ tank
- Use of existing oil jetty

Cepsa Project: Fast-track Implementation



Site available, Civils started Mar'16



MSAR unit & equipment delivered Apr'16

Mechanical and E&I erection & integration Apr-May'16



Conventional Build

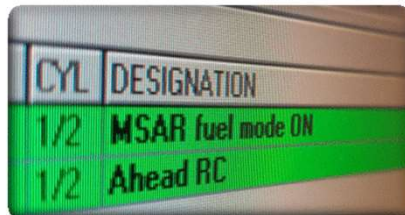
For larger refinery projects, conventional stick-built plants can also be designed and installed, as opposed to the previously illustrated modular approach, according to client's preferences & standards (Ex-Rated, Scada-controlled etc).



MSAR® for Diesel Engines

Synthetic HFO

- MSAR® is proven in Wärtsilä 4-stroke diesel engines
- JDA with Maersk commenced in 2008 to demonstrate MSAR® use in large 2-stroke diesel propulsion engines
 - Laboratory and land-based tests completed 2009-2013
 - Two sea-borne “proof of concept” vessel tests completed in 2014
 - Joint refinery scoping studies carried out during 2014-15
- “Operational LONO Trial” contracts with Cepsa and Maersk signed Q4 2015
 - Fast-track commercial-scale MSAR® facility installed & commissioned within 9 months
 - 1,400 MSAR® running hours on Seago Istanbul completed in 2017 and interim LONO received from Wärtsilä.



Proven long term handling, storage & shipping

MSAR® for Boilers for Power Generation

Synthetic HFO

- Significant worldwide emulsion fuel experience
- Experience applied to MSAR® improvements
- >60 million tons emulsion fuel fired : 50MWth to 770MW



Baseload Power Applications - Kingdom of Saudi Arabia (KSA)

Project: Replace up to 500KB/D of HFO used for power with lower cost MSAR® fuel (1):

- National imperative to reduce domestic crude oil use.
- Power facilities dominated by SEC (62%).
- 500KB/D HFO demand today cannot be met by domestic supply (>50% imports).
- MSAR® is an economic HFO option, freeing distillates, improving combustion and emissions of NOx and PM.
- Major utilities, OEMs and energy companies involved in MSAR® evaluation (part of the Unconventional Oil portfolio).



Major centres of oil-fuelled power generation

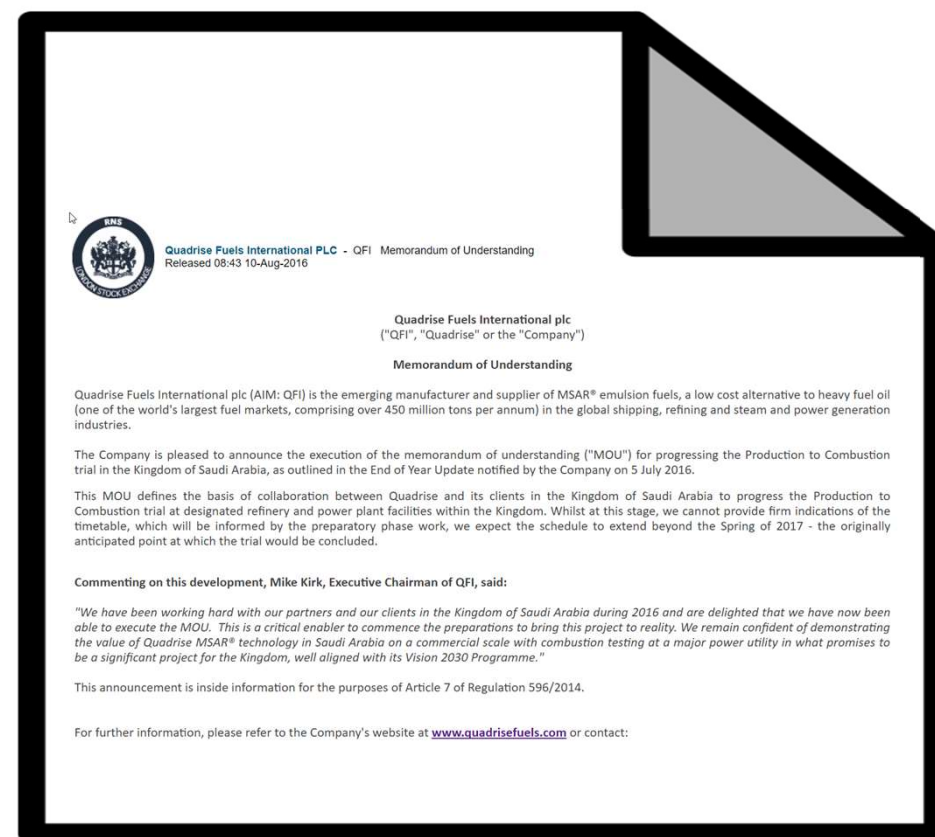


Major refining centres

Baseload Power Applications - Kingdom of Saudi Arabia (KSA)

Project: Replace up to 500KB/D of HFO used for power with lower cost MSAR® fuel (2):

- MOU signed with oil major is the culmination of extensive development work over several years.
- A baseload 400MWe boiler trial is scheduled to commence 2017 year end to supply ~1 million barrels MSAR® from a refinery, via tanker, for a 6 week trial during 2018.
- Commercial roll-out is planned later in 2018 on success with MSAR® supply from both domestic and regional refineries to the west coast power plants.
- Planned production of MSAR® in KSA will also result in a shortfall (vs 500KB/D HFO demand), requiring imported MSAR® from third party suppliers, e.g. Middle East, Med.





Global Opportunities



Complementary Global Opportunities

- Refinery power & steam opportunities.
- Synergies of working collaboratively with national oil companies and refiners at global fuel hubs to provide MSAR® for Marine & Power.
- Selected upstream opportunities.



Power

- Initial focus commercial roll-out in KSA for Power generation (**40%** of global power market).
- Expand selectively into other markets in Middle East and Asia.

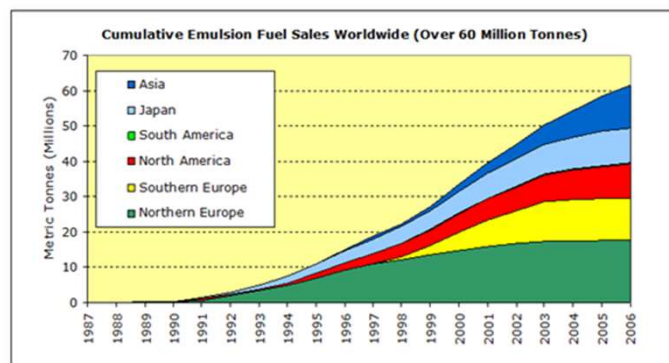


Marine

- Initial focus on using positive outcomes of marine trial to secure OEM (MAN & Wärtsilä) approvals for MSAR® use alongside scrubbers.
- Expand to commercial shipping operators deploying scrubbers supplied by fuel hubs.

MSAR® production is an opportunity for refineries seeking an **affordable, quickly implemented solution to improve distillate yields**. Either as a destination for residue streams as a result of 2020 upgrading projects, an interim solution or a standalone project.

Global Experience



MSAR®/Quadrise References – Global oil-in-water emulsion fuel use

Major ORIMULSION® Users (up to y/e 2006)

Plants in **Blue** indicate facilities where the **Quadrise team** were actively involved in engineering, commercial development (including evaluations) and operations.

Country	Plant Name	Dates Start-End	Boiler Design Fuel	Boiler Rating MWe	Orimulsion® Consumption [million tonnes] Per year Total	
					Per year	Total
Singapore	Power Seraya Stage I	04-06	HFO	3x250	1.5	2.5
Guatemala	Constellation Energy Planta Arizona	04-06	HFO	150 Diesel	0.3	1.0
South Korea	KOSPO Youngnam	03-06	HFO	2x200	1.0	2.0
China	GEPB Nanhai A/B ⁽²⁾	01-06	HFO	400 + 100	0.6	3.6
	GEPB Heng Yun ⁽²⁾	01-06	HFO	200	0.2	0.9
	GEPB Huang Pu ⁽²⁾	01-06	HFO	500	0.1	0.6
Italy	ENEL Fiume Santo 3, 4	99-04	Coal, HFO	2x320	1.1	4.0
	ENEL Brindisi Sud 1,2,3,4	98-05	Coal, HFO	4x660	1.4	8.0
Germany	RWE Ibbenbueren ⁽¹⁾	98-02	Coal, HFO	770	<0.1	0.2
Barbados	Arawak Cement	97-06	HFO	Cement Kiln	0.3	0.6
Denmark	SK Power Asnæs 5	95-03	Coal, HFO	640	1.4	6.1
Lithuania	LE Lietuvos Elektrine	95-06	HFO	150+Steam	0.2	0.7
Japan	Hokaido Electric Shiriuchi	97-06	Orimulsion®	350	0.2	0.8
	Kansai Electric Osaka 4	94-05	HFO	156	0.2	1.4
	Kashima-Kita 1	91-06	HFO	95+Steam	0.4	6.0
	Kashima-Kita 2	94-06	HFO	125+Steam		
Canada	NB Power Dalhousie 1	94-06	HFO	105	0.8	7.0
	NB Power Dalhousie 2	94-06	Coal	215		
UK	PowerGen Ince	91-97	HFO	500	1.2	5.2
	PowerGen Richborough	91-96	Coal	3x120	0.3	1.7

Notes: (1) ORIMULSION® was used as a start-up and combustion support fuel for coal.
(2) ORIMULSION® co-fired with LSFO.



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