

Proud to Serve Oman

Pathways to Sustainability

شركة تنمية نفط عمان
Petroleum Development Oman



His Majesty
Sultan Qaboos bin Said

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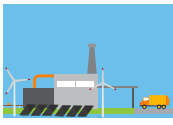
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Introduction

Petroleum Development Oman (PDO) is responsible for producing some 70% of Oman's oil and gas production. With this operatorship comes a great responsibility. We need to ensure our operations and activities are carried out in a manner that causes no harm to people or the environment. How we utilize Oman's valuable natural and physical resources on a daily basis affects not only our performance but also the ability of future generations to access and enjoy these same resources in the short or longer term. We remain committed to ensure compliance with the Sultanates laws and regulations. At the same time we are also constantly thinking about how we can further improve our performance. To achieve this ambition, we are embracing many internationally recognized environmental best practices. We are also actively seeking out new and innovative green technologies and solutions to help further reduce our environmental footprint. We have embedded this same 'think green' mindset into our new residential development at Ras Al Hamra as well as across our headquarters at Mina Al Fahal where energy efficiency, water conservation and the integration of renewable energy remain at the forefront of managing our operations responsibility.

Through this booklet you will learn about some of the ways in which we have brought together energy and innovation to produce greener solutions. Each of these examples provide some of the tangible ways in which we are helping to positively contribute to Oman's energy future.











HE Minister of Environment and Climate Affairs Message

Allah the Almighty has bestowed Oman with a range of natural resources and environmental diversity which we must conserve and sustain. Since the dawn of the renaissance under the wise leadership of HM Sultan Qaboos bin Said, the Sultanate has endeavoured to enact environmental laws with regulations that are geared towards environmental conservation.

There is no doubt that the world is witnessing an increasing interest in environmental issues which include protecting it against pollution so that it may be preserved for current and future generations. As such, fruitful inter-institutional collaboration can play a vital role in unifying these efforts and achieving shared environmental goals.

The Ministry of Environment and Climate Affairs has managed to complement the environmental systems and processes and update all environmental laws and regulations. The Ministry has also completed its digital trans-formation which has paved the way for providing high-quality e-services, streamlining procedures, accelerating transactions, as well as adopting the LEAN approach to save time. These efforts have allowed the Ministry to lead the way in continuous improvement initiatives, which has gained the approval of local and global institutions and investors.

In this vein, the wide range of PDO's environmental efforts and projects provide examples of environmental conservation and optimum use of natural resources. This is especially the case for its award-winning renewable energy and produced water utilisation ventures which have gained regional and international recognition.

In order to live in a clean environment, we must unite our efforts to protect it and strike a balance between environment and economic development. Only then can we ensure the right of posterity to live in a safe and healthy environment.



H.E Mohammed bin Salim bin Said Al Tobi
Minister of Environment and Climate Affairs



Managing Director's Message

At all times, PDO seeks a high standard of environmental performance and aims to promote long-term benefits to our shareholders, our employees and the society of Oman as a whole. To achieve this, we are committed to complying with legal and regulatory requirements, our corporate policies and procedures, as well as the prioritised adoption of international standards and best practices.

In recent years, we have launched a raft of new initiatives to complement our flagship projects, such as the large scale Miraah project in the Amal field which harnesses energy from the sun to create steam and the immense natural wetlands scheme we have created in the Nimr field to treat produced water. These groundbreaking projects underline our dedication to environmental stewardship, as well as demonstrating how we are innovating our approach to energy and water management choices. We have also recently installed thousands of solar panels onto our car parks at Mina Al Fahal headquarters in Muscat, the result of which will be the provision of around 6MW of renewable energy to our offices.

We recently joined the World Bank Zero Flaring Initiative – a programme which encourages governments, companies and development organisations to work closely together to end continuous flaring by 2030. As part of this approach, we will continue to strive towards implementation of economically viable solutions to eliminate routine flaring as soon as possible and ahead of the World Bank target date. Overall, our environmental performance has seen steady improvement, with a substantial fall in the number of oil spills, a significant reduction in flaring intensity and the development of a new waste management plan. However, we see our energy journey as one of striving for continuous improvement.

Underpinning all these exciting initiatives is our long-held desire to protect and preserve our environment while developing ever-more efficient exploration and production techniques. In the future, we will transition from an oil and gas company to a full-scale energy business, where renewables will play an increasingly important role.

In a rapidly changing world, you can be sure that we will stay committed to a path of continuous improvement as we strive to contribute to the sustainable development of Oman's economy, society and environment.



Raoul Restucci
Managing Director





استدامة
ESTIDAMA



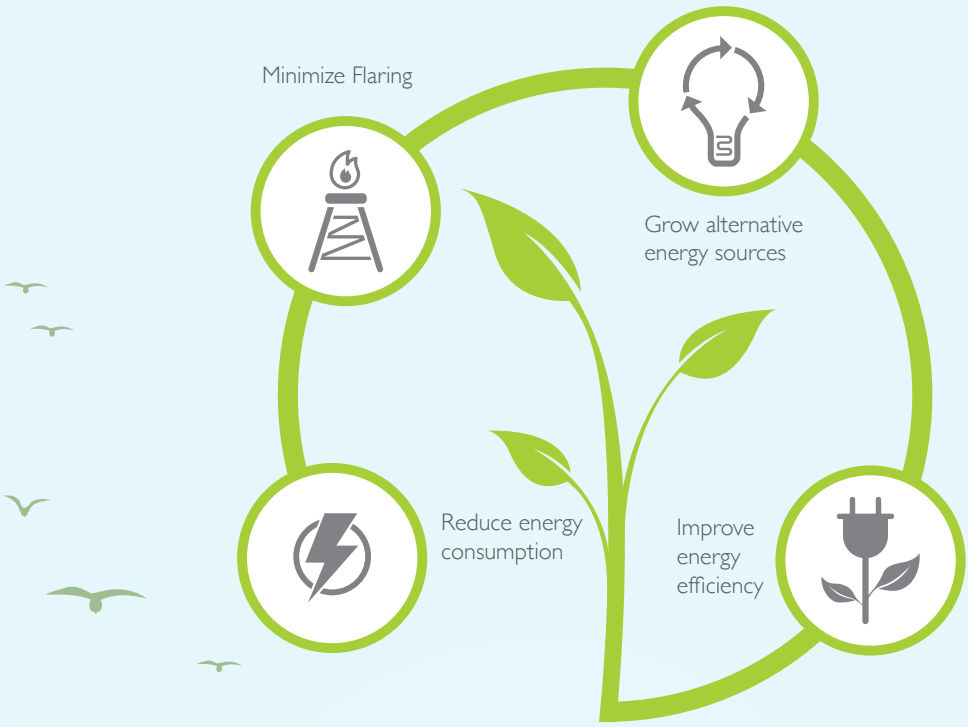
Energy Management

be part of the change



ENERGY MANAGEMENT

Using energy efficiently in our operations means we can divert the energy we save to other sectors of the economy and society. At the same time, the efficiencies we gain help us to reduce the greenhouse gas emissions we emit and therefore reduce our carbon footprint. Our strategy for energy management and greenhouse (GHG) management is built around four key focus areas:



In this section we will focus on a number of projects we have implemented into our assets and projects to help us drive further efficiency improvements into our existing and future operations.

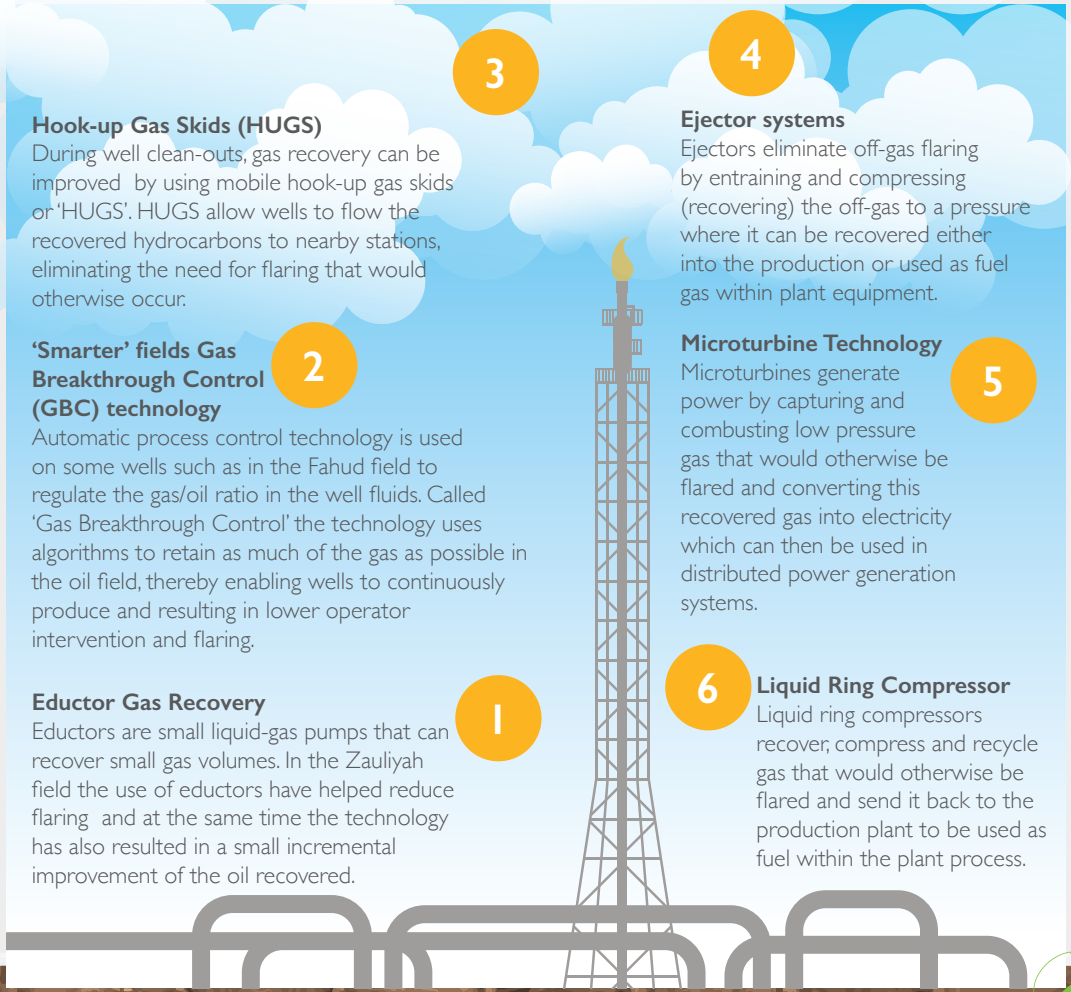


MINIMISE FLARING

Flares are an important part of oil and gas facilities as they provide a safe and controlled means for the disposal of gas during non-routine or emergency events. Associated gas is typically produced as a byproduct of the production of crude oil. One of the most effective way of minimizing flaring in existing operations is to find economic uses for the gas.

We have had a policy of no continuous flaring in all new developments and facilities. We have also been taking proactive steps to minimize flaring of associated gas in our existing facilities. We have implemented a wide range of flare reduction approaches ranging from capturing the gas and using in within our processing facilities, converting the gas into electricity and by improving equipment reliability and availability.

Importantly, many of the flare reduction technologies we have trialed (e.g. microturbines) can be replicated in other fields within PDO. We also recently joined the World Bank "Zero Routine Flaring" initiative (ZRFI). The ZRFI is an internationally recognized mechanism that aims to eliminate the legacy of routine (or continuous) flaring. Below is a brief description of some of the implemented flare technologies that are being deployed to further minimize flaring in our operations.



3

Hook-up Gas Skids (HUGS)
During well clean-outs, gas recovery can be improved by using mobile hook-up gas skids or 'HUGS'. HUGS allow wells to flow the recovered hydrocarbons to nearby stations, eliminating the need for flaring that would otherwise occur.

2

'Smarter' fields Gas Breakthrough Control (GBC) technology
Automatic process control technology is used on some wells such as in the Fahud field to regulate the gas/oil ratio in the well fluids. Called 'Gas Breakthrough Control' the technology uses algorithms to retain as much of the gas as possible in the oil field, thereby enabling wells to continuously produce and resulting in lower operator intervention and flaring.

1

Eductor Gas Recovery
Eductors are small liquid-gas pumps that can recover small gas volumes. In the Zauliyah field the use of eductors have helped reduce flaring and at the same time the technology has also resulted in a small incremental improvement of the oil recovered.

4

Ejector systems
Ejectors eliminate off-gas flaring by entraining and compressing (recovering) the off-gas to a pressure where it can be recovered either into the production or used as fuel gas within plant equipment.

5

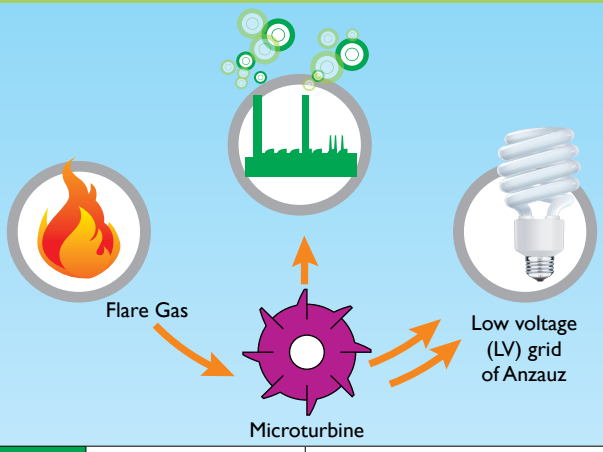
Microturbine Technology
Microturbines generate power by capturing and combusting low pressure gas that would otherwise be flared and converting this recovered gas into electricity which can then be used in distributed power generation systems.

6

Liquid Ring Compressor
Liquid ring compressors recover, compress and recycle gas that would otherwise be flared and send it back to the production plant to be used as fuel within the plant process.

Microturbines Converting gas into power

A future of reducing overall flaring in the concession area by converting gas into electricity



Currently at PDO	Reducing Anzuz flared gas by approximately **1500 m3/day**	Generating a steady output of around **185 - 195 Kilowatts of electricity**

Zero Flaring in Well Test Operations

Improvement in well test flaring performance in PDO started with the use of green burners. Green burners work by mixing air with hydrocarbons from the tested well to produce fine droplets which can then be safely combusted. This mixing helps enable proper atomization of the hydrocarbons which in turn allows for good ignition and combustion to occur, reducing the amount of solid particulates such as ash, soot, unburnt hydrocarbons or the production of black smoke.

Green burners have improved the environmental performance associated with our well testing. However a further initiative was subsequently launched that now strives to create zero flaring from our well test operations. Depending on the well to be tested, we evaluate the available options and choose the one most suitable for the location and well test conditions. Options include:

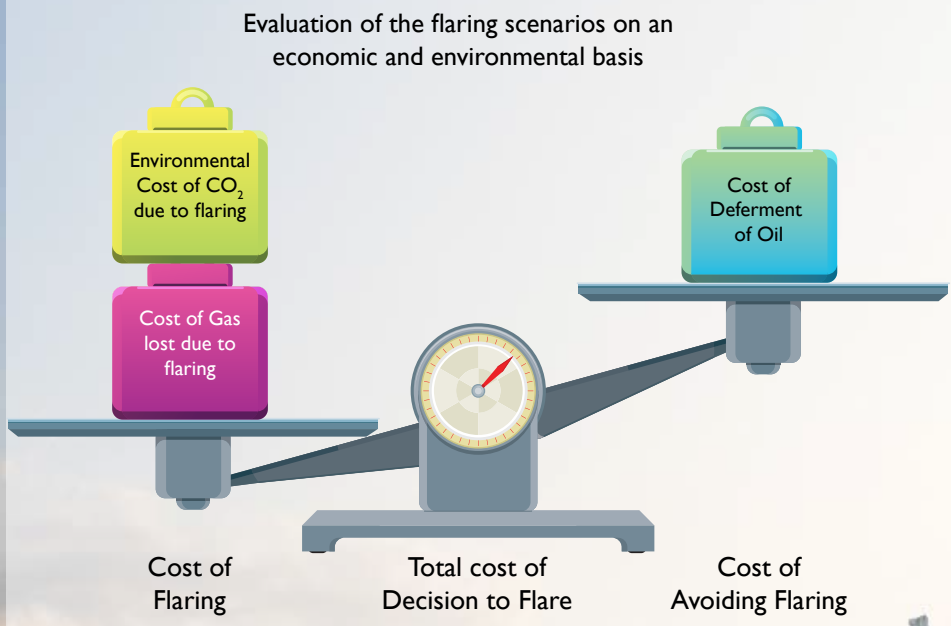
- Conduct inline testing whenever possible. This means we flow reservoir fluids directly to nearby stations where practicable. This option requires flowline installation and is mainly feasible in our development wells. This option can be applied to both oil and gas wells.
- Injection to nearby flowline or wells. This approach requires additional piping, storage and pumping capabilities suitable to the well production and target line/wells. This option is mainly applicable to our oil wells.
- Storage and trucking of oil. This approach requires additional storage and trucks to carry the oil to nearby stations or sludge farms. This option is only applicable to our sweet oil wells i.e. those wells uncontaminated with hydrogen sulphide (H_2S).

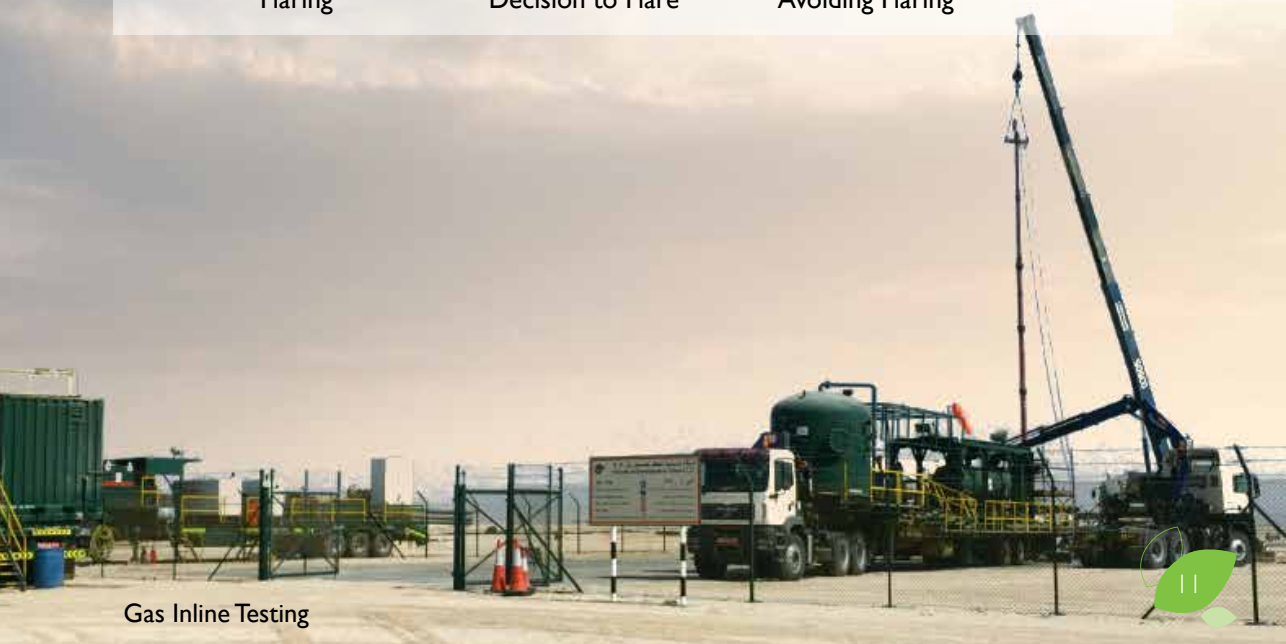


Oil storage and trucking

Flaring Waiver and ALARP Demonstration Tool

Currently in our oil facilities, around 1-2% of total oil and gas production is lost due to flaring. Of this, non-routine operational flaring comprises more than 70% of our total overall flaring. Gas is an important and valuable natural resource and the unnecessary loss of it can lead to lower efficiencies as well as the release of greenhouse gas (GHG) emissions which contribute to climate change. To help combat operational flaring, we have developed an electronic system through which our management can make informed, value-led decisions on whether it is economically and/or environmentally preferable to flare during non-routine events such as when plant operating conditions are upset or if equipment (e.g. compressors) are temporarily unavailable. The flaring waiver and ALARP (as low as reasonably practicable) demonstration tool evaluates each flaring scenario on a case by case basis to help determine when we should reduce flaring within our operations.





Gas Inline Testing

RENEWABLE ENERGY

We remain committed to reducing our energy consumption and seeking new ways for providing alternative energy supplies. Presently, our operations are in large, fully dependent on fuel gas to generate electrical power for our business needs. However, we are also aware the level of solar irradiation (clearness) in Oman is among the highest in the world and that there is significant potential scope to integrate solar into our operations. In this section, we highlight some of the major solar projects undertaken to date:

Miraah - Solar Steam Generation System

Miraah, once completed, will arguably be one of the largest solar projects in the world producing some 1,021 megawatt (MW) of peak thermal energy. Miraah will capture and concentrate the sunlight to generate around 6,000 tons of solar steam each day. The steam will feed directly into our existing thermal enhanced oil recovery (EOR) operations, providing a substantial portion of the steam required at the Amal oil field in Southern Oman.

At the same time, Miraah will save around 5.6 trillion BTUs (British Thermal Units) of natural gas each year, freeing up gas that would otherwise be burnt to produce the steam. The mega Miraah project is more than 100 times larger than the existing pilot project built by our partners GlassPoint Solar for PDO in 2012 which generates some 50 tonnes per day of steam. The full-scale Miraah project will comprise 36 glasshouses, built in succession and commissioned in modules of four.

Meet Miraah
The Worlds Largest Solar Thermal Plant

2015 Construction Start

2017 First Steam

Use of solar instead of burning gas to make steam

Miraah will reduce **GHG** emissions by more than **300,000** tons each year

Equivalent to taking about 63,000 cars off the road

6,000 tons Daily Steam Output

3 kms² or **741** acres Project Area

36 Glasshouses



Car Park Solar Panels

We have installed thousands of solar photovoltaic (PV) panels into our car parks at Mina Al Fahal to supplement the power used in our headquarters at Muscat. The 5.92 MWp (megawatt peak) solar carpark project will generate around 9,500,000 KWh (kilowatt hours) per year of solar electricity and save about 42,000 m3/d of gas that would otherwise be burnt to generate the same electricity. The solar electricity generated from the rooftops of the carparks will be connected to three of the main office buildings and feed into the domestic grid at off-peak times.



PDO Adopts Solar Power for Headquarter Offices in Muscat

Enough power to provide electricity for almost

1,000
homes

Cuts greenhouse gas emissions by around

6,700
tonnes annually

Equivalent of taking more than

1,400
cars off the road

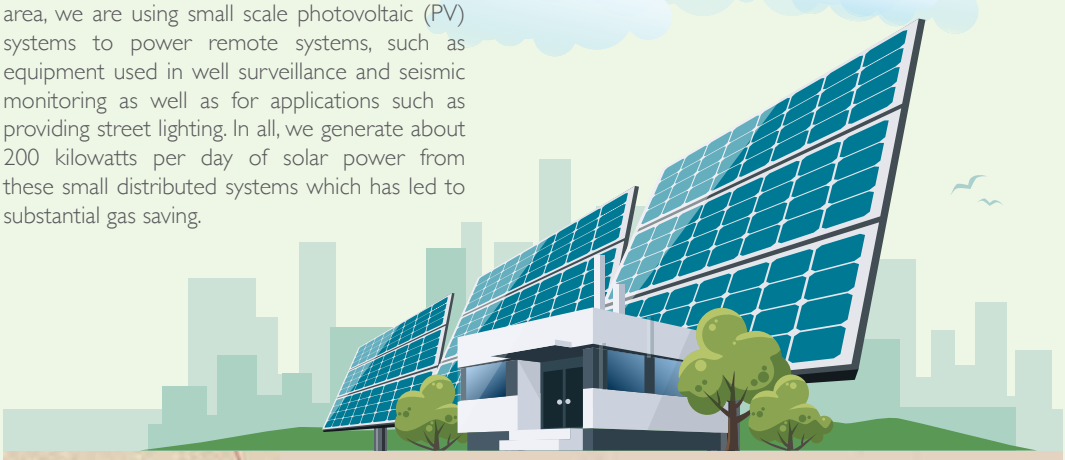
Equivalent to planting around

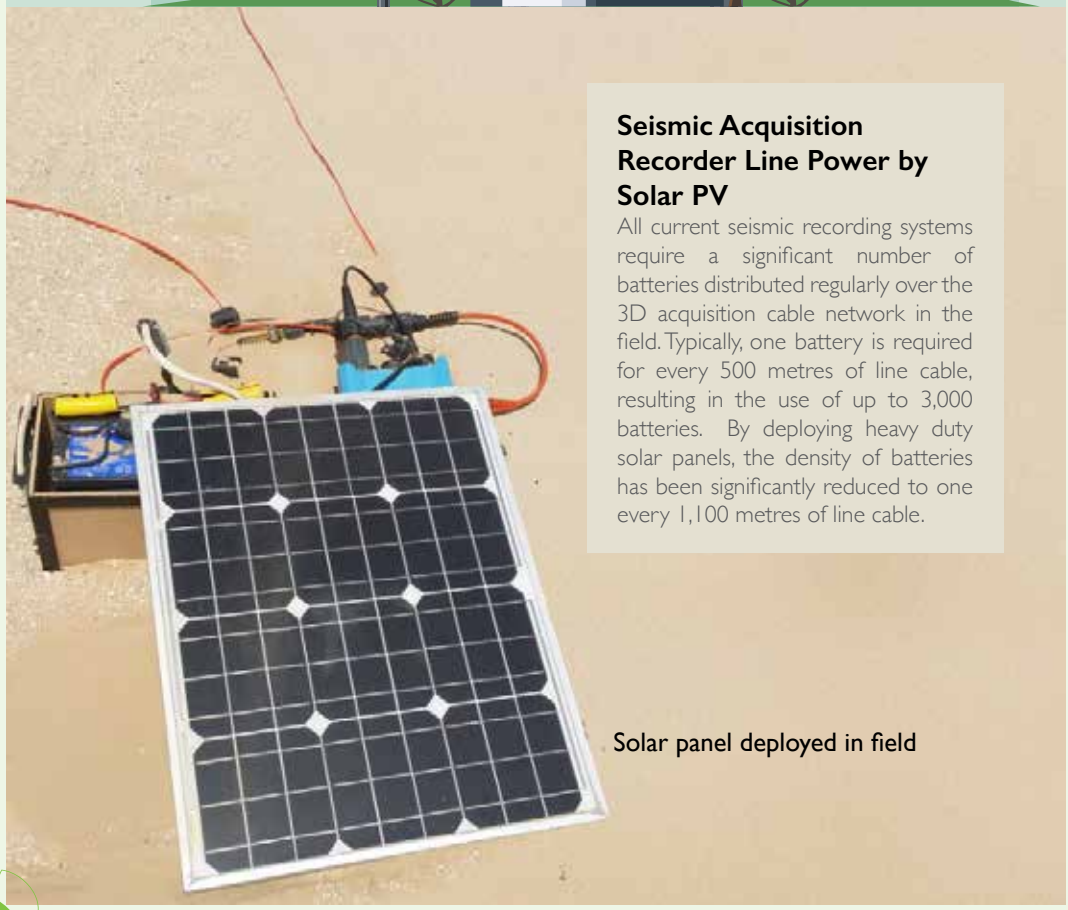
173,000
trees

Saving more than 3.1 million cubic metres of gas a year

PV in Well Surveillance and Seismic Monitoring

At multiple remote locations in the concession area, we are using small scale photovoltaic (PV) systems to power remote systems, such as equipment used in well surveillance and seismic monitoring as well as for applications such as providing street lighting. In all, we generate about 200 kilowatts per day of solar power from these small distributed systems which has led to substantial gas saving.





Seismic Acquisition Recorder Line Power by Solar PV

All current seismic recording systems require a significant number of batteries distributed regularly over the 3D acquisition cable network in the field. Typically, one battery is required for every 500 metres of line cable, resulting in the use of up to 3,000 batteries. By deploying heavy duty solar panels, the density of batteries has been significantly reduced to one every 1,100 metres of line cable.

Solar panel deployed in field



Solar Light-Emitting Diode (LED) street lights



Solar water heater

Energy EFFICIENCY

Improving energy efficiency allows us to produce more energy for less effort. Improvements in how we generate and use energy can be seen through the introduction of a range of technologies we have incorporated into our operations, such as the integration of cogeneration and waste heat recovery systems into our steam generation facilities which has improved the energy efficiency of our power generation significantly.

LED lighting replacement project Energy-Saving



More than
49,000
total number of replacements

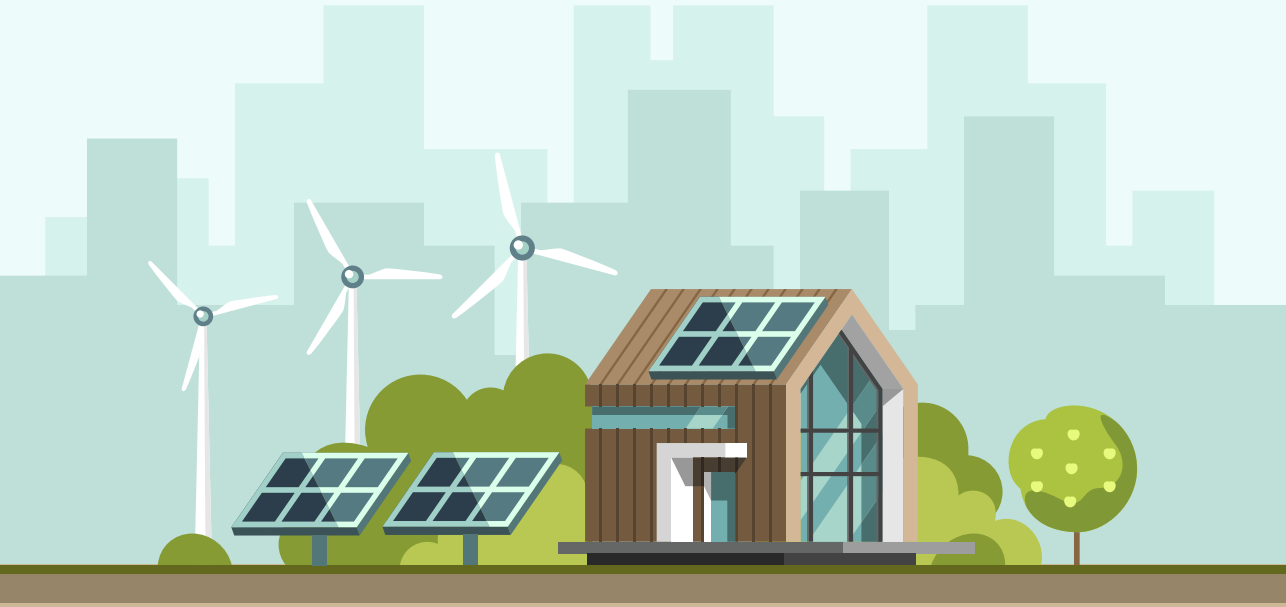


Tubelight
"2 Feet LED &
4 Feet LED Lights
50%

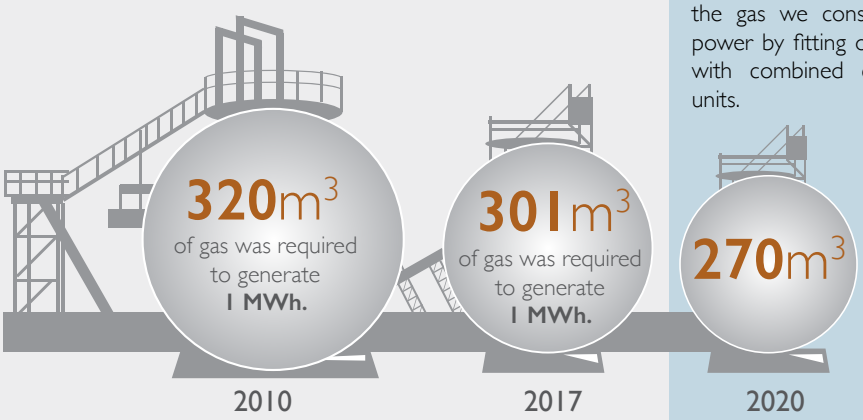
Percentage of saving
LED vs Conventional Lights



88%
Street Lights



Gas required to generate 1 MWh.



By 2020 we aim to further reduce the gas we consume to generate power by fitting our power stations with combined cycle gas turbine units.

As part of our bid to reduce domestic power demand by 4% per annum from 146 MW to 126 MW (launched in 2013), we managed to cut our energy demand by 3% in 2016.

Cogeneration

PDO is constructing several new power stations that will generate not only electricity but also steam. This is because hot exhaust gases emitted by the stations can be used to boil water in a process referred to as cogeneration. By utilising the power station's waste heat to cogenerate steam, most of the energy required for PDO's steambased EOR projects can be obtained without burning additional fuel or emitting additional carbon dioxide (CO2). We are constructing several new power stations that will generate electricity and steam at the same time. The process is referred to as cogeneration and captures hot exhaust gases from the turbine and uses this energy to boil water to produce steam. By using the power station's waste heat to produce cogenerated steam, most of the energy required for our steam based EOR projects can be obtained without burning additional fuel or emitting additional carbon dioxide.

Consumption Optimization

A key energy efficiency measure adopted by the Mabrouk Phase III project involved optimising the total power requirement for both the air cooler and gas export electric heater by using gas/gas heat exchange. Around 2900 kilowatts per day is saved from both the air cooler and electric heater.



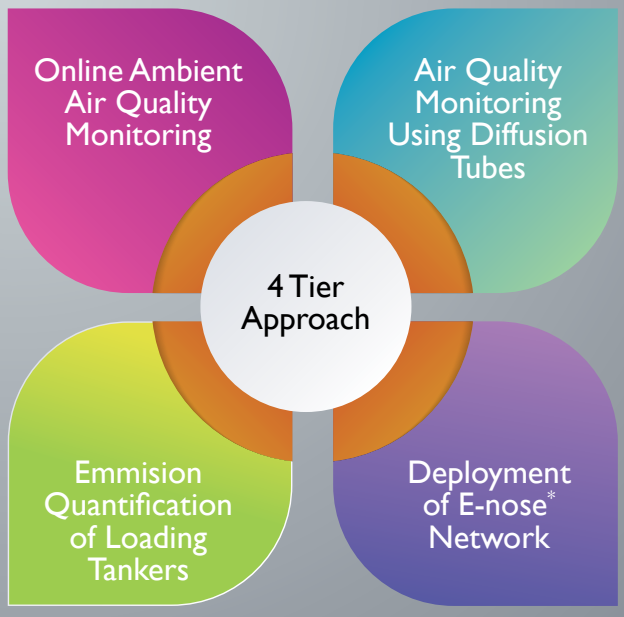
Pioneering Sustainability Initiatives at Ras Al Hamra

The following are some of the sustainability initiatives which are being implemented for the first time on a large scale in Oman at our Ras Al Hamra housing and leisure development project:

- The use of the External Insulation Finishing System (EIFS) for building external cladding to reduce the heat loss and minimise energy consumption
- Energy-efficient heating, ventilation and air-conditioning (HVAC) design through controlled refrigeration
- Air handling units within individual houses to significantly reduce energy consumption when compared to traditional window AC/split AC unit

Air Emission Management

Our operations (Interior and Coast) include a wide range of hydrocarbon based activities handling, storage, bunkering, filling, transporting and treatment processes. Each of these processes can result, to a greater or lesser extent, in the emission of some air pollutants. These pollutants can arise from point source emissions, for example from a flare as well as from small fugitive sources such as from passing valves. To monitor the impacts from point source and fugitive emission sources and to maintain best industrial practice, we have initiated a four-tier approach to assessing air quality on a regular basis:



**Electronic noses, in short eNoses, are compact instruments comprising a sensor array that respond to small variations in the reactive gas concentration in ambient air.*

Ambient Air Monitoring

We regularly monitor ambient air quality to assess the impacts of our localized emissions to ensure no harm arises to the environment and/or human health. Within our operations, we are constantly striving to minimize our air emissions which arise mainly from the combustion of fuels, flaring of gases and transportation.

In order to monitor the ambient air quality across the concession area, a total of three mobile units have been deployed. These units cover areas depending on the risk level and receptors sensitivity. Based on this, a plan was developed jointly with the Ministry of Environment and Climate Affairs to select monitoring areas and locations. Monitoring data are used to assess the air quality against thresholds and trigger interventions. In addition, a number of diffusion tubes had been deployed to establish baseline and provide data for detailed air quality assessment.

Odors

To identify sources of odors at Mina Al Fahal industrial complex, we have installed a network of 'electronic noses' (eNoses) comprised of 9 fixed and one mobile e-nose device. These electronic noses are compact instruments which consist of a sensor array that responds to small variations in the reactive gas concentration in the ambient air. The eNose triggers an alert when it detects a change in the chemical air composition that may be malodorous.

H_2S

PDO is breaking new ground in sour gas production i.e. gas containing significant concentrations of hydrogen sulphide or H_2S. H_2S is highly toxic gas and therefore managing and mitigating the risks from sour operations is paramount for the safety of our staff, contractors and local communities. At Yibal Khuff we are implementing state-of-the-art gas processing and a sulphur recovery plant with a configuration that combines no fewer than seven different technologies to safely treat and manage the H_2S.

SO_x & NO_x

Combustion of fossil fuels may result in the release of air pollutants such as sulphur and nitrogen oxides into the atmosphere. In order to understand the impact of these air emissions and the level of compliance to local and international air emission standards, we have mapped all combustion sources within our operations such as flares, power plants, and incinerators on a geographical information system (GIS) platform. A unique calculation methodology for different combustion equipment types has been developed and air dispersion modelling conducted at all locations which may pose a high risk of emission exposure. Additionally, ambient air quality monitoring using diffusion tubes has been carried out and has demonstrated the risk of emission exposure is ALARP.



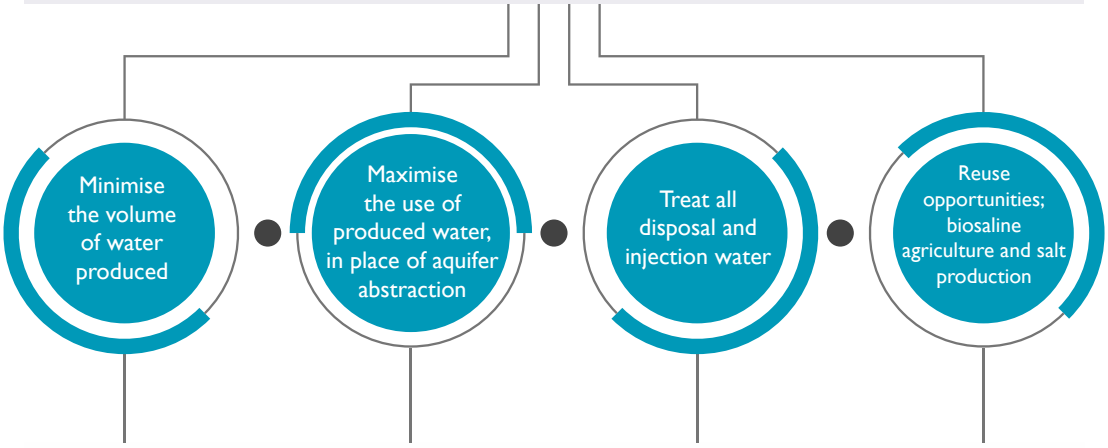

QUALITY

Water Management

Water MANAGEMENT

The main source of water in our facilities is produced water, which is brought to the surface along with oil, often in significant volumes. Overall, some nine barrels of water are produced for every barrel of crude we extract, and this is set to increase over the coming years as the producing oil fields mature. In addition to produced water, we use water from aquifers for water flood projects, and as raw water to generate steam.

To sustain oil production, we need effective management of the produced water we generate and also efficient management of the water we use. Our water management strategy is founded on four key principles:





Nimr Wetland Project

The internationally recognized Nimr wetland project is widely acknowledged as one of the most innovative, environmentally friendly innovations in the global oil and gas sector. The project, operated with our partner Bauer Nimr is one the largest industrial constructed wetland system in the world, consisting of a series of sloping reed fields and evaporation ponds, in all the size of 640 football pitches. The project is currently treating approximately 175,000 m^3/d of produced water with far less energy intensity than conventional deep-water disposal. In total, by the end of 2017, it had processed approximately 230 million m^3 of produced water and recovered near to 1,800,000 US barrels of oil since operations began in October 2010. The pioneering enterprise has led to a greening of around 10.5 km2 of desert and a projected saving of 24 billion cubic feet of gas over 10 years — a 98% reduction in energy requirements.

About

300,000

tonnes of CO_2 reduction per annum

More than

120 Birds

and 2 fish species recorded

Around

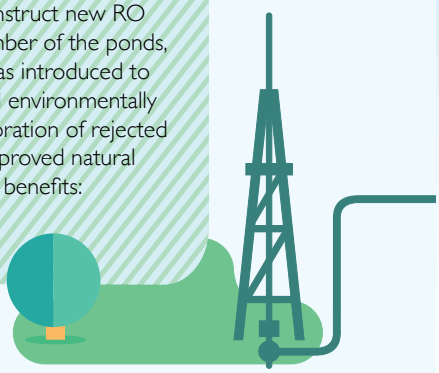
175,000 m^3/d

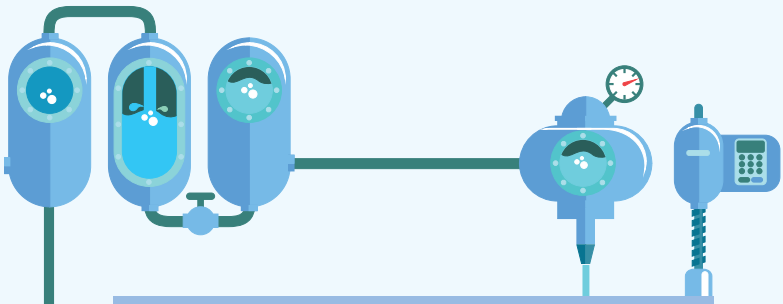
of produced water treated



Assisted Evaporation for Reverse Osmosis (RO) Rejected Water

The volume of reverse osmosis (RO) reject water is slowly increasing due to the increase demand on RO plants water. This waste water is disposed of into evaporation pits. Due to the low evaporative efficiency of these ponds and the change in weather conditions across the year, there is always a need to construct new RO evaporation ponds. To minimize the number of the ponds, a new mechanical drive technology was introduced to provide a fast, efficient, economical and environmentally friendly solution to accelerate the evaporation of rejected water. The mechanical system has improved natural evaporation with the following benefits:





Avoids potential for overflow that can sometimes occur with natural evaporation systems

Avoids mist/particles occurring outside the lined ponds

Reduction in the need for new pit construction

Water Optimisation

Reverse osmosis (RO)

We carried out an optimisation trial at a potable water reverse osmosis (RO) plant and successfully increased permeate recovery and reduced RO reject disposal volume by **17%.** These learnings will be incorporated into other potable water RO plants with the anticipation of reducing the RO reject disposal volume by **7,000 m³/d** and aquifer abstraction by **28,000 m³/d** by 2020.

Forward Osmosis (FO)

The use of innovative forward osmosis (FO) desalination technology, particularly to treat RO reject water has further reduced both aquifer abstraction and disposal. In **2016,** PDO's water consumption from its desalination units decreased by **7%.**

Reuse Opportunities

We have commenced a four-year research project with Bauer Nimr to evaluate and demonstrate, at field-scale, the reuse of treated produced water for irrigating valuable salt-tolerant plants in order to apply this concept at a larger scale in future. After different levels of wetland treatment, **13** plant species using three water qualities, varying in salt and boron concentrations are compared. The research work covers an area of about **22** hectares and draws on about **2,000–2,200 m³/day** of treated produced water from the wetlands.

We also have ongoing collaboration work with Sultan Qaboos University in Muscat to use local soil and low-salinity treated produced water to manufacture compressed stabilised soil blocks as a way of reducing construction costs. Preliminary findings indicate that the new compressed blocks possess good strength and thermal insulation and consume a lower quantity of cement than conventional cement blocks. Further trials and analysis are underway in the hope of eventually commercialising these stabilised soil blocks in Oman.

Water Efficiency
The Ras Al Hamra (RAH) Project

A concerted effort has been made to optimize potable water consumption and prevent any unnecessary watering at PDO's Ras Al Hamra residential and leisure project. This has resulted in an overall water consumption reduction and savings of up to 40% (RAH project) and 66% at the PDO School. Methods used include:

- Installing drip irrigation systems with automatic timer control settings and rain sensors
- Using automatic irrigation control with remote monitoring systems and software to control water use for a state-of-the-art golf course
- Employing grey water treatment for non-potable uses, such as toilet flushing, irrigation etc
- Planting native/ adaptive plants for the landscaping
- Using low flow water faucets to control the flow of water

Reduce downhole water from subsurface (Downhole Oil Water Separation)

We are continuously evaluating the use of many new innovative water and energy technologies such as down-hole technology (DHT). DHT is used to separate the oil from the water by using a combination of gravity and coalescing plates which enables the unwanted water to be safely disposed to a zone down below the production zone within the same well.





Environmental Performance

Environmental Performance and Management

PDO seeks a high standard of environmental performance with the aim of furthering the long-term benefits to its shareholders, its employees and the society of Oman as a whole. To achieve this, the Company has committed itself to pursue Goal Zero - "No harm to people and environment" through compliance with regulatory and corporate requirements, as well as prioritized adoption of international standards and best practices. This section provides synopsis of overall PDO Environment performance and management.

Environmental Performance Dashboard

Establishing key performance indicators (KPIs) is a fundamental step to ensuring continued environmental improvement. Many enhancements have been identified for the current PDO environmental dashboard, such as the need to link certain KPI indicators to the overall production from oil and gas, as well as the use of international benchmarks for performance. The dashboard is updated every month with easy access to all employees.

Development of the Environmental Legal Register

A desktop review of the related environment regulations was conducted to establish a PDO-related Environmental Legal Register. Information gathered was acquired from different related bodies (e.g. Ministries of Legal Affairs, Regional Municipalities and Water Resources and Environment and Climate Affairs). Regulations were classified into different thematic requirements: permits, compliance obligations, compliance and records keeping, awareness and the communication of the consequences and information. The register paved the way to conduct compliance gap assessment and develop gap closure plan.

EAT: Online Environment Awareness Training

This simplified online training tool aims to enhance awareness amongst PDO and contractors community. The tool is designed for staff at all levels and is fully tailored to enhance environmental management performance and practices.

The tool is accessible to all staff and upon completion of EAT, a Certificate of Completion is issued. Refresher training is required every three years.


CERTIFICATE OF COMPLETION

Environmental Awareness Training

Environmental Screening Process

Environmental screening is the first step in the integrated impact assessment (IIA) process. The outcome of the screening process determines the anticipated key environmental, social and health impacts, if there is any likely project showstoppers and the project category type (i.e. category I, II or III depending on the scale of its likely impact). A process called 'Lean' was applied to simplify the environmental screening process, improve its quality and reduce its overall delivery time. The updated screening process resulted in the accurate categorisation of projects by integrating social and health aspects with environmental ones. The screening tool has now been converted to an online web based system. It provides a simple repository and tracking system for all screening reports. It has also improved communication and information sharing.

Impact Assessment

If screening determines further impact assessment is needed, a more detailed Integrated Impact Assessment (IIA) is conducted. IIA identifies and assesses key Environmental, Social and Health (ESH) impacts, evaluates alternatives and helps ensure the eventual selected design choices are ALARP and where needed, appropriate mitigation and monitoring measures are implemented. Importantly, the IIA ensures ESH considerations are integrated along with other aspects of the project which may affect the feasibility, design, cost, construction, operation and decommissioning of a project. At the same time, the IIA ensures that all environmental regulatory requirements, both governmental and institutional, are fully met during all stages of the development along with our internal corporate requirements. In PDO, IIA is carried out for:

- All new activities and development of new facilities
- Significant modification of existing activities or facilities, which may increase existing risks or introduce additional hazards
- Decommissioning or abandonment of facilities.

Development and Update of Environmental and Social Feature Layers

PDO has developed a wide range of environmental and social feature layers in its Geographical Information System (GIS). GIS is a tool widely applied by over 4,000 users annually. These layers play an important planning role in checking environmentally and socially sensitive features of a given location. The tool helps project teams during the planning and design stage of their projects. In addition, the layers, or maps, are also used during the environmental screening phase of the IA process to proactively identify and avoid any negative impacts to environmentally or socially sensitive areas within our concession area. The GIS database evolved from co-ordination of all stakeholders to obtain relevant data, including different government ministries and authorities. It has added several new environmental layers such as wadis, protected areas, soil types, and water protection zones.

EcOman Centre (Knowledge World)

Reflecting PDO's commitment to the environment, we announced the EcOman Centre at Mina Al Fahal as our Gift to the Nation for 2010. This was built alongside the Oil and Gas Exhibition Centre and offers an engaging journey through the evolution and future of energy. The EcoOman Centre aims to help visitors of all ages to understand the possibilities of harnessing sustainable energy resources. PDO's Gift to the Nation is a tradition, marking every five years of His Majesty's reign, that hails back to 1990 when PDO built a Technical Library. More recent Gifts to the Nation include the Oil and Gas Exhibition Centre, the Planetarium and, in 2005, the Traffic Safety Institute.

The EcOman Centre was conceived as a place dedicated to informing and inspiring the general public, by encouraging them to appreciate and adopt an eco-friendly attitude and lifestyle. It also underlines PDO's strong commitment to sustainable development. The complex has three theme areas: the Power Tower, Energy Journey and Better World and runs exhibitions, contests and quizzes for children to aid their understanding of environmental issues.



A Winning Environment

We have launched two nationwide competitions for schools and businesses to build a positive environmental culture across the country.

The competitions focus on energy management and the use of renewable resources.

We have has signed a Memorandum of Understanding with the Ministry of Education (MoE) which will support pupils enhance their research in, and awareness of, the field of renewable energy.

We have also penned an agreement with Riyada, the Public Authority for Small and Medium Enterprises, for a competition to provide solutions for the oil and gas industry to reduce energy consumption and encourage the use of "green" resources, such as solar power, across the sector.

Biodiversity

PDO does not operate in any nature conservation areas. To protect the biodiversity in our concession area, we operate a procedure which sets out the minimum requirements for the protection of flora and fauna in environmentally sensitive areas when activities are taking place. All activities and projects need to adhere to this procedure, which complies with Oman's environmental legislation and the Company's HSE policy, which calls for no harm to people and the environment.

Biodiversity Studies

- Biodiversity surveys have been carried out for the entire concession area to map out biodiversity features and identify sensitive areas.
- Studies are carried out to identify sensitive flora and fauna that might be impacted and include any potential consequences for biodiversity.
- Controls are implemented to manage biodiversity impacts.

Marine life

- We conduct regular marine surveys to monitor the impact of discharges from the Mina Al Fahal effluent treatment plant into the marine environment.
- We conduct daily marine patrols around the bay to check for any spillages.
- Our diving teams regularly clear discarded fishing nets around the coral reefs at nearby Al Fahal Island.

Greening PDO

- We regularly endeavor to plant native trees and support re-plantation and plant rehabilitation programmes.
- At one PDO plant, a PDO contractor has been encouraged to develop a flourishing vegetable patch using treated water from the gas depletion compression facility. They first started growing flowers and cauliflower before moving on to sunflowers, cucumbers, sugar cane, okra, sweet corn, radish and pumpkins.

Minimizing OUR ENVIRONMENTAL FOOTPRINT

Use of Photodegradable Marker Bags to Replace Pin Flags

For seismic surveys, photodegradable marker bags were sourced, filled with sand, and deployed in place of metal pin flags. The use of such bags not only eliminate the risks posed by metal pin flags to people and animals but also reduces the need to deploy vehicles to collect them once surveys were over. Degradation of the bags was monitored and has been verified.

Stakeless Source Positioning

Technology was developed and implemented which enabled vibrator operators in seismic surveys to navigate directly to the requisite locations for vibration tests using a customized GPS guidance system with a table display. This cut vehicle deployment with consequential reduced emissions and terrain footprint by accurately guiding crews to test sites.

Water Pillow System

We are drilling in an average of 600 wells annually with an associated construction of 600 water pits to store well site water. Potential risks associated with water pits construction include large water loss and threat to stock life. Hence, we are aiming to eliminate, where practicable, the use of water pits.

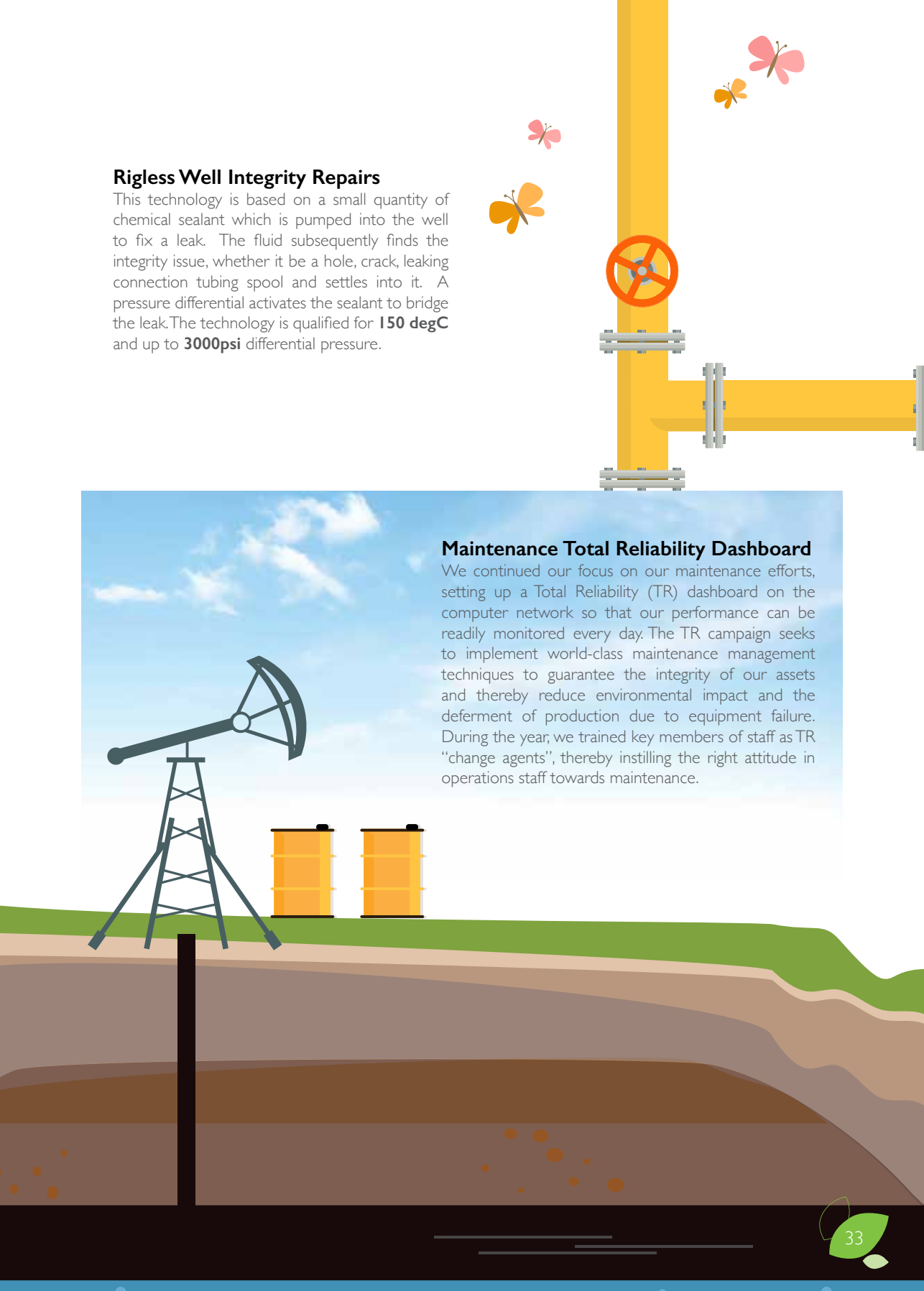
A reduction in the number of water pits has occurred by having 'master' water pits serving more than one rig rather than having one water pit for every location. In 2016 a pilot project was conducted where the water pits were replaced by a water pillow system, which resulted in no need for a water pit to be constructed. This concept is now being extended into the Lekhwair field where 20 wells will be drilled.

Water Pillow System



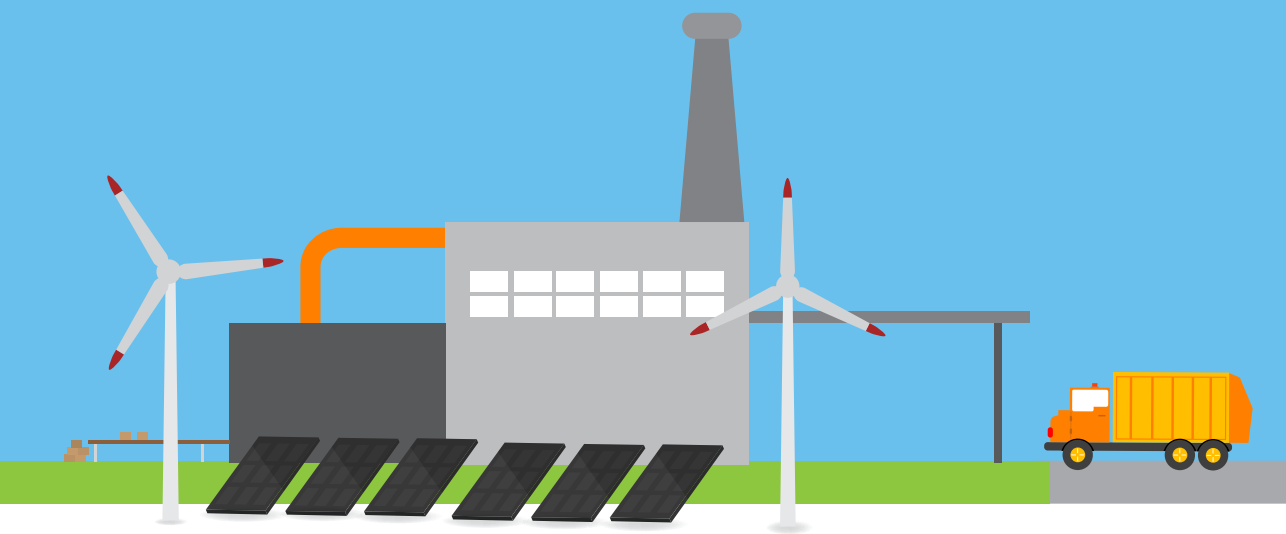
Rigless Well Integrity Repairs

This technology is based on a small quantity of chemical sealant which is pumped into the well to fix a leak. The fluid subsequently finds the integrity issue, whether it be a hole, crack, leaking connection tubing spool and settles into it. A pressure differential activates the sealant to bridge the leak. The technology is qualified for **150 degC** and up to **3000psi** differential pressure.



Maintenance Total Reliability Dashboard

We continued our focus on our maintenance efforts, setting up a Total Reliability (TR) dashboard on the computer network so that our performance can be readily monitored every day. The TR campaign seeks to implement world-class maintenance management techniques to guarantee the integrity of our assets and thereby reduce environmental impact and the deferment of production due to equipment failure. During the year, we trained key members of staff as TR "change agents", thereby instilling the right attitude in operations staff towards maintenance.



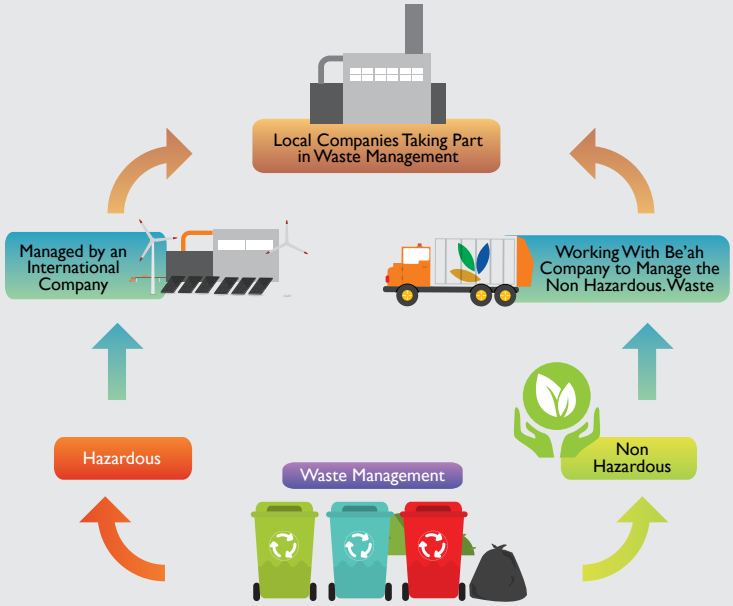
Waste Management



WASTE MANAGEMENT

As a part of a continuous improvement effort in waste management, we have developed a waste management plan (WMP) covering all waste streams from "cradle to grave."

The WMP includes a four-year action plan for each waste stream with a specific focus on waste reduction and reuse. It aims to reverse current waste management practices that emphasize waste treatment and disposal. Many projects have been implemented to improve the way in which we manage our wastes. Currently, our waste management covers the following:



Green Plate Contest



A "Green Plate" competition aimed at reducing food waste within PDO camps and permanent accommodation camps (PACs) was launched in 2016.

The main objective was to reduce food waste, raise awareness and minimize costs associated with food purchasing, storage, preparation, consumption and disposal.

The contest encouraged personnel to "take what you want, eat what you take" to avoid excessive leftovers.

The volume of leftovers was measured each day and the one with the least average waste per employee was declared as a winner. Camp operators submitted a monthly report showing the daily weight of food wastage per person, and as a result, food waste was significantly reduced by almost 60%.

Sludge Treatment

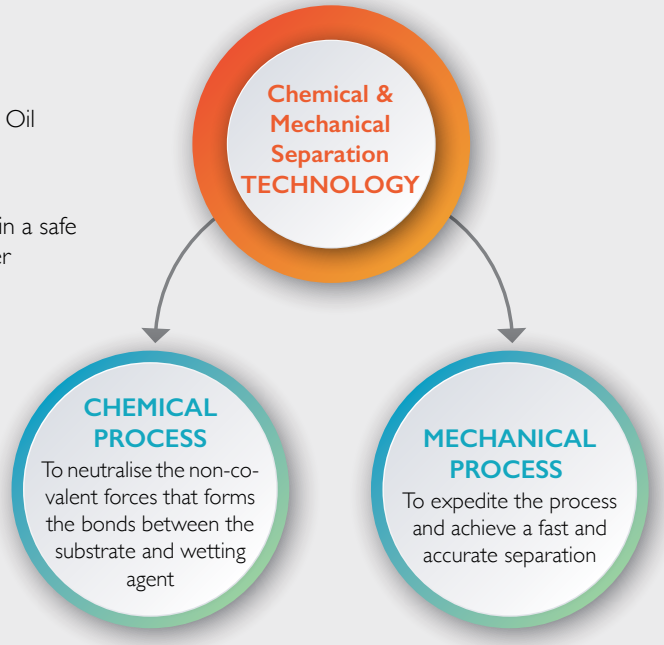
Oily sludge is received from various operational activities like vessel cleaning, pipeline pigging and wells maintenance activities. To manage this, we introduced a technology combining chemical and mechanical separation techniques used to break emulsions of hydrocarbons/water/solids. The process is based on a series of chemical reactions that interact with other reagents releasing heat and neutralising the non-covalent forces that form the bonds between the substrate and wetting agents. This makes it feasible to separate the components of an emulsified mixture of minerals, water and hydrocarbons. Mechanical forces are then used to separate the constituents based on specific gravity differentials.

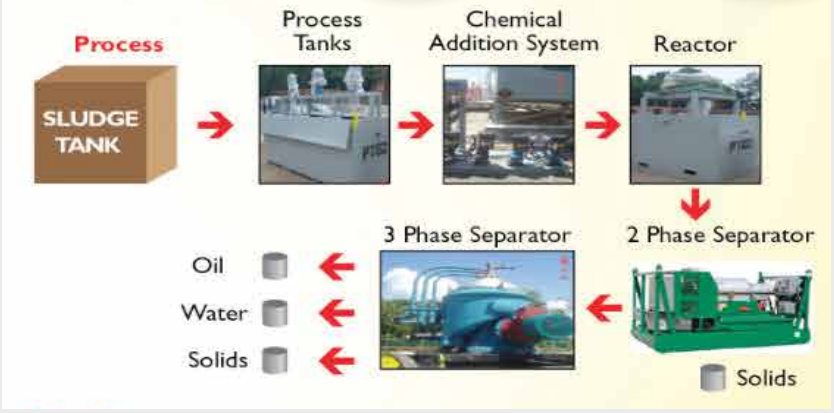
SLUDGE TREATMENT

Clean-up of Oil Sludge
and Heavy Oil Pits

Benefits

- Recovery of Quality Crude Oil from the sludge
- No External Heat Source
- Treatment of crude sludge in a safe and environmentally manner
- 40 - 45 % Oil Recovery





PDO NORM Decontamination and Disposal Strategy

NORM (Natural occurring Radioactive Material) is associated with almost all oil and gas fields around the world. Since NORM emits low levels of Alpha, Beta and Gamma radiation the materials containing NORM scales are considered as a hazardous waste. Generally, NORM waste generation increases as oil fields age in addition to other physico-chemical changes associated with the subsurface geology. PDO oil fields are aging and therefore need water injection to maintain reservoir pressure. To extract a barrel of crude oil, PDO has to inject more water, resulting in increased production water carrying NORM in a mixed form. The NORM precipitates in subsurface equipment like electric submersible pumps (ESPs), tubulars and surface equipment such as Xmas tree, wellheads, flowlines, oil-water separators, holding tanks and manifolds etc. In light of the accumulated quantities, NORM decontamination facility was built and being operated to decontaminate various equipments in alignment with Omani and International regulations related to NORM management.

Hazardous Waste Management

We have launched a campaign to deal with our hazardous waste which includes a five-year contract with an international company. The move marks a major milestone on the journey to tackle a long-standing legacy issue which has seen the accumulation of large and diverse volumes of hazardous waste. Besides the treatment and proper disposal of accumulated waste, the integrated contract brings many benefits, such as mobile or in situ treatment of large spill sites. This minimizes transportation costs, maximizes oil recovery from oily sludge, using internationally recognized practices, establishes reuse opportunities and reduces overhead costs. To determine the adequate treatment and management options, we have developed a Hazardous Waste profile for all hazardous waste streams and quantify all existing stockpiles before awarding the contract.

The contract deals with all of our hazardous waste streams, including chemicals, oil-based mud cuttings and sludge, contaminated soil, paint, tyres, and NORM. The PDO waste management strategy is moving away from conventional waste management practices and focusing more on waste reduction and recycling opportunities.

Recycling Programme

A major recycling programme has been rolled out in our offices as part of our corporate drive to be a more sustainable operator. We have installed metallic waste segregation bins in all office areas to collect papers, plastics, cans and general waste.



The waste management strategy





In addition, we are encouraging reduction in the use of paper by discouraging staff from printing reports and presentations. We have introduced black-and-white printing only, which is five times cheaper than colour. There is also a move to persuade staff to use mugs instead of paper cups for drinks.

A 3R Case Study: PDO School

The Reuse, Reduce Recycle strategy was used to build the new PDO School in Ras Al Hamra
The stipulations for the construction were:

Use a minimum amount of wood for building components
Use at least 20% of recycled materials i.e. steel, aluminum, wood etc. for building
Use a minimum of 50% of wood-based materials, certified in accordance with the Forest Stewardship Council (FSC) guidelines for wood building components
Implement a waste management plan
Recycle 75% of total construction waste.



Spills, Soil and Groundwater



SPILLS
AND GROUNDWATER

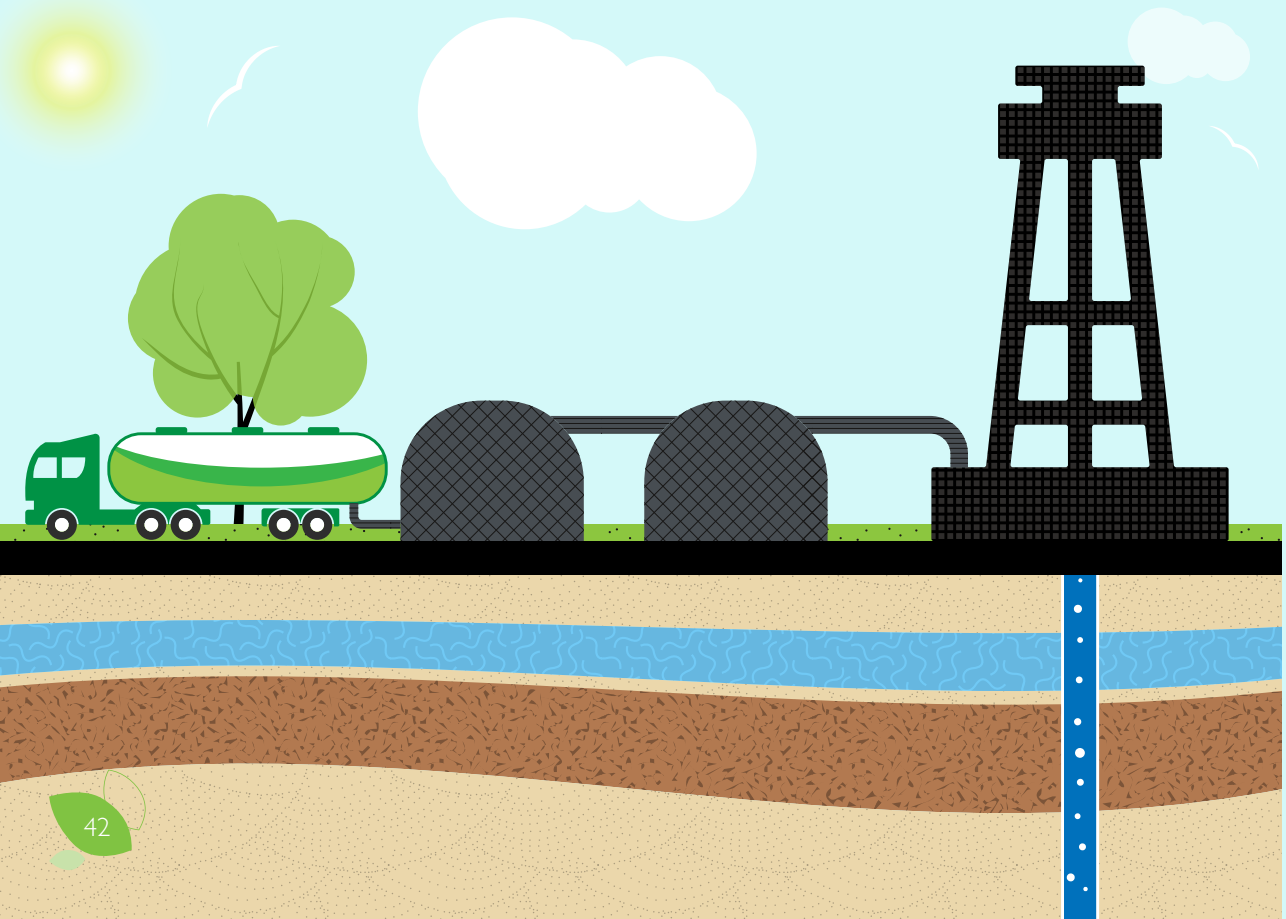
PDO initiated an extensive soil and groundwater risk assessment programme with a key objective to develop and implement a groundwater monitoring programme. The assessment started with developing a soil and groundwater "vulnerability map" using an aquifer vulnerability index (AVI). The AVI method is based on two key parameters:

- Thickness of each sedimentary unit above the uppermost aquifer.
- Estimated hydraulic conductivity of each of these layers.

All major facilities located in medium to very high (Yellow to red) vulnerability were included in a Phase-1 Risk Assessment. This assessment involved a detailed site verification of potential causes of contamination (threats) and evaluation of the existing controls in place. Following this assessment; all sites that were classified medium to high risks were taken into a Phase-2 risk assessment. The assessment involved:

- Soil and groundwater sampling and analysis
- Conducting infiltration and permeability tests
- Conduct spill scenarios and transport pathways

The output of this assessment was a plan for groundwater monitoring as well as a plan for site cleanup. No groundwater contamination was identified in any of the assessed facilities. Upgrading of some engineering controls were also done as outcome of this assessment. A plan for long term monitoring of groundwater is being developed.



In addition to that, the following projects have been conducted:

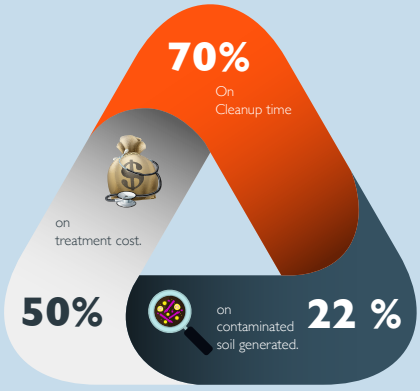
Pit Less Drilling

Every year an average of 600 wells are drilled with an associated construction of 600 waste pits to store drilling cuttings. A number of challenges are associated with the drilling of these wells in particular water consumption, chemical use and footprint. Pit less drilling technology comes to address these challenges and eliminate the need for constructing waste pits. The technology consists of three main equipment. A recirculation tab (RCT) is located beneath the shale shakers where it grinds the drill cuttings to make them finer. The cuttings are then shifted to the centrifuge for the final separation between the cuttings and fluids after initial separation by de-watering process that use specific type of polymers. The result is dry cuttings which can be reused and clear fluid which can be used in the other upcoming sections of the same well or for new wells. The technology was piloted in a number of locations in PDO and succeeded in eliminating the need for constructing waste pits, reducing water consumption by 60% and reusing the drilling mud. The work is ongoing to deploy it at a larger scale within PDO drilling operations.



Improve The Process Of Major Spills Cleanup

Major oil spill cleanups consume significant time, effort and cost and importantly can cause potential environmental damage and production deferment in some cases. We launched a Lean project, focusing on the assessment of major spill cleanup practices, with the aim of streamlining its clean-up process. As part of this, different workshops were conducted and several lean tools were implemented such as interviews, value stream mapping, waste identification, root cause analysis, and a countermeasures proposal. The outcome was the development of a standard operating procedure for spills clean-ups to ensure consistency across our operations. Following the completion of the lean project, the following achievements were made:



Reduction

Cathodic Protection - Remote Monitoring

Currently, measurements of cathodic protection at the rectifier, solar units and test post are performed manually by sending a technician to the remote area. This has many implications, such as time, cost and safety, the latter aspect which is heightened for locations with a potential H2S hazard.

Hence, having a system that can be monitored remotely addresses the above issues and improves the quality of the data as there is less room for human error. In addition, the data is made available at the user's desktop whenever needed without having to wait for the next technician visit. This may potentially help identify problems sooner and therefore minimize potential environmental incidents such as leaks.

Assets register:

- An IT SAP based tool that registers all asset equipmentd
- Easy follow up and tracking for regular maintenance and repair
- Improved efficiency and avoidance of potential spillage/leakages

Sustainable Management of Contaminated Soil Stockpiles

Over the years, large volumes of oil-contaminated soil have accumulated in our waste yards. This soil is generated by oil spills resulting largely from flowline integrity issues. A project was established to investigate sustainable remediation options for contaminated soil stockpiles, as a joint research initiative between the Ministry of Environment and Climate Affairs, Sultan Qaboos University (SQU) and PDO.

The SQU research team carried out a comprehensive site assessment involving geotechnical Investigations such as density and percolation tests, soil characterization including, soil analysis and leachability tests, a groundwater appraisal and finally a risk assessment based on the source-pathway-receptor model.

The research is the first sustainable remediation project in Oman and helped to establish sustainable options for the management of contaminated soil based on the scientifically identified risk levels. It also helped to introduce the concept of sustainable remediation and risk-based management. This will pave the way for the application of the same concept to other stockpiles and remediation activities in PDO and Oman in general. The project helped to develop an action plan for contaminated sites including the development of policy statements and a contaminated land framework in the Sultanate to standardize and formalize the approach and associated methodology in line with internationally recognized practices.





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