

Enhanced Oil Recovery



A large source of oil often remains within reach of existing oilfield infrastructure after conventional production methods such as primary depletion and water flooding reach their economical limits.

Enhanced oil recovery (EOR) techniques are used to produce the remaining oil and have become an important part of how Maersk Oil develops oil fields.

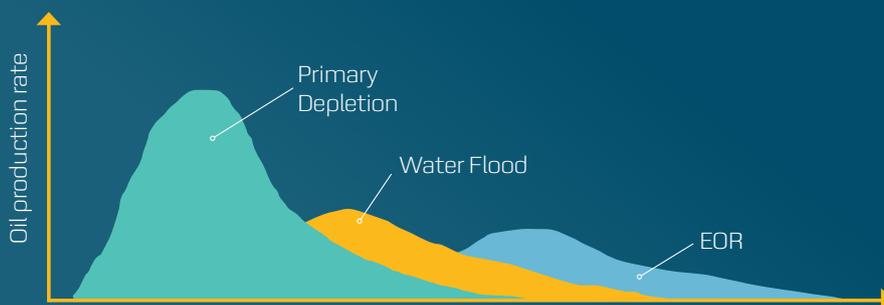
EOR is typically classified as the tertiary recovery process in field development. It primarily occurs after both primary production, when natural reservoir pressure drives production, and secondary recovery, when energy is added to a reservoir via a process that doesn't change the physical properties of the fluid.

With improvements in reservoir characterisation and modeling, engineers may find that water flooding is required at the start of a development project to offset pressure decline or even that an EOR method may be considered from the beginning of development.

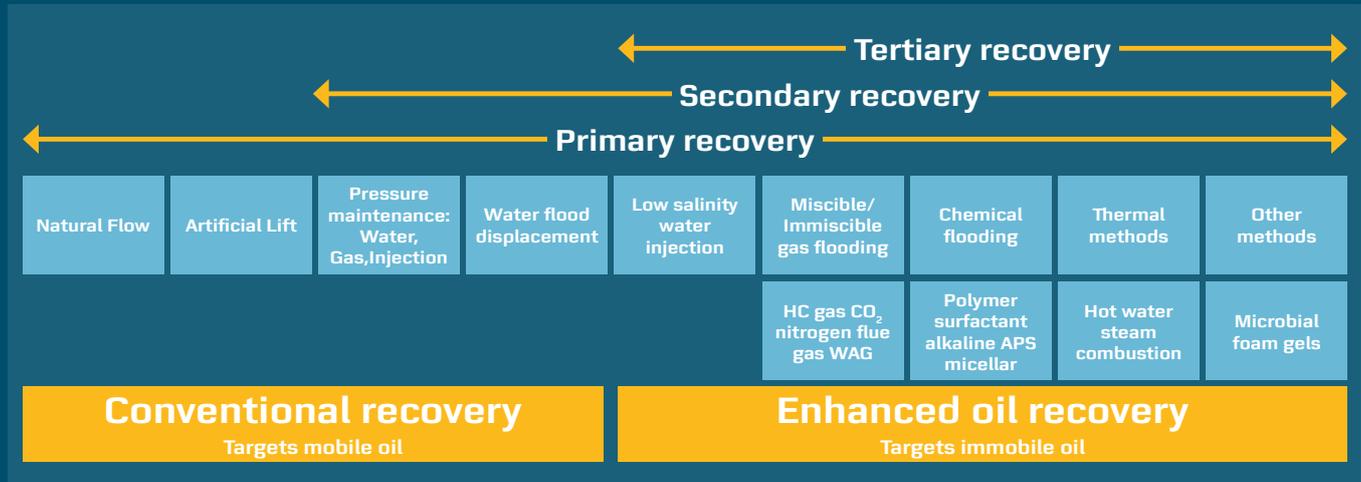
This is especially true when considering offshore assets, such as those that make up the bulk of our portfolio, where the lifecycle is limited and timely consideration is therefore crucial in order to maximise economic recovery.

Planning for EOR from the earliest stages of field development saves money, boosts ultimate recovery and ensures maximum return on investment.

Production life cycle of an oil



What is EOR?



Enhanced Oil Recovery methods

EOR methods include low salinity water flooding, hydro-carbon gas injection, thermal techniques, carbon dioxide flooding, polymer flooding, alkaline flooding, inert gas injection and surfactant flooding.

Within these EOR methods, hundreds of technologies are being researched and developed across the industry.

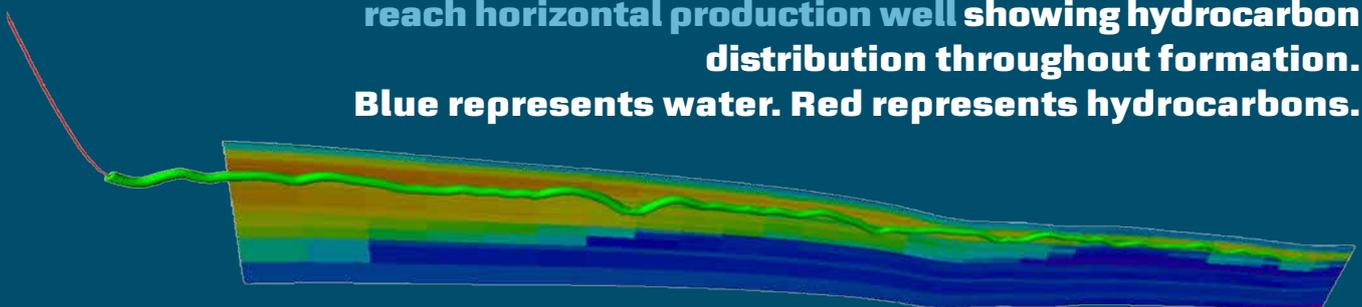
Maersk Oil collaborates with industry and educational partners on various research projects, with a strong interest and expertise in producing from tight carbonates, long horizontal

bore holes and the offshore environment.

Though, our research is not limited to these areas, they represent some of the unique challenges Maersk Oil encounters in our projects.

EOR has become an important part of how we develop oil fields. We currently have an actively operated EOR project in Qatar, and an active non-operated EOR project in Algeria. We have implemented secondary recovery techniques in almost all our assets in Denmark and UK by injecting water for pressure support and oil sweep.

Al-Shaheen vertical cross section with an extended reach horizontal production well showing hydrocarbon distribution throughout formation. Blue represents water. Red represents hydrocarbons.



EOR methods at a glance

Low Salinity Water Injection

reduces the tension between oil and water, alters rock wettability, which is the interaction between fluid and solid, and improves the oil sweep. It also aims to provide pressure support, an effective oil displacement.

Gas flooding

is applied for pressure support, sweep improvement, viscosity reduction, oil swelling and changing the oil composition. This method enables moderate to highest incremental recovery among all EOR methods.

Chemical flooding

improves sweep efficiency with a high viscosity injection fluid and/or change in wettability of oil bearing rock. It also reduces interfacial tension between oil and water by a factor of 1,000 or more to form a movable oil bank in a porous formation.

Thermal techniques

reduce the viscosity of oil with heat, by swelling the oil and changing the oil composition. These techniques achieve high incremental recovery and include methods such as hot water or steam injection, high pressure air injection or in-situ combustion.

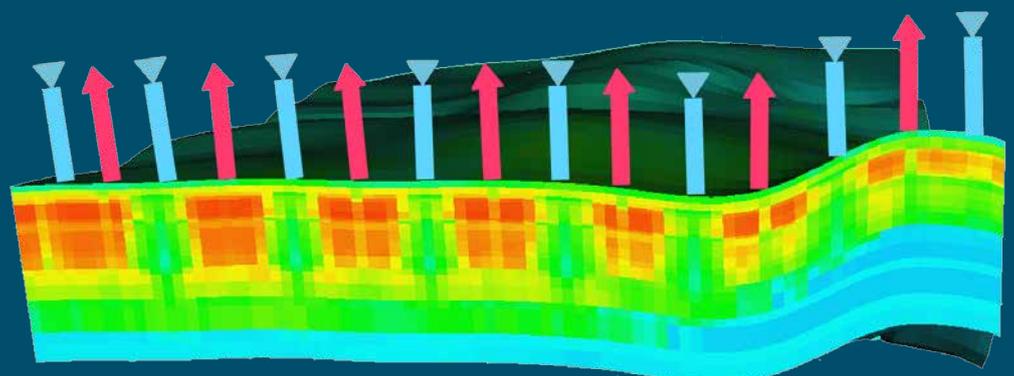
Water Alternating Gas at Al-Shaheen

Maersk Oil has had notable success with Water Alternating immiscible Gas (WAG) EOR at our Al-Shaheen field in Qatar. The success of this mechanism, alternating injections between water and gas, relies on the ability to predict incremental oil recoveries. This is done using robust fluid models that describe the properties of different oil types and injection gases. While the gas is the agent to reduce

oil viscosity, the water is used to sweep the oil. When alternating the injections of the gas and water, our engineers have better control over the movement of the hydrocarbons. While this mechanism is used throughout the industry, Al-Shaheen is considered unique as it is one of the largest offshore WAG projects in the world, and uses ultra-long horizontal wells for injection and production.

A cross sectional representation of a Water Alternating Gas (WAG) EOR scenario in Al-Shaheen displaying 3D change in saturation.

Red represents hydrocarbons.
▼ Injection wells
▲ Production wells



Low salinity water injection

Low salinity water injection is a fairly new, yet potentially very significant mechanism as the application and operations are very simple and inexpensive as an increment to water flooding. The success of this mechanism relies on a positive exchange between the oil and rock surface when the salt content of the water is diluted. Diluting the salinity of

the water within the formation changes the 'wettability' of the rock. It causes a shift in the rock parameters from oil-wet, when oil sticks to rock, to water-wet, when water sticks to rock and forces the oil to move from the rock surface. Our researchers are currently testing low salinity water injection in the lab and have experienced promising results.

EOR Development Lifecycle

Improving efficiency in every step of the EOR roadmap.

EOR projects are among the most complex and difficult undertakings in the upstream industry. Success lies in improving efficiency in every step of the EOR roadmap by synchronising diverse measurements, applying advanced technologies and integrating knowledge across multiple domains.

Maersk Oil continues to develop promising EOR mechanisms. Getting a particular mechanism ready for implementation on large scale production may take many years.

FROM SCREENING TO FULL FIELD EXPANSION



1-5 years

+5 years

Project execution and risk reduction through established processes, technology and expertise.