



appea

INDUSTRY ACTION ON EMISSIONS REDUCTION



Cover image: Courtesy Woodside

australian petroleum production & exploration association limited

APPEA'S VISION

APPEA's vision is Energy for a better Australia.

APPEA'S OBJECTIVES

INFLUENCING

Be the influential & respected voice for industry to create a positive operating environment.

LEADING

Be a leader for the industry on the issues that matter.

COLLABORATING

Foster positive interactions between industry, stakeholders and the community to achieve shared goals.

ADVOCATING

Raise awareness of the economic, environmental and social benefits of the oil and gas industry in the community.

OPERATING

Be an efficient, forward-looking, outcomes focused association.

The economic contribution of the Australian oil and gas industry

Australia's oil and gas industry has invested more than \$350 billion in the economy over the last decade.

Together, these projects create tens of thousands jobs.

Businesses ranging from national firms to local cafés all share in the economic benefits generated by the oil and gas industry.

The oil and gas industry supports 80,000 jobs directly and indirectly in Australia and hundreds of thousands more in the manufacturing sector rely upon natural gas.

The industry paid more than \$5.3 billion in wages to direct employees in 2016-17. The industry's average wages are more than double the national average.

The industry supports a vast supply chain of businesses in manufacturing, services and construction. This is in addition to the hundreds of thousands of jobs in electricity generation, manufacturing, transport and other industries which rely on our outputs.

Increasing LNG export volumes contribute to GDP growth. In 2018-19, LNG exports were around 75 million tonnes valued at \$52 billion. LNG exports are expected to have increased to 81 million tonnes valued at around \$49 billion in 2019-20.

The industry contributes around 2.5 per cent to Australia's GDP and around 11 per cent of our total exports (goods and services) – this is expected to grow in the coming years.

This document provides an overview and case studies of some of the activities and initiatives undertaken by the oil and gas industry to reduce its greenhouse gas emissions.

It is a companion document to the APPEA *Climate Change Policy Principles*, which outlines the industry's views on the policy approaches that should be used for efficient and effective responses to dealing with climate change.¹

1. For more information and for a copy of the Principles, see www.appea.com.au/2016/02/appea-updates-climate-change-policy-principles.

APPEA'S POSITION ON CLIMATE CHANGE

APPEA supports the science of climate change and acknowledges the need to reduce emissions, consistent with Paris Agreement targets, across the globe. This will require action by individuals, companies, and governments.

Societies around the world will continue to face two major, interdependent challenges:

- Maintaining and expanding affordable, secure energy supplies to meet growing consumer demand.
- Addressing the social, economic and ecological risks posed by rising greenhouse gas emissions and climate change.

Managing greenhouse gas emissions and meeting growing energy demand requires action by individuals, companies, and governments.

Making genuine progress requires an integrated set of solutions. This includes actions by industry to reduce emissions, provide and advance lower carbon energy technologies, and support effective national and international policies.



Reliable and competitively priced energy underpins economic growth and stability, and is crucial to raising living standards in both developing and advanced nations.

Therefore, policies aimed at reducing greenhouse gas emissions must do so at the lowest possible cost. The best way to facilitate this is to ensure that emission reduction policies are economy-wide and allow access to global carbon markets.

The global challenge

Throughout the world, policy-makers are implementing a variety of regulatory responses to reduce greenhouse gas emissions and mitigate the risks of global climate change.

The Intergovernmental Panel on Climate Change (IPCC) found in its 2014 Fifth Assessment Report (AR5) that:

- The human influence on the climate system is clear.

- The more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts.
- Humans can limit climate change and build a more prosperous, sustainable future.²

The multilateral United Nations Framework Convention on Climate Change (UNFCCC) has elicited a global commitment to holding the increase in the global average temperature to well

below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial levels.³

More recently, the IPCC found that limiting global warming to 1.5 degrees Celsius above pre industrial levels would require rapid, far-reaching and unprecedented changes in all aspects of society, but would have benefits to people and natural ecosystems.⁴

2. IPCC (2014), *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland (available at www.ipcc.ch).

3. UNFCCC (2015), *Adoption of the Paris Agreement*, 12 December (available at unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf).

4. IPCC (2018), *Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, IPCC, Geneva, Switzerland (available at www.ipcc.ch).

THE ROLE OF NATURAL GAS IN REDUCING GREENHOUSE GAS EMISSIONS

Natural gas is a lower-carbon form of energy suitable for electricity generation, industry and households.

Gas has an essential role to play in reducing emissions. In the home, natural gas is a cleaner and lower emissions fuel compared to the National Electricity Market (NEM) average.

Gas-fired generators can be rapidly started making them complementary with intermittent renewable energy. Exporting gas as liquefied natural gas (LNG) assists our Asian trading partners to reduce their emissions.⁵

Natural gas: integral to a low carbon Australian economy

Australia generates significant national economic, environmental and social benefits through the use of its substantial natural gas resources.

Using more natural gas in Australia's power generation and resource processing would significantly enhance the nation's ability to meet increasing energy needs and reduce emissions.

With structural changes underway in the power sector and growth in renewable energy technologies, natural gas is the perfect partner to intermittent renewable energy that requires "on call" electricity generation to manage falls in renewable output or peaks in demand. As more renewable energy is integrated into the grid, this balancing role becomes more critical.

If the industry can develop them, Australia's natural gas resources can underpin an historic shift to a lower emissions generation sector.

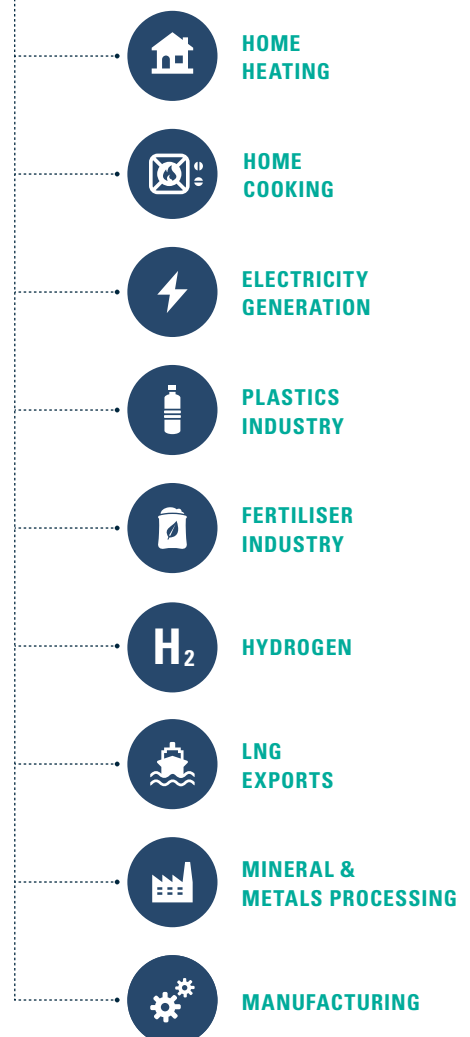
The increased use of natural gas also has several additional environmental benefits, such as:

- Reduced emissions of fine particulates.
- Reduced emissions of sulphur dioxide (an important contributor to smog and acid rain) and nitrogen oxides.
- Significantly lower demand for water for power station cooling.

5. See *Gas Vision 2050* for more information. *Gas Vision 2050* was developed by Australia's peak gas industry bodies and demonstrates how gas can continue to provide Australians with reliable and affordable energy in a low carbon energy future. See also www.appea.com.au/media_release/gas-vision-2050 and www.appea.com.au/wp-content/uploads/2017/03/GasVision2050_March2017.pdf for more information. A second edition of *Gas Vision 2050* is being developed and is expected to be released later in 2020.



NATURAL GAS





Natural gas: integral to low carbon economies in Asia

Australia's LNG industry is in a unique position to contribute substantially to the economic development of the nation and to reduce greenhouse gas emissions. Australia's resources of natural gas and proximity to growing markets make us well placed to meet the global climate change challenge while substantially contributing to Australia's economic growth. While the demand for energy as part of the industrialisation of Asian economies is a key driver, the properties of natural gas as a lower emitting and cleaner burning fuel is also driving much of the international demand for LNG.

Australia's LNG exports have for decades made a strong and positive contribution to the global efforts to reduce greenhouse gas emissions. This contribution will increase in the period to 2030, and beyond.

Natural gas is a highly flexible fuel with a diverse range of uses

- Natural gas is commonly used to generate electricity, heat and steam for industries, including alumina refining and food and beverage manufacturing.⁶
- Natural gas is also a critical feedstock for industry that often cannot be substituted in producing fertilisers, cleaners, polymers and refrigerants.
- Natural gas is ideally suited as a complement to renewable electricity generation because gas generation plants can be rapidly turned on and off to respond to changes in intermittent generation from renewable sources.
- Natural gas is the fuel of choice in cogeneration and trigeneration. These technologies can provide electricity, heating and cooling at very high thermal efficiencies approaching 80 per cent.⁷
- Compressed natural gas and LNG are used in the transport sector, and this use can be expanded.
- Innovative technologies, such as natural gas fuel cells, have been developed that can provide electricity and heat requirements in applications ranging from a small house to a medium sized office or factory. These technologies can deliver thermal efficiencies as high as 85 per cent.⁸
- Natural gas can provide a fuel source for hydrogen made through the process of steam methane reforming (SMR), with any greenhouse gas emissions generated during SMR managed through market offset or technical abatement to offer a carbon-neutral product.⁹

6. See also *Natural Gas: Essential for Australian Manufacturing* at www.appea.com.au/2016/12/natural-gas-essential-for-australian-manufacturing.

7. These technologies are already being deployed in commercial buildings in Australia (see cogentenergy.com.au/coco-cola-place-40-mount-street-north-sydney and www.qantas.com.au/travel/airlines/electricity/global/en#power for examples).

8. Recently there have been significant advances in ceramic fuel cells that run on natural gas, with a range of commercially available products now on the market.

9. See www.energyinformationaustralia.com.au/natural-gas-to-hydrogen-conversion for more.

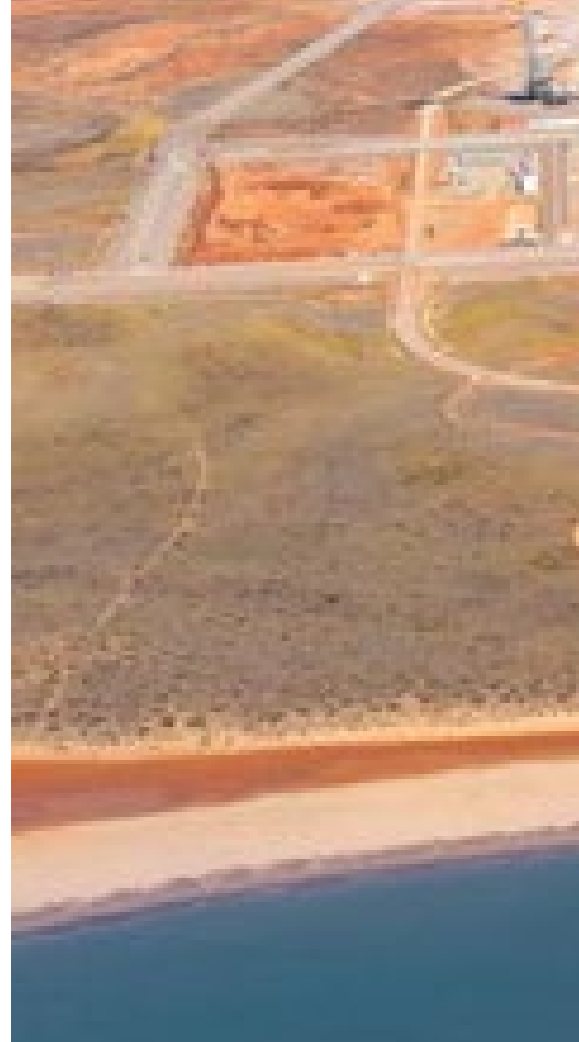
ACTIVITIES TO REDUCE GREENHOUSE GAS EMISSIONS

These actions encompass the entire oil and gas exploration and production life cycle and include:

- Industry joint initiatives.
- What we do when we design our facilities.
- What we are doing in our facilities (both in Australia and globally).
- What we are doing around our facilities.
- Low emissions research & development.

Industry joint initiatives

The oil and gas industry, both internationally and in Australia, has come together around several industry initiatives to act collectively to reduce greenhouse gas emissions and play a positive role in climate change policy developments.



Oil and Gas Climate Initiative

The Oil and Gas Climate Initiative (OGCI) is a voluntary global, CEO-led initiative which aims to lead the industry response to climate change. Launched in 2014, OGCI comprises thirteen oil and gas companies, seven of whom are APPEA members, that pool expert knowledge and collaborate on action to reduce greenhouse gas emissions.

OGCI aims to increase the ambition, speed and scale of the initiatives members undertake as individual companies to reduce the greenhouse gas footprint of their core oil and gas business – and to explore new businesses and technologies.

OGCI Climate Investments

In November 2016, OGCI launched a billion-dollar investment vehicle, OGCI Climate Investments.

OGCI Climate Investments invests in technologies that have the potential to significantly reduce greenhouse gas emissions, and that are economically viable.

OGCI Climate Investments focus is on innovative companies with promising technology and business models that are ready to be commercialised.

Zero Routine Flaring by 2030

This World Bank Initiative, brings together governments, oil and gas companies (six of whom are APPEA members), and development institutions who agree to cooperate to eliminate routine flaring no later than 2030.

Companies that endorse the Initiative will develop new oil fields they operate according to plans that incorporate sustainable utilisation or conservation of the field's associated gas without routine flaring. Oil companies with routine flaring at existing oil fields they operate will seek to implement economically viable solutions to eliminate this legacy flaring as soon as possible, and no later than 2030.

APPEA *Climate Change Policy Principles*

APPEA is committed to working with policymakers as they develop policy responses to climate change.

Versions of these Principles has existed since 2003. APPEA uses a principles-based support broad-based endorsement by our members, accounting for business size and operations, to drive a coherent, thoughtful and consistent approach to our advocacy that can place us at the cutting edge of thinking around these issues.

The first formal edition of the Principles was issued in November 2010 and a second edition of the Principles was issued in February 2016. A third edition is under development.



The APPEA *Climate Change Policy Principles* bring the Australian industry together around a common set of objectives and views on policy approaches and were developed to assist policymakers develop efficient and effective responses to dealing with climate change.

Climate and Clean Air Coalition Oil and Gas Methane Partnership

The Climate and Clean Air Coalition (CCAC) created a voluntary initiative to help companies reduce methane emissions in the oil and gas sector.

The Oil and Gas Methane Partnership was launched in September 2014. The Oil and Gas Methane Partnership provides companies a mechanism to systematically and responsibly address their methane emissions, and to demonstrate this systematic approach and its results to stakeholders.

In 2017, eight companies, six of whom are APPEA members, signed a set of Guiding Principles on Reducing Methane Emissions

across the Natural Gas Value Chain.

The principles, which have now been signed by twenty companies and have fourteen supporting organisations, are to:

- Continually reduce methane emissions.
- Advance strong performance across gas value chains.
- Improve accuracy of methane emissions data.
- Advocate sound policies and regulations on methane emissions.
- Increase transparency.

The *Guiding Principles* are complementary to and mutually reinforcing of other initiatives, including the OGCI.

HOW WE DESIGN OUR FACILITIES TO MINIMISE EMISSIONS

This section provides case studies on actions taken by the industry in both the design and construction of its facilities to reduce emissions or to minimise the facility's emissions profile.

LNG facilities operate for decades and operators understand that decisions they make in design could be the biggest determinant of emissions performance over the life of the facility. To ensure that operators make rational investment decisions, many apply shadow carbon prices to assess the impact of current and potential future policies that could place financial pressure to reduce emissions.

Australia's LNG projects include design features to maximise energy efficiency and minimise its greenhouse gas emissions footprint, throughout the design and operations planning phases of the project.

Ichthys LNG Project

For example, the use at the Ichthys LNG Project at Darwin in the Northern Territory of an onshore combined cycle power plant will significantly improve efficiency compared to an open cycle gas power plant.

Waste heat recovery units are installed to reduce the need for fired heating down to essentially zero during normal operations. Fired heaters are provided for start-up only. In some projects, waste heat recovery units have also been installed offshore to reduce the requirement for fired heating significantly.



Projects are designed to minimise operational venting and flaring by, for example, installing vent gas recovery systems, which recover otherwise unused vent gas to the fuel gas systems.

acid Gas Removal Unit (AGRU) incinerators are designed with waste heat recovery systems. The exhaust gases are used to pre-heat combustion air to minimise the need for gas firing to maintain sufficient combustion temperature.

At the Ichthys LNG Project, an innovative power-sharing cable has been included in the design of the offshore facilities, connecting the central processing facility (CPF) and floating production, storage and off-taking facility (FPSO).

This feature results in reduced fuel consumption and emissions on these facilities through rationalisation of power generation capacity offshore.

Shell Australia QGC's LNG Facility

At Shell Australia QGC's LNG Facility on Curtis Island in Gladstone, Queensland the following controls were embedded in the design of the facility to minimise greenhouse gas emissions:

- Waste heat recovery units were installed on the gas turbine compressor stacks to capture heat from fuel gas combustion and subsequently eliminate the need for fired heating during normal operations.
- Boil off gas is emitted when the ambient temperature converts LNG, which is liquefied at -161 degrees Celsius, to a gas. Boil Off Gas Compressors were embedded in the design to re-inject boil off gas from the LNG tanks as well as vapors generated during ship loading back into the process. In the absence of Boil Off Gas Compressors, this gas would be flared, resulting in higher greenhouse gas emissions.



Image: Courtesy Santos

- Like Boil Off Gas Compressors, Regeneration Gas Compressors were selected as part of the design to re-inject moist gas from the acid gas removal unit dehydrators during regeneration cycles back into the process. In the absence of Regeneration Gas Compressors, this gas is typically flared, resulting in higher greenhouse gas emissions.
- Inlet Air Chilling was selected as part of the design to improve combustion efficiency in the gas turbine compressors during elevated ambient temperatures. This works by cooling and controlling the air intake to the compressors and maximising the air (oxygen)/fuel gas ratio which in turn optimises the combustion efficiency and power output to the compression process. This reduces fuel gas combustion volumes and associated greenhouse gas emissions.



Prelude Floating Liquefied Natural Gas (FLNG) Project

Shell Australia operates the Prelude Floating Liquefied Natural Gas (FLNG) Project, located in Commonwealth marine waters in the northern Browse Basin, 200 kilometres offshore northwest Australia and 460 kilometres north-north east of Broome.

The Prelude FLNG Project comprises the FLNG facility itself and subsea systems including: production wells and manifolds; flowlines; riser base manifolds; flexible risers that transport the gas, condensate and any produced formation water to the FLNG facility; and umbilicals used to control the wells and associated equipment.

Throughout the Prelude Front End Engineering Design (FEED)¹⁰ and detailed design of the project, energy efficiency has been included as a criteria in all major equipment selection decisions.

Numerous design and operational energy efficiency opportunities were investigated and many were implemented in the Prelude design, such as:

- Shell's proprietary Double Mixed Refrigerant (DMR) process uses mixed refrigerant for precooling and liquefaction cycles which allows for a flexible process to enable full power utilisation over a wide range of ambient temperatures. The composition of the pre-cool refrigerant can be modified to balance the ambient temperature changes and cut-point temperatures. Traditional propane pre-cool (C3MR), single mixed refrigerant processes cannot be adjusted in this way. Another option was Nitrogen Cycle, but DMR has better liquefaction efficiency. Nitrogen Cycle can use almost double the amount of compression power to make LNG compared to DMR technology. Using DMR technology means there is less fuel gas demand and lower greenhouse gas emissions.
- Shell's three-stage DMR process technology rather than a two-stage DMR process increases the liquefaction efficiency by 8 per cent (at the expense of additional equipment required for a third stage). It means, however, that potentially more LNG can be produced using the same amount of power and fuel gas which translates to the lower emissions intensity per tonne of LNG produced (that is, the same greenhouse gas emissions for 8 per cent more production).
- Prelude FLNG was able to increase efficiency in production by reducing cooling water temperatures (that is, taking colder seawater from a depth of 150 metres rather than taking seawater from surface). At this depth, the sea water supply is nearly constant at a temperature of 21-22 °C. For every degree that the temperature of the cooling medium is colder, 0.6-0.7 per cent of production is gained for the same energy cost. Taking this quantity of seawater 150 metres below surface is novel for FLNG from a design, construction and installation perspective.

Common technology approaches across the LNG industry in Australia

There are some common technology approaches across the LNG industry in Australia. Each of these can reduce greenhouse gas emissions and include:

- Capture of waste heat from gas turbine exhausts to provide process heat.
- The use of boil-off gas compressors to recover boil-off gas during routine ship loading.
- Commitment to no routine flaring or venting.
- Use of activated-methyldiethanolamine (aMDEA) for the removal of reservoir CO₂.

Individual LNG projects have also taken additional and different approaches to the selection of process technology in response to the attributes of each individual project. For example:

- The use of particular LNG process technology and size of each LNG processing train.
- The type and size of gas turbines used to provide mechanical and electrical power.
- Air or water cooling.

10. See www.shell.com/about-us/major-projects/prelude-flng.html for more information on the Prelude FLNG project.

WHAT WE ARE DOING AT OUR FACILITIES TO REDUCE EMISSIONS

This section highlights a series of case studies of activities and initiatives undertaken by APPEA member companies at facilities across the industry to reduce their greenhouse gas emissions.



Reducing methane emissions across natural gas value chain

The reduction of methane emissions from across the natural gas value chain has been a priority for the natural gas industry for decades. Minimising the loss of the product that the industry sells makes good commercial sense, ensures safety, and delivers on vital environmental objectives. Active scientific research in this area is improving the understanding of methane sources, and emerging technologies are enabling better detection and measurement of emissions.

Methods to reduce emissions include:

- reducing flaring and venting as far as practical, such as via strategic planning of field operations;
- where flaring or venting cannot be avoided (for testing or safety reasons), ensuring appropriate design and controls are put in place to maximise efficiency and avoid unacceptable impacts;
- designing and constructing wells to strict industry standards;
- regularly inspecting well heads and process piping and equipment subject to a rigorous maintenance and inspection regime;
- leak detection and repair (LDAR) programs¹¹ and continuous monitoring and/or regular testing of wells and process equipment.

Mandatory leak detection and repair programs in Queensland onshore gas facilities

The Queensland *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) requires petroleum operators to apply a rigorous, risk-based approach to the safety of operations and possess a comprehensive asset integrity regime to minimise risks associated with the development and operations of petroleum infrastructure. While petroleum production operators have their own operating procedures for leak detection and classification, the *Code of Practice for leak management, detection and reporting for petroleum production facilities*¹² (the Code) is a mandatory standard under the P&G Act and provides a consistent leading practice minimum standard for identifying, classifying, rectifying and reporting leaks.

Under the Code, it is a requirement for operators to conduct leak detection and repair (LDAR) programs over the following systems:

Facility or system

| | |
|-------------------------------|-------------------------------------|
| Petroleum well – subsurface | CSG |
| Above ground facility | Well pad equipment |
| | Gathering system – high point vents |
| | Gathering system – valve manifold |
| | Gathering system – low point drain |
| | Processing plant |
| Gathering system – subsurface | CSG |

LDAR methods must be in accordance with the Code and operators are required to report incidents of leaks to the Petroleum and Gas Inspectorate as outlined in the Code. Minimum frequencies for LDAR monitoring are outlined in the Code. Each facility is required to develop a risk-based monitoring plan (informed by previous results of inspections/audits).

All Queensland operators have been conducting formal leak detection and repair programs under the Code since inception. For example, Arrow Energy, Shell Australia, Santos, Origin Energy have been conducting formal LDAR programs under the Code since its inception. Results from LDAR programs indicate that such programs can reduce emission rates from leaks by around 75 per cent.

11. These are ongoing arrangements that operate in conjunction with regulatory requirements such as the mandatory LDAR programs that apply to onshore gas facilities in Queensland.

12. See Department of Natural Resources, Mines and Energy (2018), *Code of Practice for leak management, detection and reporting for petroleum production facilities* (www.dnrm.qld.gov.au/_data/assets/pdf_file/0009/1258038/code-of-practice-leak-management.pdf) for more information.



Image: Courtesy Chevron

Improvement in fuel gas management

On Arrow Energy's central gas compression facilities in Queensland, recent modifications have been made to the fuel gas management system to improve efficiency. Originally, the facilities were designed to compress all gas received from field pressure to export pipeline pressure of approximately 9,000 kilopascals (kPA). A portion of this gas is required to fuel the compression engines. In order to use the gas as fuel, the pressure of the gas was required to be reduced to approximately 1,000 kPA. Recent modifications have been made to Arrow Energy's compression facilities such that gas inlet infrastructure is available to compress the incoming gas to the inlet fuel gas pressure requirement only. This modification has resulted in an 8-10 per cent improvement in fuel gas efficiency (when measured in terms of unit of fuel combusted per unit of gas produced). Fuel gas emissions are the dominant source of greenhouse gas emissions from Arrow Energy's compression facilities and this innovation has improved the greenhouse gas emissions performance of Arrow Energy's compression facilities.

Replacement of pneumatic control devices

Arrow Energy has systematically replaced most of the natural gas driven pneumatic control devices with air driven pneumatic control devices in its gas fields. Natural gas driven pneumatic controllers have been identified as one of the nine core emission sources of methane from the oil and gas industry by the CCAC Oil and Gas Methane Partnership. Gas driven pneumatic devices are powered and actuated by natural gas through pneumatic controllers. These devices release or "bleed" natural gas to atmosphere by design. In addition to emissions by design, pneumatic controller loops and pneumatic pumps can also emit gas because they have a defect or a maintenance issue.

Recent field measurement studies have pointed out that a large fraction of total emissions from pneumatic devices in the production segment are a result of devices that are not operated as designed (due to a defect or a maintenance issue).

Since 2012, Arrow has replaced 139 gas driven pneumatic devices with an instrument air system for pneumatic gas supply/use. This has largely eliminated methane emissions from control valves and created additional safety benefits. The switch to an instrument air system gas has reduced greenhouse gas emissions by up to 1,000 tonnes CO₂-e per year.

Sub-sea technology

The last 20 years has seen the rapid uptake of the use of sub-sea technology to ensure the efficient development of resources located offshore. In the past the development of these fields required numerous large platforms. The advances in sub-sea technology now enable large amounts of production infrastructure to be placed directly on the sea floor avoiding cost (and emissions) associated with large fixed platforms.

APPEA members are also at the forefront of taking this technology a step further with the use of sub-sea compression facilities where for only the second time globally compression systems will be placed directly on sea floor. These advances in technology enable more efficient field development, minimise the amount of equipment required and further improve safety and environmental outcomes.

Hybrid electric/gas turbine drives

A number of APPEA members use hybrid electric/gas turbine drives to power the liquefaction compressors. In conjunction with the gas turbine, each of the liquefaction compressors is also equipped with a large electric 'helper motor', which ensures the power requirements of the compressor are closely matched to the output of the gas turbine, thus ensuring the gas turbine can be continually operated at its maximum efficiency.



Image: Courtesy Woodside

Advanced Process Control

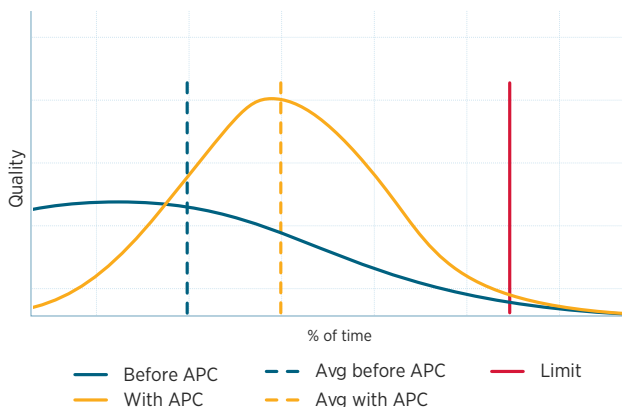
Many incremental energy-efficiency gains are possible with more precise control of processes at facilities across the industry. As an example, Woodside Energy Ltd (Woodside) installed Advanced Process Control (APC) systems, where computer algorithms make extensive incremental changes. APC allows facilities to operate closer to design limits, which may result in higher throughput, and/or reduced energy use. An APC at Pluto LNG in Western Australia improved process stability and reduced flaring by 10,000 tonnes CO₂-e per year. As Woodside develops data science capabilities, they are finding more opportunities to use equipment in smarter ways to reduce emissions intensity and add value.

Advanced air filters

An LNG facility is essentially a large, industrial refrigerator, cooling natural gas to below -161 degrees Celsius for transport in liquefied form. The process is driven by gas turbines. Over time dust and contaminants in air can degrade performance of the turbines and reduce their efficiency. Following implementation at the Karratha Gas Plant in Western Australia, Woodside upgraded turbine air filters at Pluto LNG, to capture these tiny particles. The advanced filters reduce performance degradation, increasing production, with no increase in emissions. This is equivalent to an annual emission saving of approximately 20,000 tonnes CO₂-e, contributing to Woodside's 2016-2020 5 per cent emissions reduction target.

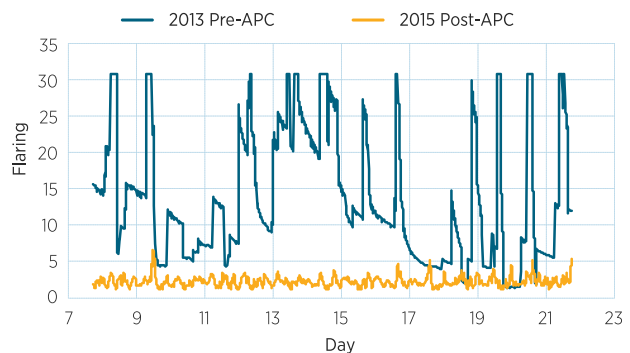
Pluto gas plant power optimisation

Woodside's Pluto LNG gas plant was designed to operate with four gas turbine generators (GTG) – all of which were required to power the facility. Through increased plant reliability and upgrades to the electrical power system, Pluto can now operate safely and reliably year-round with on less GTG, reducing the facility's energy intensity. This change has resulted in an additional 20,000 tonnes CO₂-e of emissions savings per year.



Source: Woodside (2018)

Flaring



BP – Tackling methane

IPCC data suggests that methane accounts for around 20 per cent of manmade greenhouse gas emissions.

Since methane is the primary component of natural gas, BP is committed to taking a leading role in addressing the methane challenge.

Across much of their upstream operations, BP has adopted standard procedures for leak detection and repair (LDAR) that determine the scheduling and number of inspections, as well as how they track and report methane leak repairs.

BP inspect their major operations for leaks at least annually and often more frequently, depending on the technique used and regulatory requirements.

In many locations, BP uses technology like infrared cameras to identify and help prevent small seeps from becoming more hazardous leaks.

At their Sangachal terminal in Azerbaijan, BP trialled infrared cameras with specialised software to detect and more accurately quantify methane emissions. This will help prioritise leak repairs and improve reporting.

Thirteen of BP's 22 major projects scheduled to be delivered by 2021 are gas, so BP is designing them in ways that should reduce methane emissions from the outset.

As one example, BP's Khazzan site in Oman has a central processing facility so there is no need for processing equipment at each well site. Fewer processing sites lower the potential for emissions.

ACTIONS TAKEN ELSEWHERE TO REDUCE EMISSIONS

This section provides a series of case studies of activities and initiatives undertaken by APPEA member companies around their facilities and in the broader community to reduce greenhouse gas emissions. This includes a variety of activities across the industry and across Australia.

Darwin LNG and WALFA

The Darwin LNG (DLNG) project is a leader in emission abatement through their partnership with the West Arnhem Land Fire Abatement (WALFA) project, the pioneer of the Savannah Burning abatement methodology.

Supported by DLNG since 2006, WALFA is now recognised globally as a world class program with success in both greenhouse gas abatement alongside social, cultural and economic co-benefits.

With a cumulative total abatement since inception of over 2 million tonnes CO₂-e, WALFA is the second largest greenhouse gas offset program in Australia and has been the catalyst for over 80 other similar projects across northern Australia.

The Project's success is not limited to greenhouse gas emissions abatement alone – it has also resulted in the conservation of rainforest vegetation, protection of local wildlife and rock art sites, facilitated reinvigoration of cultural aspects of land management, while supporting more than 300 Indigenous jobs per year over the years the project has been operational.

Ichthys LNG Project Savannah Fire Management Program

The Ichthys LNG Project has agreements with the Indigenous Land and Sea Corporation (ILSC) and Perpetual Trustees to deliver a savannah fire management program in the Northern Territory. This \$34 million program will fund the development, establishment and operation of individual fire management projects on indigenous held land. In addition to generating Australian Carbon Credit Units (ACCUs), it is aimed at providing positive social, economic, cultural and environmental outcomes.

Santos carbon offsets – Chinchilla white gums

Over the last decade, Santos and joint venture partners have developed a 1,250 hectare plantation of locally adapted native tree species, mainly Chinchilla White Gum, near Injune, Queensland. In 2018 Santos and these partners received approximately 30,000 ACCUs under the Australian Government's Emissions Reduction Fund, recognising the environmental benefit of the carbon stored in these trees.



Woodside carbon offsets – Blue Mallee trees

Woodside has invested approximately \$100 million over the past decade to develop its own carbon offset project as part of Pluto LNG. This saw the planting of over 40 million Australian blue mallee trees across more than 17,000 hectares. Since 2008, these plantations have sequestered over 850,000 tonnes CO₂-e.



Image: Courtesy Santos



Image: Courtesy Santos

Greenhouse Gas Storage

Greenhouse gas storage is the process whereby large volumes of captured carbon dioxide are safely injected and stored deep underground rather than being released to the atmosphere.

Since 1996 the global oil and gas industry has led the world in the practical deployment of this technology. Equinor is operating large projects alongside their Sleipner and Snøhvit gas processing operations and in Canada, Shell has developed the Quest Carbon Capture and Storage (CCS) project.

In Australia, the oil and gas industry has been at the leading edge of researching and deploying greenhouse gas storage technologies. The industry instigated significant research efforts into greenhouse gas storage in the late 1990s through the Australian Petroleum Cooperative Research Centre which undertook the first assessments of possible storage sites across Australia.

Several years later that work was taken over by CO2CRC Limited. They are recognised as one of the world's leading collaborative research organisations focused on carbon capture and storage.

The CO2CRC continues to receive backing from the oil and gas industry.

The Australian industry has privately funded several hundred million dollars undertaking detailed storage site and project scoping assessments in the Perth, Carnarvon, Browse, Bonaparte and Cooper Basins. The Gorgon Project on Barrow Island, operated by Chevron, includes the Gorgon Carbon Dioxide Injection Project, the safe underground injection and storage of between 3.4-4.0 million tonnes CO₂-e greenhouse gases per year, or around 100 million tonnes over the life of the project.

Gorgon Carbon Dioxide Injection Project

The Gorgon Carbon Dioxide Injection Project is the largest greenhouse gas mitigation project in Australia and the largest undertaken by industry globally. The Australian oil and gas industry has also assisted other organisations undertaking storage site assessments in the Gippsland and Perth Basins.

In addition to assessing potential storage sites the Australian oil and gas industry has played a pivotal role in the development of legislative and regulatory regimes required to enable the technology to be deployed. The legislation enabling the Gorgon Carbon Dioxide Injection Project is believed to be the world's first storage specific legislation and the Project was the first large scale project to have its environmental impact assessed under State and Federal Environmental laws.

The experience at Gorgon was subsequently used to help develop the Australian *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and continues to be a test case for regulatory developments in other areas such as the reporting of storage site emissions.

Santos CO₂ capture

Santos has entered front end engineering design (FEED) for the Moomba CCS project.

The project proposes to capture the 1.7 million tonnes of CO₂ currently separated from natural gas at the Moomba gas processing plant each year and to reinject it into the same geological formations that have safely and permanently held oil and gas in place for tens of millions of years.

The CO₂ would be compressed, dehydrated (removing any water) and transported to a target field nearby for injection. Santos is collaborating with experts including Occidental Petroleum, which has world-leading operational expertise in CO₂ injection in the United States.

In 2020 Santos will complete the design phase and be ready to make a final investment decision, subject to the required Government policy being in place. CO₂ injection could commence from as early as 2022.

With the right policy settings and incentives to accelerate CCS deployment, the Cooper Basin could become a large-scale, commercial CCS hub capturing emissions not only from oil and gas, but from other industries such as power generation, steel, cement and chemicals.

Ichthys LNG facility CCS-ready

The Ichthys LNG facility has been designed as carbon capture and storage (CCS)-ready, meaning that provisions have been made in the design to be able to retrofit the facility with CCS capability in the future. INPEX has conducted investigations into capturing reservoir CO₂ from the AGRU and re-injecting this CO₂ in a suitable reservoir. This included a detailed site selection and characterisation assessment, which indicated that suitable storage reservoirs may exist but at a significant distance from the LNG facility. To date, in excess

of US\$10 million has been spent on evaluating CCS as an abatement option for the Ichthys LNG Project. These studies confirmed that, whilst there may be no technical barriers to implementation, implementation of CCS cannot be commercially justified for this project at this stage.

Woodside LNG fuels

Western Australia is well-placed to lead the uptake of LNG fuels, with large LNG production facilities close to fuel-intensive mining developments. Around three billion litres of diesel are imported into the Pilbara every year, primarily for mining. The ships moving mining exports to market use around five billion litres of heavy fuel oil.

LNG can replace these higher-emissions fuels, reducing greenhouse gas emissions by up to 33 per cent on a lifecycle basis, while virtually eliminating emissions of sulphur dioxide and fine particulate matter, and dramatically reducing emissions of nitrous oxide.

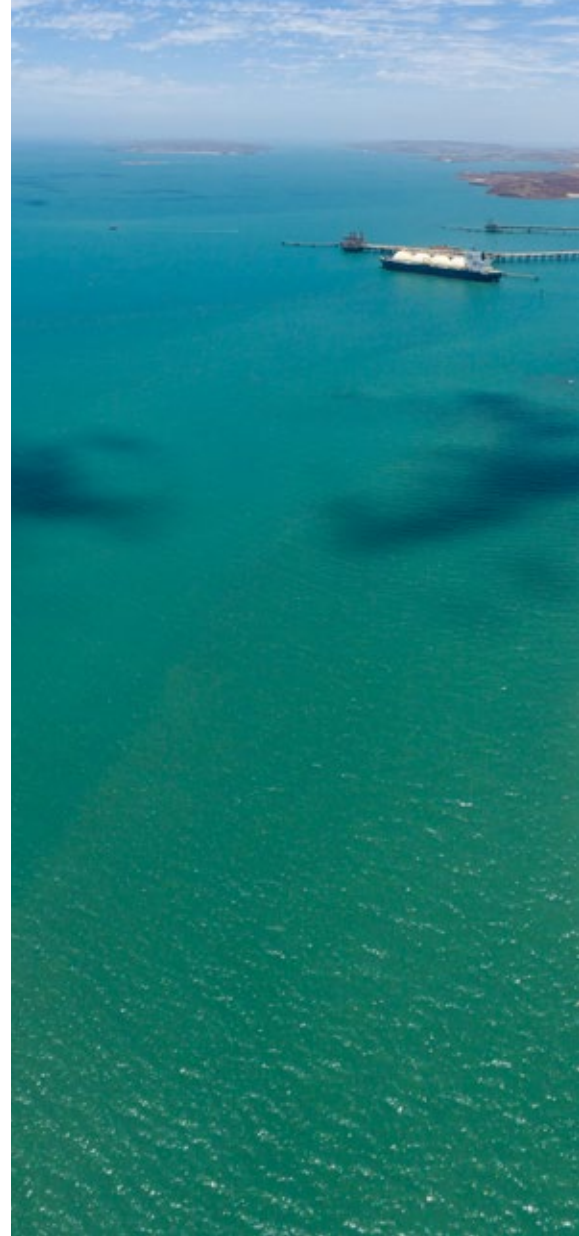
Construction of the Pluto LNG Truck Loading Facility has been completed to supply trucked LNG into the Pilbara region and beyond. This LNG can displace diesel used in remote power generation and mining equipment with lower emissions and locally produced fuel.

Woodside is finalising plans for an LNG bunkering operation in the Pilbara to capture the significant environmental and economic benefits of using LNG, instead of fuel oil, for the busy iron ore shipping trade. Transitioning iron ore shipping from the Pilbara to a new LNG-fuelled fleet could result in greenhouse gas emissions savings of nearly 6 million tonnes a year, equivalent to taking 1.8 million cars off the road.

Solar and battery powered oil wells in the Cooper Basin

In 2018 Santos commenced work on a program to convert oil well pumps to run on solar power.

A pilot pump at the Hobbes-1 oil



well at Limestone Creek has been operating on solar power since August 2018, proving that solar PV and batteries can maintain reliability and availability in the harsh environment of the Cooper Basin. This was Australia's first oil well running on solar and battery, off grid. Santos has since identified a further 56 wells that can benefit from this solution, based on the success of the pilot. The project will cost just over \$16 million, with the Australian Renewable Energy Agency (ARENA) contributing \$4.2 million, or about 25% of the cost.

In 2019, Santos delivered 22 of the 56 wells. Santos aims to commercialise this technology by providing adequate scale to achieve supply chain and execution synergies. The rollout to 22 wells included trialling multiple vendors and designs to reduce unit costs.



Santos is now focused on delivering the next 34 wells, to be executed in 2020. There are over 200 existing pumps across the Cooper Basin that could be covered and ultimately Santos aims to use solar power as the standard energy source for new onshore oil wells.

Converting oil well pumps to solar power will deliver environmental and commercial benefits by reducing crude oil consumption, long distance fuel haulage and emissions associated with burning crude oil..

Solar power plan at Port Bonython

Santos has started to use solar power to drive its petroleum processing plant at Whyalla in South Australia. The solar panels are expected to generate more than 3 gigawatt-hours a year of power, replacing more than 6 per cent of electricity used at Santos's Port

Bonython oil and gas processing operation. The 2.12 megawatt project comprises 62 arrays of solar modules and covers 14,500 square metres, and was completed on time and safely in less than nine months.

Darwin LNG Battery Project

Santos, as operator of DLNG, is investing in an innovative battery project to reduce the facility's carbon emissions from power generation by 20 per cent. The battery will enable the existing turbines to run at maximum efficiency and remove the need to run an additional turbine, saving thousands of tonnes of fuel gas and reducing maintenance costs.

DLNG will become the world's first LNG plant to install a battery to reduce emissions, providing a template for other LNG facilities.

Battery Energy Storage

By pioneering the installation of a lithium-ion battery – an energy storage system – on an offshore platform, Woodside is demonstrating that innovative approaches to oil and gas operations can reduce emissions. The one megawatt hour (MWh) battery, built by ABB Australia, provides backup capacity in Woodside's Goodwyn-A platform's power generation system. This allows the platform to run on three gas turbine generators, rather than four. This is expected to decrease fuel consumption by 3,000 tonnes per year, improving energy efficiency by 4 per cent. The battery can provide one megawatt (MW) for an hour, allowing time to start the standby generator or adjust demand for energy.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Australian oil and gas industry is a strong supporter of research, development and demonstration (R,D&D) in Australia including R,D&D into low emissions technologies and greenhouse gas emissions reduction.

Much of this R,D&D is undertaken through collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA), a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly-reported independent research and Australian universities including through the sponsorship of numerous university research chairs. The industry also participates in numerous Cooperative Researches Centres, including most recently in establishing the Future Energy Exports Cooperative Research Centre (FEnEx CRC). FEnEx CRC will bring together universities, other research organisations, oil and gas companies and APPEA to execute cutting-edge, industry-led research, education and training to help sustain Australia's position as a leading LNG exporter, and enable it to become the leading global hydrogen exporter.

This is in addition to the industry's CCS-related collaboration with research organisations such as the CO2CRC, outlined above.

Hydrogen

Woodside is the pioneer of the LNG industry in Australia and our experience in producing and exporting LNG, underpinned by strong customer relationships, positions us well for complementary opportunities in large-scale hydrogen.

In June 2018, Woodside signed a non-binding memorandum of understanding with Korea Gas Corporation to cooperate on hydrogen opportunities, and with Pusan National University in South Korea to jointly explore technology applications across the hydrogen value chain.

In March 2020, Woodside also signed an agreement with Japanese companies JERA Inc, Marubeni Corporation and IHI Corporation to undertake a joint study examining the large-scale export of hydrogen as ammonia for use decarbonising coal-fired power generation in Japan.



Image: Courtesy Chevron



Image: Courtesy Woodside

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