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Shale Gas

The Facts about the Environmental Concerns

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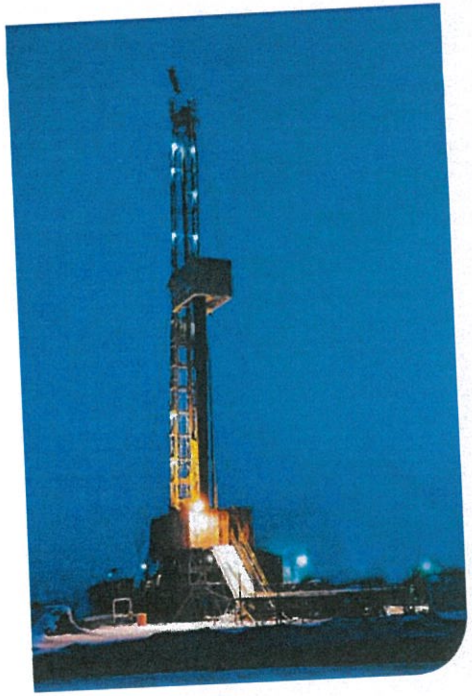

2009-2012 Triennium Work Report

June 2012

SHALE GAS

The Facts about the Environmental Concerns

Produced by:

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

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IGU foreword

The International Gas Union is pleased to present the publication "Shale Gas: The Facts about the Environmental Concerns."

The shale gas revolution in North America, and now beyond, has had a profound impact on the short and long-term supply outlook for natural gas, and has reinforced the foundational role that natural gas plays today and will continue to play in the global energy mix of the future.

The rapid development of this resource, however, has attracted, and continues to attract, significant and at times extreme attention. This attention is particularly focused on the potential environmental impacts of the extraction process.

To date, sharply contrasting opinions about the environmental impact of shale gas development has characterized the debate. Therefore, a rational, objective, fact-based discussion of the environmental concerns that can lead to operational and regulatory approaches that ensure that this resource is developed in an environmentally responsible manner is required.

As such, the IGU believes it is time to present such an objective, fact-based assessment of the key environmental concerns that have surfaced related to shale gas. The IGU is also recommending a number of best practices that need to be adopted in order to improve the overall extraction process in a manner that protects the environment.

Datuk (Dr) Abdul Rahim Hashim
President, IGU

Torstein Indrebø
Secretary General, IGU

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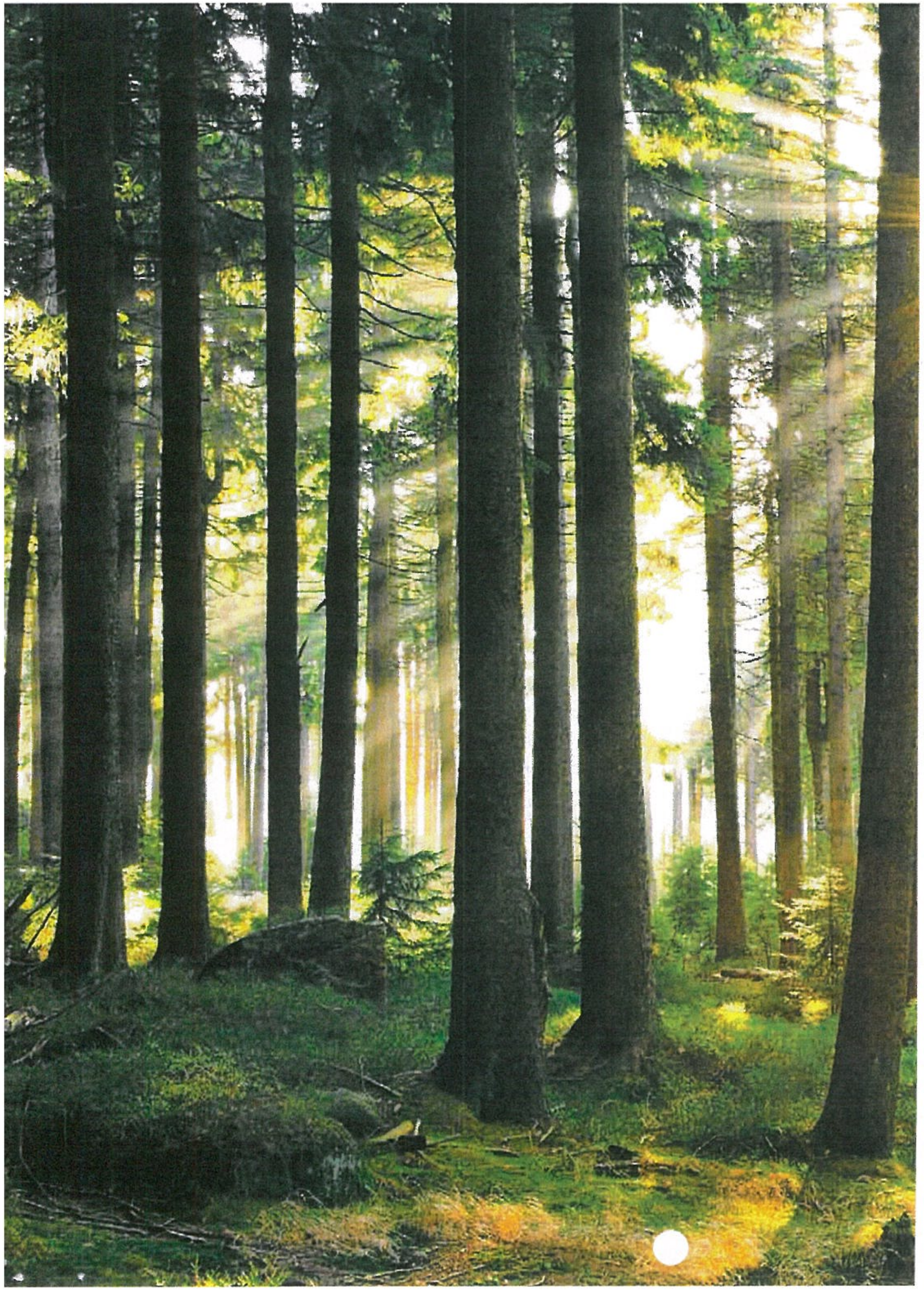


SHALE GAS

The Facts about the Environmental Concerns

Hydraulic fracturing is a technique used to access natural gas deep underground in shale formations. Hydraulic fracturing, also known as fracking or hydraulic stimulation, involves injecting pressurized water-based fracturing fluid into geologic formations to allow natural gas to escape the shale and to flow to production wells.

The Production Process Comprises of Six Main Steps:

- Site development and preparation, which involves building access roads, production facilities and well pads.
- Vertical drilling to a depth of several thousand metres, where shale formations exist.
- Drilling horizontally from the end of the vertical well, sometimes with several horizontal wells extending in several different directions, once the vertical well is at the appropriate depth.
- Hydraulic fracturing of shale formations, using a fracturing fluid comprising of about 99.5 per cent water and sand, plus 0.5 per cent chemical additives.
- Recycling or the disposal of the wastewater that was used in the hydraulic fracturing process and any naturally produced water that is brought to the surface.
- Well completion and operation, the latter lasting up to a decade or more.

Hydraulic fracturing used to produce shale gas is key to maintaining an abundant supply of clean burning natural gas for years to come. The practice was developed in the late 1940s, and has been used extensively since the 1950s. Recent innovations have been able to combine vertical and horizontal drilling with hydraulic fracturing to cost effectively extract natural gas shale formations. Despite hydraulic fracturing's strong record of safety and efficacy, there are some environmental concerns surrounding the technique:

1. "Shale gas drilling takes up a larger land-use footprint than does conventional energy production."
2. "Hydraulic fracturing can have adverse effects on drinking water."
3. "Hydraulic fracturing uses enormous quantities of water."
4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."
5. "Hydraulic fracturing and associated wastewater disposal causes earthquakes."
6. "Disposal of wastewater harms the environment."
7. "Air emissions related to shale gas production are worse than those created by burning coal."
8. "Shale gas extraction is not regulated."

This publication will address each one of the above environmental concerns, laying out the facts and context related to the concerns, as well as a set of recommendations for best practices for the shale gas industry going forward.

PART I - Executive Summary

Process Steps and Environmental Concerns to be addressed:

PROCESS STEP: Site development and preparation

1. "Shale gas drilling takes up a larger land use footprint than does conventional production"

PROCESS STEP: Vertical drilling and effect on drinking water

2. "Hydraulic fracturing can have adverse effects on drinking water"

PROCESS STEP: Horizontal drilling

No environmental concerns raised

PROCESS STEP: Hydraulic fracturing and water use

3. "Hydraulic fracturing uses enormous quantities of water"
4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public"

PROCESS STEP: Disposal of wastewater

5. "Hydraulic fracturing and associated wastewater disposal cause earthquakes"
6. "Disposal of wastewater harms the environment"

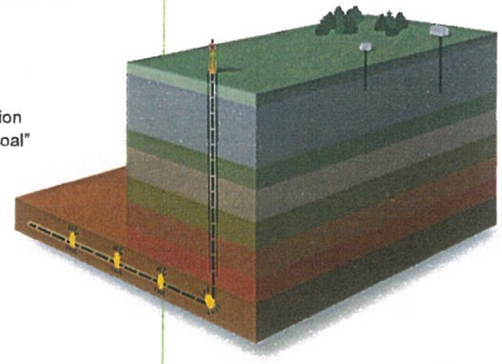
PROCESS STEP: Well completion and abandonment

No environmental concerns raised

CONCERNS: Air emissions and regulations

7. "Air emissions related to shale gas production are worse than those created by burning coal"
8. "Shale gas extraction is not regulated"

Hydraulic fracturing used to produce shale gas is key to maintaining an abundant supply of clean burning natural gas for years to come.



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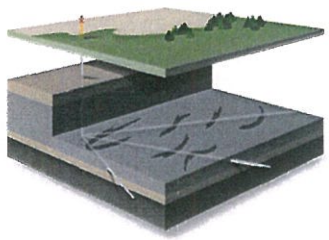
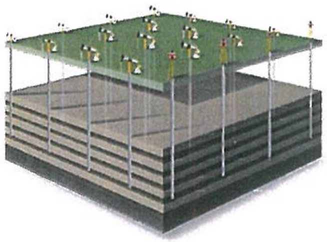
A

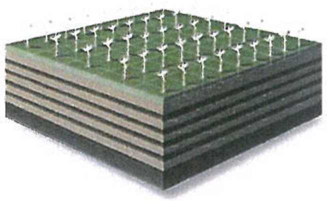
Shale Gas



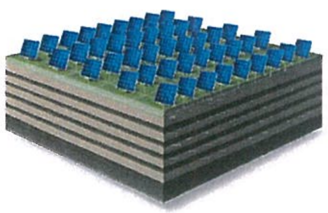
Conventional Gas



Wind



Solar



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1. PROCESS STEP:

Site development and preparation

The Concern:

"Shale gas drilling takes up a larger land-use footprint than does conventional energy production."

The Facts:

- Shale gas production requires a drastically smaller land-use footprint than conventional natural gas drilling and other forms of energy production, such as solar and wind power.
- Current common practice is to drill multiple horizontal wells from one vertical well. This allows for higher natural gas production from each well and a smaller land-use footprint.

The Context:

- Land use by energy extraction: shale gas, conventional gas, wind, solar. *(see graphic A)*

Recommended Industry Best Practices:

- Select, plan and operate well sites in a manner in which local community and land use impacts are kept to a minimum.
- Continue to maximize the number of vertical wells per well pad to further reduce the total land-use footprint.

2. PROCESS STEP:

Vertical drilling and effect on drinking water

The Concern:

"Hydraulic fracturing can have adverse effects on drinking water."

The Facts:

- Vertical drilling is a well-established practice and millions of wells have been safely drilled through aquifers with no significant issues.
- Groundwater is protected during vertical drilling by a combination of the protective casing and cement.
- The few extremely rare cases where groundwater was affected were due to faulty well casing installations, not hydraulic fracturing. These situations were resolved immediately and with no significant impact on groundwater.
- Most natural-gas producing shale formations are 3,000 to 4,500 metres underground. Domestic use water aquifers are typically less than 300 metres underground. There is no physical path between the shale formations and the aquifers; therefore fresh water contamination is not possible through hydraulic fracturing.

The Context:

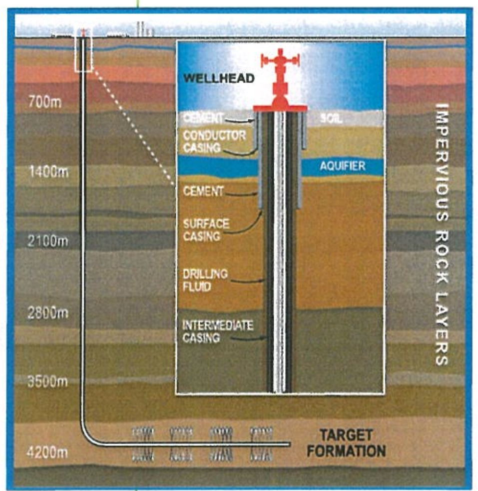
- Distance between the wellhead, aquifer and target shale formation.
- Proper well-bore design. *(see graphic B)*

Recommended Industry Best Practices:

- Study local geology to identify sub-surface drinking water sources within 250 metres of well site prior to drilling.
- Where water sources exist within 250 metres of the well site, test water before, during and after drilling to monitor water integrity.
- Quality assurance programs to ensure proper well-bore design, construction practices are followed and well integrity testing is undertaken during the life of the well.
- Maintain rigorous oversight of sub contractors, quality assurance programs, contractual expectations, auditing and training to ensure standards are met.
- Set minimum well depths.

B

Well-bore Design



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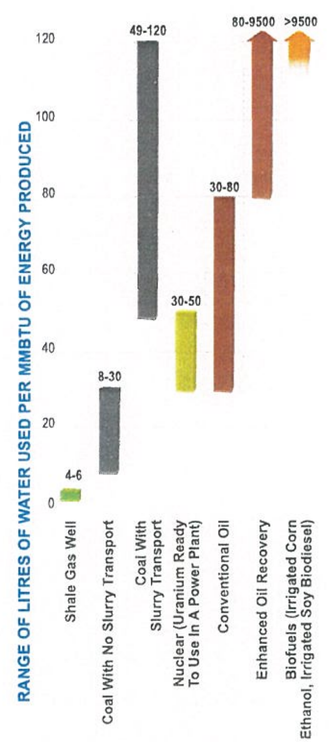
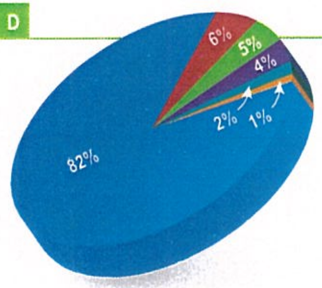
C

Comparison Chart



D



Percent of Water Use

- Municipal/Public (82.5%)
- Industry and Mining (4.5%)
- Natural Gas Production (less than 1%)
- Irrigation (6%)
- Power Generation (4%)
- Livestock (2%)

3. PROCESS STEP:

Hydraulic fracturing and water use

The Concern:

"Hydraulic fracturing uses enormous quantities of water."

The Facts:

- Shale gas production requires less water than conventional production of oil and other forms of energy. The amount of water used to produce energy by source ranges from five litres (1.3 gallons) per MMBTU for shale gas to more than 9,500 litres (2,500 gallons) per MMBTU for biofuels.
- Hydraulic fracturing of a single well consumes 11 million litres to 19 million litres (3 to 5 million gallons) of water, depending on specific geology and fracturing requirements.
- The industry is attempting to reduce the amount of water used by improving the overall hydraulic fracturing process and reusing water when possible.
- The sourcing and use of water is heavily regulated.

The Context:

- Shale gas requires the least amount of water to produce the same amount of energy: 1 MMBTU. *(see graphic C)*
- Water used in shale development is a fraction of the total water usage for agricultural, industrial and recreational purposes. *(see graphic D)*

Recommended Industry Best Practices:

- Collect and disclose water usage data.
- Continually reduce, re-use and recycle water to mitigate overall water requirements.
- Invest in viable technology enhancements to reduce water usage.

For illustrative purposes only.

4. PROCESS STEP:

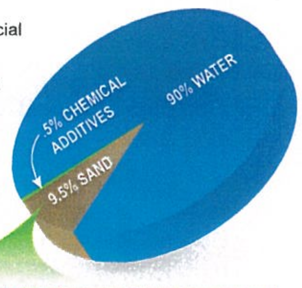
Hydraulic fracturing fluids

The Concern:

"Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."

The Facts:

- Hydraulic fracturing fluid is typically comprised of more than 99.5% water and sand, and 0.5% chemicals.
- A typical fracture treatment will use 3 to 12 additive chemicals, depending on the characteristics of the water and the shale formation being fractured.
- Many of those chemicals are present in common household and commercial applications. Some, used in extremely low concentrations, are toxic.
- The hydraulic fracturing fluid is controlled and doesn't contact fresh water.
- Industry is taking steps to voluntarily disclose more information about the chemical composition of fracturing fluid and several American states have established mandatory reporting requirements.



The Context:

- Typical chemicals present in fracturing fluid.

COMPOUND	PURPOSE	COMMON APPLICATION
ACIDS	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
SODIUM CHLORIDE	Allows a delayed breakdown of the gel polymer chains	Table salt
POLYACRYLAMIDE	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
ETHYLENE GLYCOL	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
BERABE SALTS	Maintains fluid viscosity temperature increases	Laundry detergent, hand soap, cosmetics
SODIUM/POTASSIUM CARBONATE	Maintains effectiveness of other components such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
GLUTERALDEHYDE	Eliminates bacteria in water	Disinfectant, sterilization of medical and dental equipment
GUAR GUM	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
CITRIC ACID	Prevents precipitation of metal oxides	Food additive; food and beverages, lemon juice
ISOPROPANOL	Used to increase the viscosity of the fracture fluid	Glass cleaner, anti-perspirant, hair colouring

Recommended Industry Best Practices:

- Fully disclose fracturing fluid additives.
- Invest in "green" or non-toxic alternatives to current additives.

For illustrative purposes only.

The intensity of seismic activity from hydraulic fracturing is typically 100,000 times less than levels detectable by human beings.

5. PROCESS STEP:

Hydraulic fracturing and wastewater disposal

The Concern:

"Hydraulic fracturing and associated wastewater disposal cause earthquakes."

The Facts:

- The intensity of seismic activity from hydraulic fracturing is typically 100,000 times less than levels detectable by human beings.
- There may be an extremely remote possibility of a relatively minor seismic event based on specific geology.
- In 2011 more than 250,000 hydraulic fracturing stages were completed. A few seismic events were reported to have been linked to the hydraulic fracturing jobs: A low-level quake in the U.K. was attributed to hydraulic fracturing and two cases in Ohio were related to injecting wastewater underground for disposal. Though discernible by humans, there was no physical damage from these events. Links between the seismic events and the shale gas projects have not been scientifically proven.

The Context:

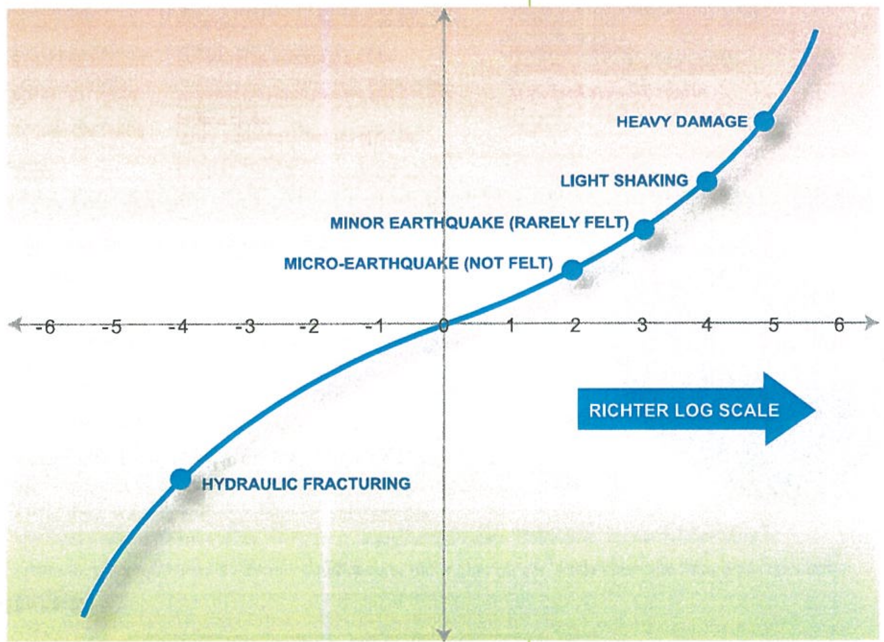
- Microseismic Events from Hydraulic Fracturing vs. Earthquakes. *(see graphic F)*

Recommended Industry Best Practices and Policies:

- Review local geology for potential fault lines prior to drilling for well site and wastewater injection.
- Monitor the process with very sensitive instruments so that operations can be halted if necessary.

F

Microseismic Events from Hydraulic Fracturing vs. Earthquakes



The percentage of wastewater that is recycled is increasing as companies become more adept at handling this waste and onsite treatment technologies become more readily available.

6. PROCESS STEP:

Disposal of wastewater

The Concern:

"Disposal of wastewater harms the environment."

The Facts:

- Wastewater from hydraulic fracturing is managed in a variety of ways, including: reuse, disposal through injection in deep underground wells, treatment at a local facility and storage in large steel tanks or in deep, lined pits.
- Underground injection is the primary disposal method for most shale gas projects.
- New wastewater treatment facilities are being built where underground disposal is not an option.
- The percentage of wastewater that is recycled is increasing as companies become more adept at handling this waste and onsite treatment technologies become more readily available.

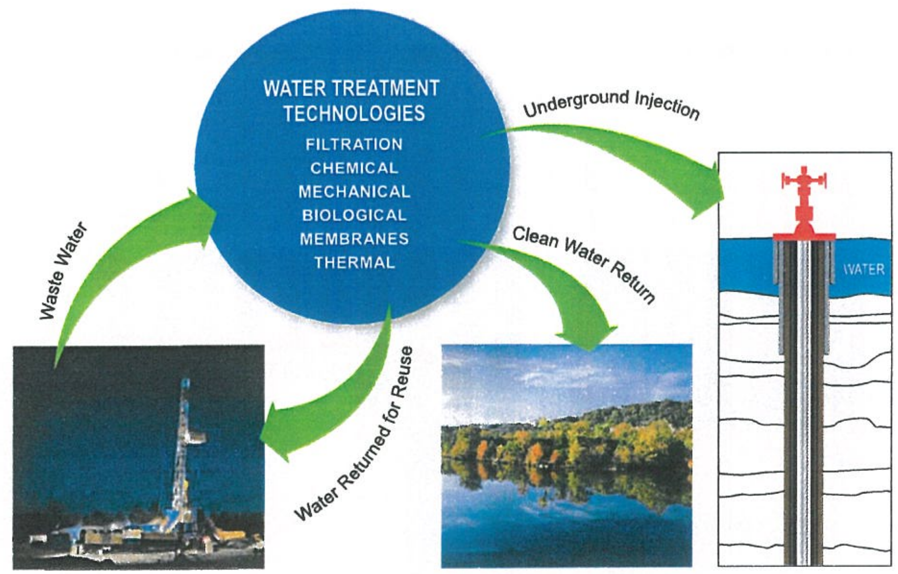
The Context:

- Managing wastewater through reuse, treatment and injection. *(see graphic G)*

Recommended Industry Best Practices:

- Use deep-ground injection wells or treat water at proper wastewater treatment facilities.
- Use "closed loop" or "covered containment systems" to minimize environmental impact.
- Document and review policies for handling and disposal of wastewater.
- Ensure proper regulations and compliance to proper wastewater disposal requirements exist.

G



For illustrative purposes only.

A number of reputable studies find that producing electricity from natural gas creates 36 to 47% lower emissions than producing electricity from coal.

7. CONCERN:
Air emissions

The Concern:
"Air emissions related to shale gas production are worse than those created by burning coal."

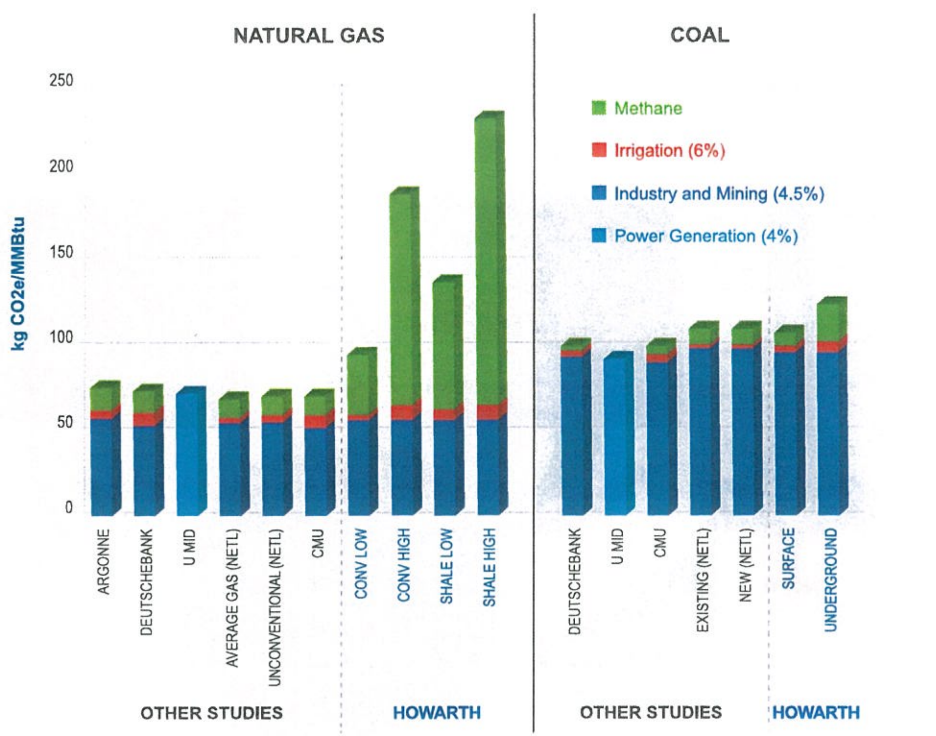
The Facts:
- A number of reputable studies find that producing electricity from natural gas creates 36 to 47% lower greenhouse gas emissions than producing electricity from coal.
- Howarth et al of Cornell University published a paper in 2011 stating that the life-cycle greenhouse gas emissions for shale gas are higher than those for coal, due to fugitive and vented emissions of methane during the production and transportation of natural gas. This cast doubts on whether natural gas from shale is a better fuel source than coal to combat climate change.
- Many other similar studies, however, have found that life-cycle greenhouse gas emissions from shale gas for electricity generation are significantly lower than from coal. The Howarth study varied from most other analyses due to:
  1) a higher global-warming potential used for methane instead of the widely accepted value used by the Intergovernmental Panel on Climate Change,
  2) the data sources were not from the U.S. Environmental Protection Agency, and
  3) failing to consider the potential for methane mitigation.

The Context:
- The Howarth study was an anomaly in its findings of extremely elevated methane gas emissions for shale gas production. *(see graphic H)*

Recommended Industry Best Practices:
- Mitigate fugitive emissions by requiring operators to employ green-completion systems to maximize resource recovery and minimize methane releases to the environment.

H

Natural Gas & Coal Life-Cycle Emission Study Comparisons



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Other Regulatory Bodies:

ALGERIA
l'Agence Nationale de Contrôle et de Régulation des Activités dans le domaine des Hydrocarbures

ARGENTINA
National Institute for Water and the Environment

CANADA
Environment Canada

CHINA
Ministry of the Environmental Protection of the People's Republic of China

EUROPE
European Environmental Agency

POLAND
Inspectorate for Environmental Protection

UNITED STATES
Environmental Protection Agency

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8. CONCERN:

Regulation

The Concern:

"Shale gas extraction is not regulated."

The Facts:

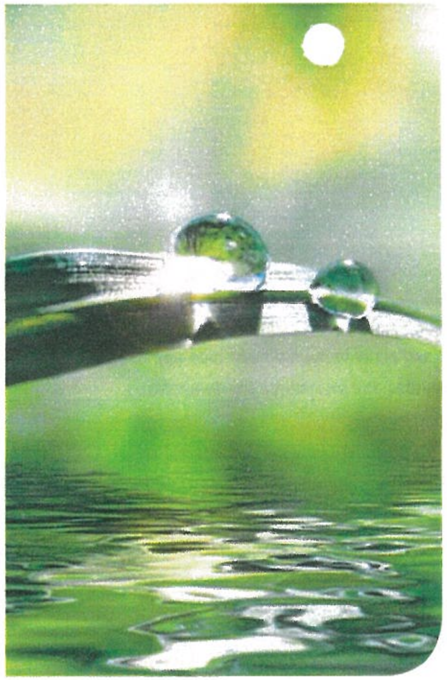
- In North America, specific, dedicated regulations pertaining to shale gas extraction are evolving. However, an extensive set of laws govern and regulate various aspects of shale gas development through many different and often interconnected regulatory bodies. In the United States, these include: the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, the Safe Drinking Water Act.
- In all other jurisdictions where shale gas is being produced or its production is being contemplated, similar regulations apply.

The Context:

- Some of the regulatory bodies whose laws and regulations govern the shale gas industry. *(see list on left)*

Recommended Industry Best Practices:

- Encourage the development of smart shale gas regulations that protect the environment, public health and safety while realizing the full economic and environmental benefits of expanded shale gas development.
- Employ best drilling practices, research and invest in new technologies.
- Maintain appropriate oversight, inspection and enforcement of all existing regulations.



PART II - Detailed Report

The Facts about the Environmental Concerns

The following section presents a detailed review of the process steps and environmental concerns to be addressed, including the relevant references

PART II - Detailed Report

Process Steps and Environmental Concerns to be addressed:

PROCESS STEP: Site development and preparation

1. "Shale gas drilling takes up a larger land use footprint than does conventional production"

PROCESS STEP: Vertical drilling and effect on drinking water

2. "Hydraulic fracturing can have adverse effects on drinking water"

PROCESS STEP: Horizontal drilling

No environmental concerns raised

PROCESS STEP: Hydraulic fracturing and water use

3. "Hydraulic fracturing uses enormous quantities of water"
4. "Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public"

PROCESS STEP: Disposal of wastewater

5. "Hydraulic fracturing and associated wastewater disposal causes earthquakes"
6. "Disposal of wastewater harms the environment"

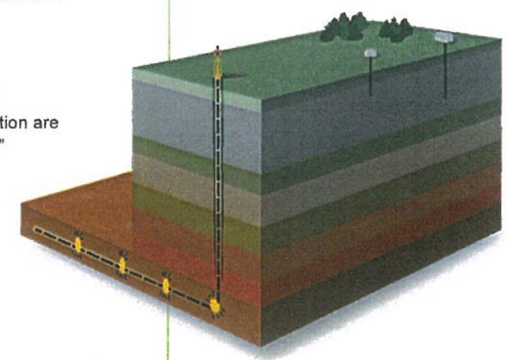
PROCESS STEP: Well completion and abandonment

No environmental concerns raised

CONCERNS: Air emissions and regulations:

7. "Air emissions related to shale gas production are worse than those created by burning coal"
8. "Shale gas extraction is not regulated"

The following section presents a detailed review of the process steps and environmental concerns to be addressed.



For illustrative purposes only.

Thanks to horizontal drilling, the actual land-use footprint required to produce natural gas from shale is dramatically smaller than that required to produce traditional oil and gas, and electricity from wind and sun.

CONCERN 1:
"Shale gas drilling takes up a larger land-use footprint than does conventional energy production."

Although shale gas production takes place deep underground, the practice requires some alteration of the surface land. Wells have to be built, as do access roads and production facilities. However, thanks to the technique known as horizontal drilling, the actual land-use footprint required to produce natural gas from shale is dramatically smaller than that required to produce traditional oil and gas, and electricity from wind and sun.

Land use by energy extraction: conventional gas, shale gas, wind, solar. *(see graphic A)*

Current practices for shale gas production involve drilling one vertical well to a depth of several thousand metres, with several horizontal wells emanating from there. This technique allows for far greater areas of shale to be accessed underground, while disturbing far less surface land, as it requires fewer wells, access roads and production facilities.

The following examples demonstrate the difference in surface land disturbance for vertical wells versus horizontal wells:

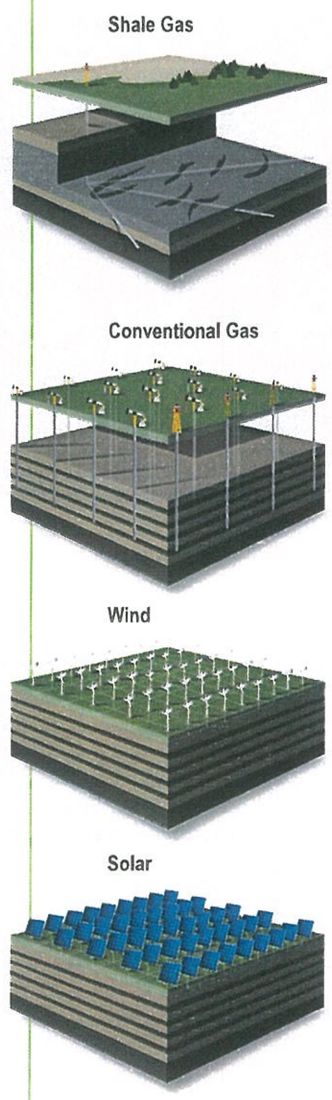
- Shale gas producers can drill up to 12 horizontal wells from one vertical well. The U.S. Department of Energy (DOE) reports that just six to eight horizontal wells from one vertical well can access the same or greater shale reservoir volume as more than 16 conventional vertical wells – each requiring its own well pad.[1]
- The DOE also states that when drilling conventional vertical wells, it is typical to install 16 well pads and drill 16 vertical wells per 2.6 square kilometres (one square mile) versus just one well pad in the same area when drilling horizontal wells.
- The same reports also shows that 16 conventional vertical wells would disturb approximately 0.3 square kilometres (0.12 square miles) of surface land, while a four-well horizontal well pad for shale gas production would disturb only 0.03 square kilometres (0.01 square miles) – more than 10 times less than the vertical wells – and access the same volume of shale gas.

It is significant to note that the number of horizontal wells drilled from a single well pad will continue to increase as producers become more adept at using this technique.

As the shale gas industry evolves, producers are finding even more ways to reduce the amount of surface land disturbance, such as drilling multiple vertical wells from one single well pad, and multiple horizontal wells from each of those vertical wells. While each of these multi-well pads is larger than a single-well pad, the combined space that they take up, for the amount of gas accessed, is significantly less than the space needed for multiple single-well pads. Therefore, it is recommended to continue drilling multiple vertical wells on a single well pad to further reduce the land-use footprint.

Another recommendation is that producers select, plan and operate well sites in a manner that keeps community and land-use impacts to a minimum. Each well site should be developed considering the natural environment, as well as the existing population and infrastructure.

A



For illustrative purposes only.

There is no physical path between naturally occurring water in aquifers and water injected for hydraulic stimulation of shale formations.

CONCERN 2:
"Hydraulic fracturing can have adverse effects on drinking water."

The process of hydraulic fracturing for shale gas production involves drilling vertical and horizontal wells thousands of metres under ground and injecting water, sand and additives into the shale formations to prop them open and extract natural gas. Some people believe that because the wells pass through aquifers to reach the shale, and because water and chemical additives are injected into the wells, drinking water sources could be affected. However, studies prove that the chances of water being affected by drilling and hydraulic stimulation of the shale formations, when done properly, are extremely remote.

There has been some widespread concern about possible water contamination from hydraulic fracturing – including elevated methane levels in water wells and chemicals likely related to hydraulic fracturing found in groundwater. In fact, the National Ground Water Association has said conclusively that properly executed hydraulic fracturing does not lead to groundwater contamination. The American organization's 2011 report on the issue says that while no widespread water quality or quantity issues have been definitively documented that are attributable to hydraulic fracturing and related activities at oil and gas sites, there have been isolated cases where faulty casing installations (including poor cement bonds) or poor management of materials/chemicals at the surface are suspected as having negatively impacted groundwater, surface water, or water wells.[2]

Vertical Drilling is a Well-Established Process:

Large-scale hydraulic fracturing has been around for more than six decades and millions of hydraulic fracturing jobs have been completed with no significant effects on drinking water.[3]

Groundwater is protected during vertical drilling by using proper well-bore design: a combination of a protective casing and cement. It also highlights the fact that aquifers lie within about 300 metres of the earth's surface, whereas shale formations are normally 3,000 to 4,500 metres underground.

It's important to note that there is no physical path between naturally occurring water in aquifers and water injected for hydraulic stimulation of shale formations. *(see graphic B)*

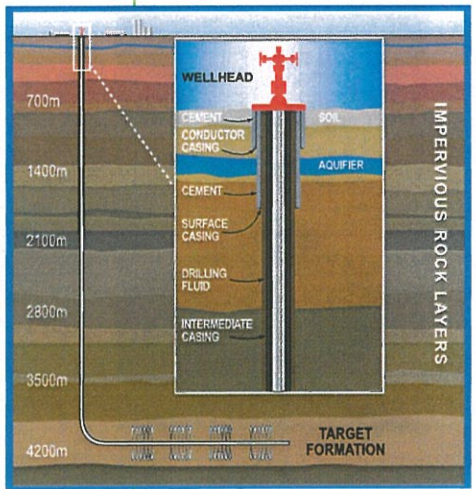
In order to ensure that groundwater is protected, a number of best practices should be followed relating to shale gas production and water before, during and after drilling and hydraulic fracturing take place.

- Prior to drilling, it is recommended to identify sub-surface drinking water sources that lie within 250 metres of the intended well site. If water sources are present within the 250-metre radius, water should be tested before, during and after each drilling to monitor water integrity.
- A further recommendation is that minimum well depths be set in order to ensure that hydraulic fracturing takes place a significant distance from water aquifers.
- Lastly, a quality assurance program needs to be in place to ensure that the proper well-bore design and construction practices are followed. During the life of the well, integrity testing should be performed regularly.

It is also imperative to maintain rigorous oversight of all parties and practices involved in the production process – subcontractors, quality assurance, audits and training programs – to ensure that everyone is meeting or exceeding standards and that accidents don't happen.

B

Well-bore Design



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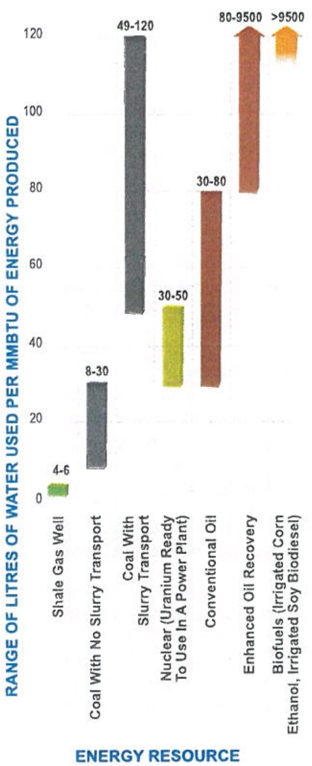
C

Comparison Chart



For illustrative purposes only.

CONCERN 3: "Hydraulic fracturing uses enormous quantities of water."

Water is a key input for shale gas production. It can take about 11 million litres (3 million gallons) of water to hydraulically stimulate a well.[4] In 2011, over 17,000 horizontal wells were hydraulically fractured for shale gas extraction. Undoubtedly, that's a large amount of water, and it has raised concerns about possible depletion of local water supplies and the need to regulate water usage. But the amount of water used in shale gas production needs to be viewed in context of other industrial, commercial and agricultural water uses.

Typically, the amount of water used in shale development is a fraction of the total water usage for agricultural, industrial and recreational purposes. *(see graphic D)*

Shale gas production also requires less water per unit of energy produced than conventional production of oil and gas and other forms of energy. The amount of water used to produce energy by sources ranges from five litres of water (1.3 gallons) per MMBTU for shale gas to more than 9,500 litres (2,500 gallons) per MMBTU for biofuels such as ethanol from corn or biodiesel from soybeans.

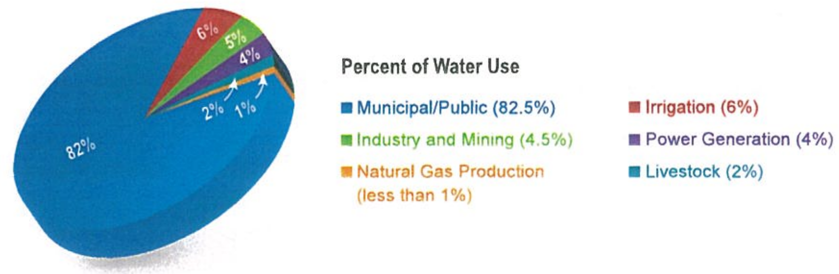
The chart on the left shows that shale gas requires the least amount of water to produce the same amount of energy: 1 MMBTU. *(see graphic C)*

As for concerns about water regulation and the possible depletion of local water supplies, it is important to remember that the sourcing and use of water – whether it is sourced from local drinking water supplies or nearby groundwater – is highly regulated in most jurisdictions.

As well, even though the amount of water used in hydraulic stimulation is already lower than that used in the production of many other fuels, the industry is constantly working on ways to further reduce overall water consumption by improving the hydraulic fracturing process and reusing water whenever possible.

It is recommended that the industry continues to reduce, re-use and recycle water to mitigate the overall volume of water required – supported by the ongoing collection of data and reporting on the amount of water used for shale gas production. It is also recommend that industry continue investing in technological enhancements to reduce the amount of water needed for hydraulic fracturing.

D



Even though the amount of water used in hydraulic stimulation is already lower than that used in the production of many other fuels, the industry is constantly working on ways to further reduce overall water consumption by improving the hydraulic fracturing process and reusing water whenever possible.

For illustrative purposes only.

CONCERN 4:
"Hydraulic fracturing fluids contain dangerous chemicals that aren't disclosed to the public."

Hydraulic fracturing fluid is the key to opening up fissures in shale formations and extracting natural gas. About 90 per cent of that fluid is water and about 9.5 per cent is sand. The remaining 0.5 per cent of the fracturing fluid contains additives – many of which are present in regular household products, cosmetics and foods.

Hydraulic fracturing fluid will typically contain three to 12 additive chemicals.[5] But, because each hydraulic fracturing job is unique – in terms of the well depth, the characteristics of the water being used and the shale formation being fractured – the fracturing fluid is uniquely constituted for each job. Each component added to the water and sand mixture serves a specific engineering purpose such as reducing friction, preventing microorganism growth, reducing biofouling of the fractures and removing drilling mud damage.

The graphic on the right lists the additives typically present in hydraulic fracturing fluid, their purpose and other common uses for these additives. *(see graphic E)*

Many of the chemicals listed in graphic E are commonly used in our everyday activities. Some, which are used in extremely low concentrations for hydraulic fracturing, can be toxic in higher concentrations. This holds true for chemicals that are routinely added to our drinking water and foods. For example, chlorine is used by water treatment facilities to make water safe for human consumption. When handled safely and used in the right concentrations, it is safe for people to drink and workers to handle. However, at higher concentrations or if an accident occurs, chlorine can have serious effects on human health and the environment.

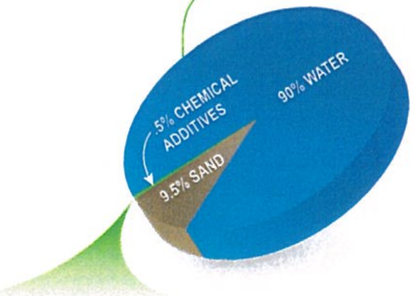
While production companies historically contended that the concentration of chemical additives in fracturing fluids was too small to be significant, and therefore not of interest to the public, the industry is taking steps to voluntarily disclose more information on fracturing fluid makeup. Several American states have established mandatory reporting requirements and the U.S. Department of the Interior is working on draft regulations that would require disclosure of chemicals used in hydraulic fracturing on public lands.

Hydraulic fracturing fluid is constantly controlled and does not come into contact with fresh water at any point in the hydraulic fracturing process.

Another key fact about hydraulic fracturing fluid is that it is constantly controlled and does not come into contact with fresh water at any point in the hydraulic fracturing process due to the cement and casing surrounding the wells.

It is recommended that the industry fully disclose all fracturing fluid additives so that the public knows which chemicals are being used, in what quantities, where and when. More investment is also recommended into "green" or non-toxic alternatives to the chemicals currently used in hydraulic fracturing fluid, such as UV light treatments to reduce the use of biocides and advanced dry polymer blender, which eliminates the need for hydrocarbon-based concentrates.

E



COMPOUND	PURPOSE	COMMON APPLICATION
ACIDS	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
SODIUM CHLORIDE	Allows a delayed breakdown of the gel polymer chains	Table salt
POLYACRYLAMIDE	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
ETHYLENE GLYCOL	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
BERABE SALTS	Maintains fluid viscosity temperature increases	Laundry detergent, hand soap, cosmetics
SODIUM/POTASSIUM CARBONATE	Maintains effectiveness of other components such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
GLUTERALDEHYDE	Eliminates bacteria in water	Disinfectant, sterilization of medical and dental equipment
GUAR GUM	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
CITRIC ACID	Prevents precipitation of metal oxides	Food additive; food and beverages, lemon juice
ISOPROPANOL	Used to increase the viscosity of the fracture fluid	Glass cleaner, anti-perspirant, hair colouring

For illustrative purposes only.

CONCERN 5:
"Hydraulic fracturing and associated wastewater disposal cause earthquakes."

Hydraulic fracturing for shale gas production involves drilling wells deep underground, injecting large quantities of water-based fracturing fluid in stages and then disposing of fluid – often underground. These activities have raised concerns about possible seismic events in nearby communities.

It's very difficult for geologists to link seismic events – earthquakes or other vibrations in the earth – to any one specific cause. The United States Geological Survey estimates that several million earthquakes occur around the world every year and that the vast majority of them go undetected because their magnitudes are so small or they are in very remote locations.[6] On the Richter scale, seismicity below a Richter level 3 is usually undetectable without sensitive instruments. And it is important to note that the Richter scale is logarithmic: A level 2 earthquake, for example, has a shaking amplitude 10 times less than a level 3 earthquake.

However, it has been proven that some human activities, including injecting fluid into deep wells, can cause seismic activity. If present, that seismic activity is usually so insignificant that it is noticed only by highly sensitive instruments, and is imperceptible to human beings.

The graphic on the right shows that the intensity of seismic activity from hydraulic fracturing of a shale gas well is typically 100,000 times less than levels detectable by human beings. *(see graphic F)*

On extremely rare occasions, humans have reported feeling seismic activity related to shale gas production. In 2011 more than 250,000 hydraulic fracturing stages were completed, along with the requisite disposal of wastewater. During that time, a few seismic events were reported: two cases in Ohio were said to be related to underground disposal of wastewater[7] and a low-level quake in the United Kingdom was attributed to hydraulic fracturing, due to "an unusual combination of factors, including the specific geology of the well site coupled with the pressure exerted by water injection."[8] Though discernible by humans, there was no physical damage from these events, and links between the seismic activity and shale gas projects have not been scientifically proven.

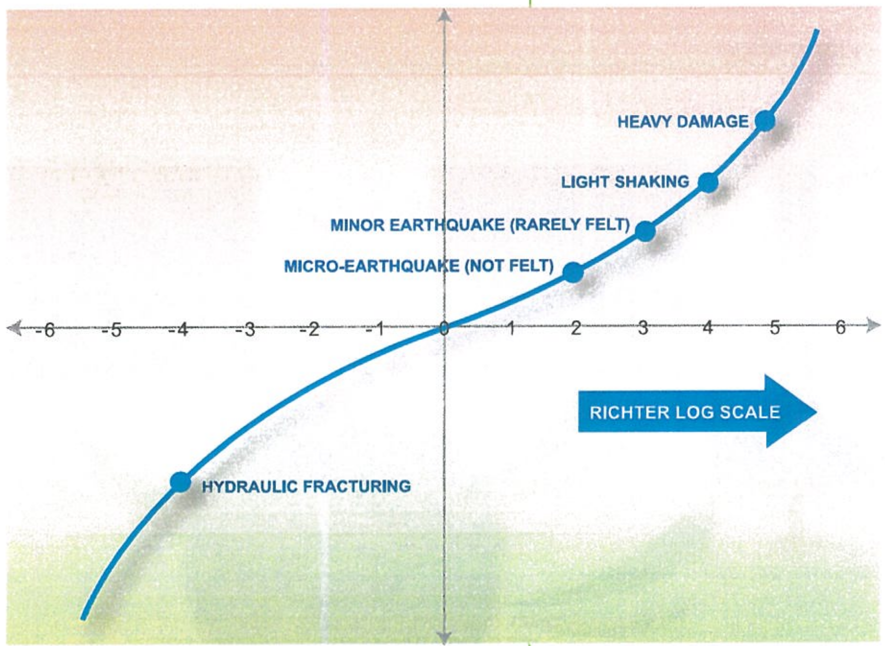
Recommendation:

Review the local geology for potential fault lines prior to drilling at well sites and wastewater injection sites.

It is widely agreed that a site's geology can have an impact on drilling. Therefore, to further ensure that shale gas production does not cause future tremors – regardless of their perceptibility – one recommendation is to review the local geology for potential fault lines prior to drilling at well sites and wastewater injection sites. Another recommendation is to monitor drilling and injection with ultra sensitive instruments so that operations can be halted if seismic activity occurs or seems likely to occur.

F

Microseismic Events from Hydraulic Fracturing vs. Earthquakes



For illustrative purposes only.

CONCERN 6:
"Disposal of wastewater harms the environment."

After a hydraulic fracturing stage has been completed and the pumping pressure has been relieved from the well, water begins to flow back to the wellhead. This "flowback" is a mixture of the original hydraulic fracturing fluid – containing less than one per cent of chemical additives – and any natural formation water – containing dissolved constituents from the shale formation itself. The disposal of this wastewater and produced water has been the cause of some concerns.

Flowback from hydraulic fracturing is managed in three main ways: reuse, disposal through injection in deep underground wells and treatment in a local facility. *(see graphic G)*

Underground injection is currently the primary disposal method for wastewater from most shale gas projects in traditional production areas. The wastewater is discharged into deep disposal wells that are subject to individual review and permitting.

However, in some areas where shale gas drilling occurs, such as the Marcellus shale areas of New York and Pennsylvania, the geology is not conducive to underground injection. Therefore, shale gas projects in these areas have typically shipped their wastewater to local treatment facilities. While these facilities are expert at treating domestic wastewater, they may not be designed to treat the specific components of shale gas production wastewater, such as salts, inorganic chemicals and Naturally Occurring Radioactive Material (NORM). Due to these concerns, new wastewater treatment facilities are being built to specifically handle wastewater from shale gas wells. Wastewater can also be stored in large steel tanks or in deep, lined pits where it is allowed to evaporate.

In addition, the percentage of water that is recycled and re-used for hydraulic fracturing stages is increasing, meaning that there is a lesser need for wastewater disposal.

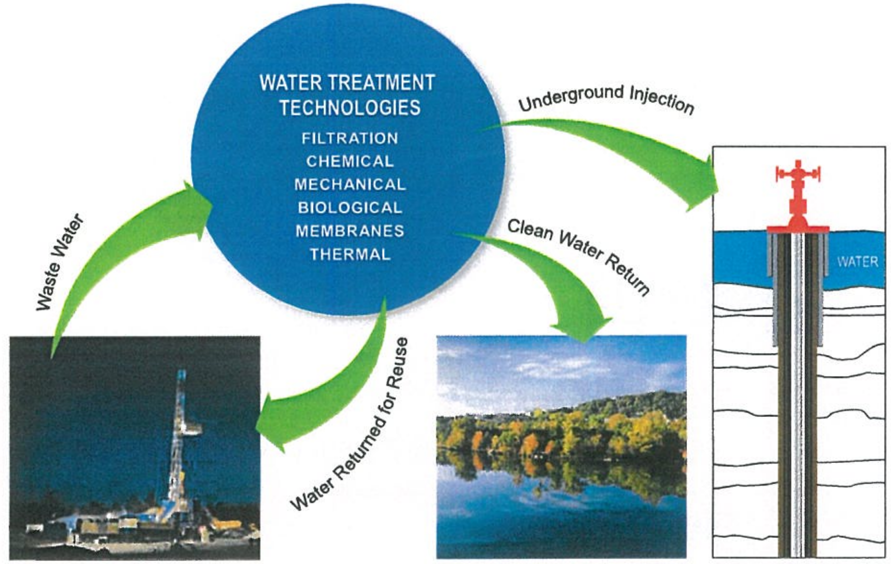
Further, as the industry invests in researching ways to use less water for hydraulic fracturing itself, and eventually decreases the number of litres used for each stage, there will be less water to dispose of or treat at the end of the process.

The percentage of water that is recycled and re-used for hydraulic fracturing stages is increasing, meaning that there is a lesser need for wastewater disposal.

One recommended best practice is that wastewater is injected into underground wells where possible or treated at purpose-built shale gas wastewater treatment facilities. "Closed loop" or "covered containment" systems should also be used to minimize environmental impact.

It is also vital to document and review policies for handling and disposing of wastewater, to ensure proper regulations exist for wastewater disposal and strong enforcement is carried out.

G



For illustrative purposes only

CONCERN 7:

"Air emissions related to shale gas production are worse than those created by burning coal."

When evaluating the overall merit and viability of any energy source, many people focus on the greenhouse gas emissions related to the production of that energy. Methane emissions from natural gas extraction, particularly shale gas, have been getting significant attention in recent months.

One study, published in 2011 by Howarth et al of Cornell University, claimed that the life-cycle greenhouse gas emissions of shale gas – that is, emissions that are associated with the production and transportation of the fuel to the end user – are higher than those of coal due to the fugitive and vented emissions of methane during the production and transportation of natural gas.[9] This particular study cast doubts on whether natural gas was in fact better than coal at combating climate change.

Many other similar studies, however, still maintain that greenhouse gas emissions from shale gas for electricity – including the life-cycle emissions – are significantly lower than from coal. In fact, a number of reputable studies find that producing electricity from natural gas creates 36[10] to 47[11] per cent lower emissions than producing electricity from coal. The reasons for the discrepancy are as follows:

- Howarth et al used a higher global-warming potential for methane than the widely accepted value used by the Intergovernmental Panel on Climate Change,
- Howarth et al used data sources that weren't from the Environmental Protection Agency (EPA), and
- Howarth et al failed to consider the potential for methane mitigation.

According to the EPA: "Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides at the power plant."[12]

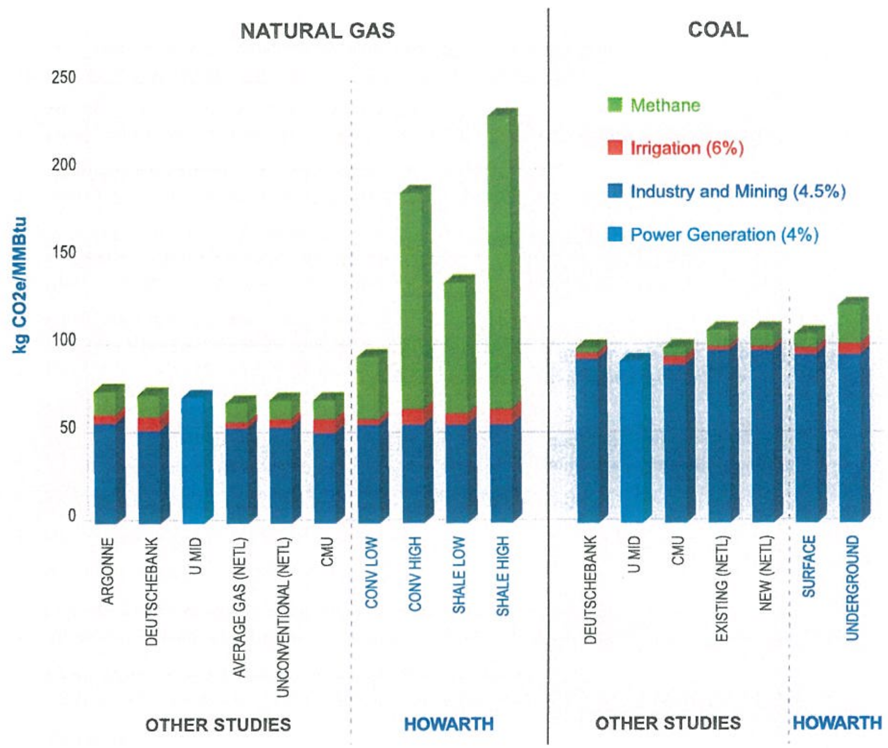
Producing electricity from natural gas creates 36 to 47 per cent lower emissions than producing electricity from coal.

The graph on the right shows how the study by Howarth et al was an anomaly in its findings of extremely elevated methane gas emissions for shale gas production compared to several other similar studies. *(see graphic H)*

Even though we recognize that the Horwath et al study was an anomaly, it is recommended to continually strive for lower greenhouse gas emissions in our industry and, specifically, work toward mitigating fugitive emissions of methane by employing green-completion systems.

H

Natural Gas & Coal Life-Cycle Emission Study Comparisons



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Other Regulatory Bodies:

ALGERIA
l'Agence Nationale de Contrôle et de Régulation des Activités dans le domaine des Hydrocarbures

ARGENTINA
National Institute for Water and the Environment

CANADA
Environment Canada

CHINA
Ministry of the Environmental Protection of the People's Republic of China

EUROPE
European Environmental Agency

POLAND
Inspectorate for Environmental Protection

UNITED STATES
Environmental Protection Agency

CONCERN 8:
"Shale gas extraction is not regulated."

According to some environmental organizations, shale gas opponents and media reports, shale gas production is largely an unregulated industry. This misconception can lead to concern that shale gas producers are not acting in the best interest of the public at large or are even breaking laws.

In North America, specific, dedicated regulations pertaining to shale gas extraction are evolving, however an extensive set of laws govern and regulate various aspects of shale gas development through many different and often interconnected regulatory bodies. The industry adheres to the same laws and regulations that the conventional oil and gas industry does. In the United States the regulatory bodies include: the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, and the Safe Drinking Water Act.

In all other jurisdictions around the world where shale gas is being produced or its production is being contemplated, similar regulations apply.

To the left are just a few of the regulatory bodies whose laws and regulations govern the shale gas industry.

In order for our industry to grow and gain more credibility in the eyes of the public, smart shale gas regulations must be developed for the future, regulations that protect the environment, public health and safety while realizing the full economic and environmental benefits of expanded shale gas development.

It is also imperative that producers employ best drilling practices, research and invest in new technologies and maintain appropriate oversight, inspection and enforcement of all existing regulations.

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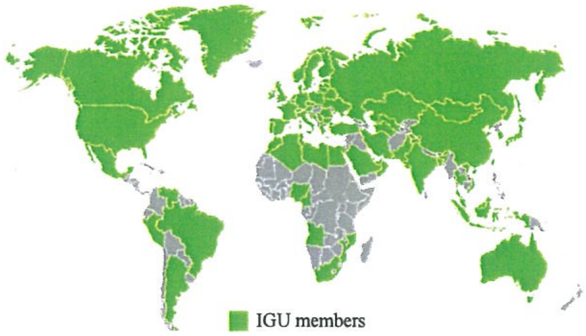
IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. IGU has more than 110 members worldwide and represents more than 95% of the world's gas market. The members are national associations and corporations of the gas industry. The working organization of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit www.igu.org.



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4 October 2013

The Chairman
Legislative Council Standing Committee on Environment and Public Affairs
Parliament of Western Australia
Harvest Terrace
Perth WA 6000

By email: env@parliament.wa.gov.au

Dear Chairman

Halliburton is pleased to have the opportunity to respond to the Committee's inquiry into the implications for Western Australia of hydraulic fracturing for unconventional gas.

Halliburton is a member of the Australian Petroleum Production and Exploration Association (APPEA) and has had the opportunity to view its submission to the inquiry. We are generally in agreement with the views set out in the APPEA submission and have therefore sought to focus the comments in this response on areas where Halliburton has additional thoughts or expertise to contribute.

1. About Halliburton

Halliburton is a leading provider of services to the energy industry and is the global leader with respect to oil and gas production enhancement, and hydraulic fracturing (HF) in particular. Over the past 60 years, Halliburton has provided hydraulic fracturing services to hundreds of thousands of wells around the world in a wide variety of settings and geological formations.

In more recent years, HF has been the catalyst for the 'revolution' in unconventional gas which has produced major economic and energy security benefits for the United States and also other nations.

At the core of Halliburton's business is technological innovation and a very strong long-term commitment to research and development. In the area of HF, technological innovation is substantially increasing the efficiency and viability of natural gas production, and doing so in a way that minimizes environmental impact. Halliburton has a strong interest in ensuring that hydraulic fracturing operations in Western Australia are performed in the most environmentally responsible and effective manner possible.

By way of background on Halliburton in Australia, the company commenced operations in this country in 1958, and now employs nearly 1,000 staff across the country, including over 300 in Western Australia. Our Australian corporate office is in Perth, with bases in Jandakot and Dampier and new facilities planned in Broome. In 2012, Halliburton spent more than $143 million on Australian vendors, of which around $50 million was spent in Western Australia.

Halliburton began providing HF services in Australia in the late 1960s, and has since performed more than 2,500 jobs (in Western Australia, including Barrow Island, as well as Northern Territory, South Australia, Victoria, NSW and Queensland) in a broad range of conventional, unconventional and geothermal plays.

2. Overview of Unconventional Gas

The APPEA submission provides a robust overview of the role of shale and tight gas globally, the substantial resources identified in Western Australia, as well as the history and operational characteristics of HF as a critical production enhancement technology.

While HF has been used over many decades in accessing conventional gas reserves, advances in HF technology over the last 10 to 15 years in particular have seen it become critical to the recovery of oil and gas from shales and other unconventional formations, such as tight sands. These unconventional sources generally must be stimulated to produce oil or gas in commercial quantities. While shale can only be accessed using hydraulic fracturing and other stimulation technology, by contrast only up to 10% of coal seam gas (CSG) requires hydraulic fracturing due to its high permeability. In Queensland, for example since 2000, only approximately 5% of CSG wells have been hydraulically fractured.

Natural gas development, particularly relating to unconventional gas sources where HF has been a critical technological catalyst, has yielded important social, economic and environmental benefits over recent years. In the U.S., for example:

- Natural gas prices have decreased from an average of $9.26 per mcf in 2008 to an average of $4.89 per mcf in 2011, primarily as a result of large-scale unconventional gas development. This has resulted in major economic benefits, both through the creation of jobs and by providing consumers lower costs for home heating and electricity. HF has boosted U.S. natural gas production by about 30 percent since 2005. Companies who use natural gas as a feedstock have built new manufacturing plants in the U.S. worth over $100 billion.

- The U.S. EPA recently noted that the increase in electric generation from natural gas has led to a decrease in the overall carbon intensity of electricity generation. (U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, ES-11 http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-ES.pdf). Greenhouse gas emissions were lower in the United States in the first quarter of 2012 than they were during any first quarter since 1992, due in significant part to increased electric generation from natural gas.

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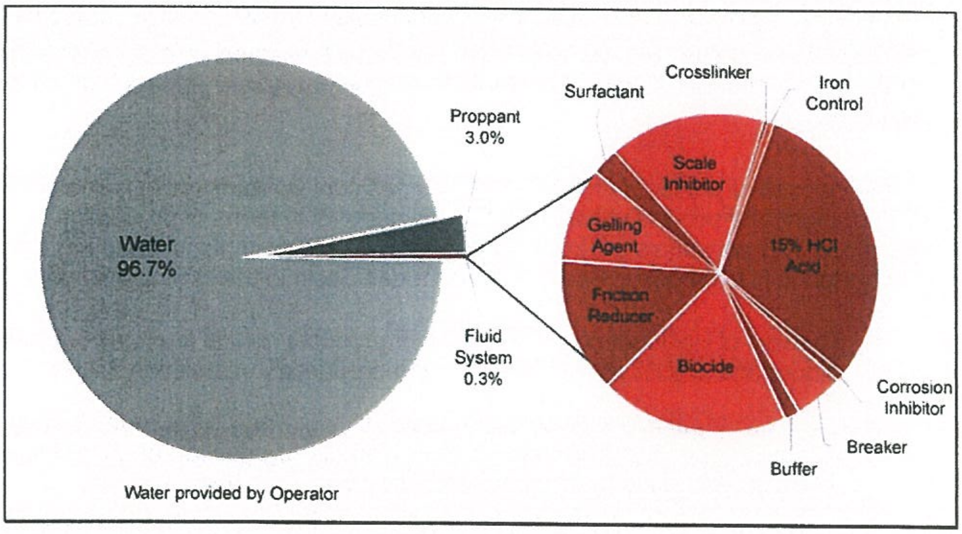
3. Hydraulic Fracturing Fluid Systems

As outlined in APPEA's submission to the Committee, HF is the practice of using highly pressured fluid to create tiny fissures in a target rock reservoir. The makeup of a fracturing fluid system for a particular well site mainly depends on the nature of the formation to be fractured, which means the specific components may vary from field to field, reservoir to reservoir and even well to well.
Water and proppant (sand) typically make up over 99% of the fracturing fluid system. The remaining small percentage is made up of chemical additives that perform a variety of functions depending on the characteristics of the formation being evaluated. Typical formulations used in Australia by Halliburton are available at: http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/fluids_disclosure.html For instance, in the case of deep HF treatment, the following diagram presents the typical composition of a fracturing fluid formulation:



The functions served by the less than 1% of chemical additives used in a typical frac formulation include: increasing the viscosity of the fluid to improve proppant transport, reducing friction, inhibiting bacterial growth, preventing corrosion in the well casing and limiting the formation of scale and other precipitants that could impede the flow of oil and gas and fluids.
Many of the chemicals in the additives used in the process are also found in foods or in household products such as cosmetics, shampoo and cleaning products. *See* http://www.energyindepth.org/frac-fluid.pdf.

4. Linkage Between Disclosure Regulation and Product Innovation

In the section of its submission entitled, 'The Delivery of Robust and Efficient Regulation', APPEA sets out the comprehensive regulatory regime that already exist in

Western Australia for onshore gas exploration and production. The APPEA submission also references the May 2013 report by the Australian Council of Learned Academies (ACOLA), 'Engineering Energy: Unconventional Gas Production', which provides a valuable overview of key economic, environmental, technological and other aspects of the industry in Australia and its potential. While the ACOLA report makes a valid point as to the importance of a robust regulatory framework, Halliburton agrees with APPEA's view that Western Australia's existing regulatory regime achieves this benchmark.
In this regard, Halliburton is aware that the Western Australian Department of Minerals and Petroleum (DMP) has recently examined the regulatory process for chemical disclosure in an unconventional gas context. DMP has recently settled on a systems-based approach to chemical disclosure combined with an environmental risk assessment approach for case-by-case assessment of chemicals and products.

Halliburton agrees with the APPEA position that DMP's approach will be workable in relation to the majority of products required by the state's unconventional gas industry. Importantly, however, for innovative HF fluids, drilling muds and other products developed by companies like Halliburton to be made available in Western Australia, supplementary regulatory arrangements to protect proprietary information will be required.

These innovative products are the result of significant investments in research and development and provide valuable economic benefits in terms of production enhancements as well as environmental benefits. For example, studies performed by Halliburton in the Marcellus Basin and the Codell Basin in the U.S. show that:

- The use of Halliburton's proprietary HF products results in an average increase in production of 33% as compared to non-proprietary stimulation fluids.
- The use of microemulsion surfactants developed by Halliburton has been found to result in long-term increases in oil and gas production of as much as 50% as compared to wells hydraulically fractured with conventional fluids.
- 24-41% more wells would need to be drilled to achieve the production enhancement that advanced technology provides.
- Halliburton's innovative products also facilitate the recycling of flowback and produced water.

See: http://cogcc.state.co.us/RuleMaking/PartyStatus/RebuttalStmts/HESIRebuttal.pdf at p. 27.

One possible supplementary disclosure regulation model available for consideration in Western Australia to support utilisation of innovative products is the approach to protecting proprietary information regarding HF fluids adopted in the U.S. by the Colorado Oil & Gas Conservation Commission ("COGCC"). The Colorado regulatory system provides for disclosure of HF ingredients and maximum concentrations on a well-by-well basis to the public. For the small number of ingredients in a particular HF formulation that are genuinely proprietary, the following information must be provided:

- (i) a chemical family name or similar description in lieu of a specific chemical name, and

- (ii) certain basic details regarding the basis for a claim for protection of proprietary information.

Regulators or medical personnel can get timely access to confidential information in the event it is needed to respond to a spill or other incident.
As an alternative, Halliburton supports the approach adopted by the Australian National Industrial Chemicals Notification and Assessment Scheme ("NICNAS"). Full disclosure is made by companies to NICNAS but proprietary information is protected from public release.

5. Benefits of Product Innovation

The recognition and protection of proprietary information in a balanced regulatory framework provides the basis for companies to invest on ongoing technological innovation. This innovation continues to result in direct and significant improvements in environmental performance and well productivity. In Halliburton's case, this is supported by a substantial annual investment in research and development, with expenditure in 2012 totalling $460 million.

Specific HF and other product innovations by Halliburton that have led to significant environmental and production benefits include:

- CleanStimAUS is a fracturing fluid system made entirely of ingredients sourced from the food industry that provides exceptional fracturing and environmental performance as compared to traditional formulations.

- PermStim™ fracturing fluid provides a cleaner, more robust system than typical guar-based fluid systems. PermStim fluid is a derivatised natural polymer that contains no insoluble residue, enabling improved well clean-up and better sustained productivity.

- 'Frac of the Future' reduces our footprint with the use of our high efficiency Q10 pumps and SandCastle vertical storage bins, which can reduce the wellsite size required from about ten acres to as little as three acres. This size reduction is accompanied by a reduction in noise and emissions through using fewer diesel engines. Reducing the number of pumping units required is reducing truck traffic to and from the wellsite. Halliburton won the 2012 World Oil HSE Award for this approach known as Frac of the Future.

- CleanStream® Service treats bacteria present in the water provided at the well site with ultraviolet light instead of the biocides that are commonly used. In many cases, the CleanStream process can be 99.9% effective, dramatically reducing the need for chemical biocides.

- ADP™ Advanced Dry Polymer Blender enables mixing any of Halliburton's fracturing fluids using a dry polymer, eliminating the need for liquid gel concentrates and resulting in conservation of petrochemical materials and reduced vehicle miles travelled transporting liquid gelled material. During 2012, the use of ADP blenders and associated dry gel has removed over 30 million gallons of hydro-treated light petroleum distillates from HF fluid in North America.

- WellLock Resin is another advanced cementing product developed by Halliburton with significant environmental benefits. WellLock resin is a synthetic thermosetting polymeric material that helps control and prevent annular flow, thereby protecting against potential migration of gas and water. Unlike other resins, WellLock resin is non-flammable and tolerates water (i.e. does not react exothermically) and has designed to work with aqueous-based fluids (i.e. water-based muds, cement slurries).

Further, the additional production benefits of these and other technologies allow for less drilling to occur with maximized production on smaller well pads, resulting in a reduced overall footprint.

6. Disclosure Through FracFocus

Halliburton has taken a number of steps to provide the public with information regarding the chemicals used in HF operations, including supporting the disclosure of information through the FracFocus Hydraulic Fracturing Chemical Disclosure Registry ("FracFocus") website: http://fracfocus.org.

FracFocus is a web-viewable system used to obtain, store, and publish information concerning the chemicals used in HF. In the U.S., FracFocus is a joint project of the Ground Water Protection Council ("GWPC") and the Interstate Oil and Gas Compact Commission ("IOGCC"). Halliburton has supported the use of FracFocus as a platform for providing the public with information regarding the fluids used in hydraulically fracturing individual wells. FracFocus has been very successful in the U.S. and Canada and is currently being considered by regulators in the EU and Australia.
The key characteristics of FracFocus are as follows:

- It allows companies to post information about chemicals used in the fracturing of oil and gas zones on a well-by-well basis. Companies upload HF fluid composition information and the data is made publicly available (no registration required) and searchable at http://fracfocus.org.

- The disclosure form is geographically tagged to allow the public and regulators to find and view information about wells based on their location. The system allows website users to locate wells by state, county, coordinates, a unique identifier known as an American Petroleum Institute ("API") number, well name and number, Chemical Abstracts Service ("CAS") number, and ingredient (chemical) name.

- The FracFocus disclosure information identifies the base fluid and additive products used to fracture a well and includes information concerning the constituents of those additive products such as ingredient names, CAS numbers, and maximum ingredient concentration in the overall HF fluid. FracFocus allows for companies to protect confidential business information through the use of general chemical descriptors in lieu of providing specific chemical identities for certain proprietary ingredients. The chemical identity and concentration information provided on FracFocus along with hazard information provided by MSDSs is sufficient in many instances to allow regulators to perform any necessary assessments.

- FracFocus has received over 48,000 disclosure records from 550 different companies and has been visited by almost 500,000 people from over 134 countries.

- FracFocus has functioned effectively as a voluntary reporting mechanism. At the same time, 18 U.S. states, representing a majority of the oil- and gas-producing states, and the US' federal Bureau of Land Management have either proposed or have already opted to require or allow companies to use FracFocus to meet state reporting requirements.

- FracFocus has been a successful regulatory tool in the U.S. and Canada because it allows regulators to provide information regarding the fluids used in hydraulically fracturing individual wells to interested members of the public and at the same time obtain information to support various regulatory functions. It is sufficiently flexible that a number of different states have been able to use it to meet their needs.

7. Protecting Groundwater

APPEA's submission to the Committee makes a clear presentation of the steps taken in the well construction management and process to protect groundwater and mitigate against the risk of HF contaminating drinking water sources. In over 60 years in which more than one million wells have been hydraulically fractured internationally there is no confirmed evidence that this type of contamination has ever occurred. A summary of recent statements by US regulators and policymakers in this regard has been collated by the American Petroleum Institute:

http://www.api.org/~/media/Files/Policy/Hydraulic_Fracturing/HF-Comments-by-US-Officials.pdf

HF has been thoroughly studied and carefully reviewed by numerous governmental agencies and regulatory officials internationally, as well as academic organisations. Studies have repeatedly confirmed that there is little or no risk to drinking water aquifers due to HF activities – references to a number of these studies are provided below.

In May 2013, a Halliburton-commissioned study by Gradient Corporation, one of the world's leading environmental and risk science firms, examined various shales and tight formations (such as tight sands) in the U.S. and concluded that the migration of fracturing fluids from a tight formation to a shallow aquifer is implausible and that HF operations do not pose any significant risk to drinking water supplies. This study updated a January 2012 study in which Gradient concluded that the migration of fracturing fluids from the Marcellus Shale to an overlying groundwater aquifer is "an implausible contamination pathway."

> http://www.energyindepth.org/new-report-hf-does-not-pose-credible-health-risk/; http://www.energyindepth.org/wp-content/uploads//2013/05/Gradient-Report_2.pdf at p. ES-5.

Gradient has also recently prepared two peer-reviewed journal articles on the lack of risk to groundwater. The first paper discusses the physical constraints on upward fluid migration from black shales such as the Marcellus and Bakken (US) to shallow aquifers that concludes that upward migration of HF fluid and brine as a result of HF activity does not appear to be physically possible.

> Flewelling & Sharma, "Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine," *Groundwater* (Jul. 29, 2013), available at http://onlinelibrary.wiley.com/doi/10.1111/gwat.12095/abstract

The second paper prepared by Gradient and a Halliburton expert examines the potential for fluid migration via induced fractures and considers the potential for interactions with natural faults to provide migration pathways. It concludes that it is not physically plausible for induced fractures to create a hydraulic connection between tight formations at depth and overlying drinking water aquifers.

> Flewelling et al., "Hydraulic fracturing height limits and fault interactions in tight oil and gas formations," *Geophysical Research Letters* (Jul. 26, 2013), available at http://onlinelibrary.wiley.com/doi/10.1002/grl.50707/abstract

A January 2013 study from the U.S. Geological Survey ("USGS") on the Fayetteville Shale in Arkansas which analysed 127 groundwater samples for the potential effects of gas production activities concluded that that there were no apparent effects on shallow groundwater quality from shale gas production.

> http://pubs.usgs.gov/sir/2012/5273/sir2012-5273.pdf; http://dx.doi.org/10/1016/j.apgeochem.2013.04.013.

The New Zealand Parliamentary Commissioner for the Environment issued a report in November 2012 stating that "there is no evidence that fracking has caused groundwater contamination in New Zealand" and that "[m]igration of contaminants into aquifers through the cracks created during the fracking process is only a remote possibility."

> http://www.pce.parliament.nz/mwg-internal/de5fs23hu73ds/progress?id=asyMs9aWhy at p. 43.

An October 2012 report regarding HF operations in the Inglewood Oil Field in the Baldwin Hills area of Los Angeles County showed that, based on actual groundwater monitoring results, the groundwater quality in the area was not affected by HF activities.

> http://www.inglewoodoilfield.com/fracturing-study.

The South African Department of Mineral Resources issued a report in July 2012 stating that "potable aquifers are expected to be far removed from shale gas target formations and safe from contamination from injected fracking fluids, as the latter are immobile under normal conditions with no 'drive' once the fracturing operation has been completed."

> http://www.info.gov.za/view/DownloadFileAction?id=174015 at p. 6.

The U.K Royal Society concluded in a June 2012 report that "[u]pward flow of fluids from the zone of shale gas extraction to overlying aquifers via fractures in the intervening strata is highly unlikely" and that, in general, it is very difficult to conceive how such upward fluid flow might occur given the hydrogeological conditions found in the relevant areas of the U.K.

> http://www.raeng.org.uk/mwg-internal/de5fs23hu73ds/progress?id=kHKyWimm/C at p. 37.

In a May 2012 report, the Council for the Taranaki Region in New Zealand found that there was no evidence of environmental problems related to the HF operations that had been undertaken in the region over a period of almost 20 years and that there is little risk to freshwater aquifers from properly conducted HF operations.

> http://www.trc.govt.nz/assets/Publications/guidelines-procedures-and-publications/hydraulic-fracturing/hf-may2012-graph-p19.pdf at p. 32.

The Shale Gas Production Subcommittee of the U.S. Secretary of Energy Advisory Board found in August 2011 that "[r]egulators and geophysical experts agree that the likelihood of properly injected fracturing fluid reaching drinking water through fractures is remote where there is a large depth separation between drinking water sources and the producing zone."

> http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf at p. 19.

The International Energy Agency released a June 2011 report titled "*Are We Entering the Golden Age of Gas?*" which states that the risks associated with natural gas exploration and production can be managed effectively.

http://www.worldenergyoutlook.org/media/weowebsite/2011/WEO2011_GoldenAgeofGasReport.pdf.

The Energy and Climate Change Committee appointed by the British House of Commons concluded in May 2011 that HF itself "does not pose a direct risk to water aquifers, provided that the well-casing is intact before this commences."

http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/795/79502.htm at s. 5, 113.

ICF International's analysis for NYSDEC in 2009 concerning the proposed development of the Marcellus Shale concluded that "hydraulic fracturing does not present a reasonably foreseeable risk of significant adverse impacts to potential freshwater aquifers."

http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf at p. 6-53.

The fundamental conclusion of the U.S. EPA's 2004 report was that HF of coalbed methane ("CBM") wells poses little or no threat to underground sources of drinking water.

http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_coalbedmethanestudy.cfm.

8. Further Information

Halliburton is willing to provide further information to the inquiry as required. We would also like to extend an invitation to the committee to visit Halliburton's facilities in Perth as well as the company's global technology centre in the United States, should an appropriate opportunity arise.

Please don't hesitate to contact me should you require any further information regarding this submission or any other questions you may have.

Yours sincerely

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7 OCT 2013

Santos

Hon Simon O'Brien MLC
Chairman
Standing Committee on Environment and Public Affairs
Western Australian Legislative Council
Parliament House
PERTH WA 6000

4 October 2013

Dear Chairman,

Parliamentary Inquiry into the Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas

Santos welcomes the opportunity to provide the following submission to the 'Inquiry into the Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas' by the Western Australian Legislative Council's Standing Committee on Environment and Public Affairs.

Who is Santos?

With its origins in the Cooper Basin in north-east South Australia and south-west Queensland, Santos is one of Australia's largest producers of gas to the domestic market and has the largest exploration and production acreage position in Australia of any company. Santos has developed major oil and liquids businesses in Australia and operates in all mainland Australian states and the Northern Territory.

Santos also has an exploration-led Asian portfolio, with a focus on three core countries: Indonesia, Vietnam and Papua New Guinea.

Santos has a significant oil and gas business in Western Australia (WA), which makes a major contribution to the company's earnings and production. Santos' oil operations in WA include the Santos-operated Mutineer Exeter and Fletcher Finucane facilities, as well as major interests in Stag, and the Barrow and Thevenard Island joint ventures. On the gas side of the business, Santos produces exclusively for the WA domestic market through its John Brookes, Spar and Reindeer fields using the company's processing capacity at Varanus Island and Devil Creek.

Santos is also an active explorer in offshore WA, with recent discoveries at Bianchi and Winchester in the Carnarvon Basin, and Crown and Bassett West in the Browse Basin.

All of the company's oil and gas in WA is sourced from offshore fields.

However, Santos and its joint venture partners discovered and developed the Cooper Basin oil and gas fields. This, combined with other onshore gas interests in

Queensland, New South Wales and the Northern Territory, arguably makes Santos Australia's leading onshore gas company.

In over 50 years of exploration and production, Santos has drilled over 2700 wells and currently produces from approximately 1300 oil and gas wells. To date, over 700 wells have been fracture stimulated in the Cooper Basin with over 1500 individual fracture stimulation stages having been pumped.

With over 3,000 employees across Australia and Asia, Santos' foundations are based on safe, sustainable operations and working in partnership with host communities, governments, business partners and shareholders

The role of natural gas
Natural gas is the fuel that will grow Australia's economy, contribute to the nation's energy security and meet the future energy demands of the energy-hungry Asian region. Natural gas is the primary fuel source for WA with more than half of WA's energy consumption derived from gas. The Australian Bureau of Resources and Energy Economics (BREE) forecasts WA gas consumption will continue to grow at approximately 2.2% per annum from 1,777 PJ in 2012-2013 to 4,036 PJ in 2049-2050 (See The Independent Market Operator 'Gas Statement of Opportunities', July 2013). Accordingly, the supply of natural gas is vital to the operation of the State economy.

The upstream natural gas industry is also a major employer in WA, and generates billions of dollars in taxes and export income each year.

Sources of natural gas
Natural gas is found in sedimentary basins, in a number of geological settings and within various rock types. All natural gas, whether it is described as conventional or unconventional, is composed predominantly of methane (CH4), with varying, usually minor, quantities of other hydrocarbons. The descriptor of conventional versus unconventional refers to the rocks or formations that the gas is trapped in and the methods required to extract it commercially.

Conventional gas
Conventional gas is trapped in porous and permeable reservoir rocks, such as sandstones, in favourable geological structures or traps, and within sedimentary basins. To date, most of the gas that has been produced, globally and in Australia, has been conventional gas. Conventional gas will flow at economic rates from wells drilled into the gas bearing formations.

Unconventional Gas
Unconventional gas is found in reservoirs that require specialised extraction technology such as dewatering or fracture stimulation to extract the gas from the formation at economic rates

1. Coal-seam gas (CSG)

CSG is natural gas that is extracted from coal. The gas is trapped in the natural fractures or cleats of the coal and also by adsorption onto the organic matter within the coal matrix. To enable the gas to flow, the coal seam needs to be de-pressured (to allow the gas to desorb) by dewatering the coal. Some coals are low permeability and in order to obtain economic flow rates of gas this permeability has to be enhanced by hydraulic fracture stimulation. However, Santos hydraulic fracture stimulates less than 10% of its CSG wells. CSG is produced in many parts of the world, and has been extracted in Queensland for the past 20 years.

2. Tight gas
Tight gas is not dissimilar to conventional gas, in terms of geological setting, except that the reservoir rock has a low permeability, meaning that it is more difficult to extract the gas than is the case for conventional, higher permeability sands. To extract the gas economically, the permeability has to be enhanced through hydraulic fracture stimulation. Tight gas has been produced in Australia in the Cooper Basin for some decades through the use of hydraulic fracture stimulation.

3. Shale
Shale gas occurs in very fine-grained, low permeability organic-rich sediments usually in deeper parts of basins. It is therefore necessary to enhance permeability to allow the gas to flow from the rock. This is typically done by combination of horizontal wells (wells with long horizontal or lateral sections giving them greater contact with the reservoir rock) and hydraulically fracture stimulation

Shale and tight gas resources are typically between two and four kilometres below the ground and separated from near-surface freshwater aquifers by at least a kilometre of impermeable rock.

What is hydraulic fracturing?
Hydraulic fracturing has been a commercial process in the oil and gas industry since 1947 and the Society of Petroleum Engineers (SPE) estimates that over 2.5 million hydraulic fracture stimulation treatments have been undertaken in oil and gas wells worldwide, with over 1 million in the United States. Hydraulic fracturing has been successfully used on wells in the Cooper Basin for nearly 50 years without incident and is currently performed in many Basins around Australia.

Hydraulic fracturing is employed where gas or oil is tightly held in low permeability reservoir sands, coals and shales to enhance the permeability of the formation and to enable the gas to flow at economic rates.

Hydraulic fracturing is not an explosive or high impact process. It is not part of the drilling process but is a completion technique applied after the well is drilled and the drill rig has moved to another well. Prior to the rig moving off, the well has been sealed with steel casing and cement. During the completion process, the casing is perforated and the well is stimulated via hydraulic fracturing. It is a process that results in the creation of small fractures in the rock to allow the oil and gas in the source rock to move more freely into the wellbore and enable economic hydrocarbon production. It involves pumping water, a specific blend of chemicals and proppants such as sand or ceramic beads down a well at sufficient pressure to create fractures in the low-permeability rock. The proppant material keeps the fractures open once the pump pressure is released and improves the production of the well.

Water accounts for about 90% of the fracturing mixture and sand accounts for about 9.5%. Chemicals account for the remaining 0.5% of the mixture and assist in carrying and dispersing the sand in the low-permeability rock. The chemicals are used for different functions and are not specific to hydraulic fracturing and have many common uses such as in swimming pools, toothpaste, baked goods, ice cream, food additives, detergents, cosmetics and soap. The chemicals are used to augment the following functions:

1. Viscosity – Gelling agents are added to the water to provide viscosity to enable the proppant material such as sand or ceramic beads to be transported down the well and into the created fractures
2. Friction Reduction – to reduce the force required to pump the fluid, friction reducers are added, making the fluid more "slippery" and easier to pump at the high pressures and rates required to create the fracture network.
3. Biocide – biocides or disinfectants are added to ensure that no microbes or organisms present in the water will destroy the gelling agents and also to ensure they will not enter and contaminate the reservoir
4. Scale and corrosion – scale and corrosion inhibitors are added to prevent deposition of mineral scales and to prevent corrosion of the steel casing or tubing.
5. Surface tension – surfactants or surface tension modifiers are added to assist the back flow of fluids from the formation

As part of the process, the sand or proppant material remains in the low-permeability rock while much of the fracturing liquid is recovered to surface prior to hydrocarbons flowing into the well.

Santos has decades of experience using this technology in the Cooper Basin in both South Australia and south-west Queensland.

The design and quality of the well construction is of paramount importance in managing, and avoiding, any environmental risks associated with hydraulic fracturing. Santos applies best practice in its drilling techniques and related activities.

Drilling and well construction
Well drilling is the process of drilling a hole in the ground for the purpose of extracting gas or oil. Drilling and completing a well or "well construction" consists of several activities as listed below, some of which are conducted several times;

- Building the well pad
- Setting up the drilling rig
- Drilling the hole to required depth
- Running formation evaluation logs to determine what the formation is and what fluids are contained within it
- Running the steel casing to line the wellbore
- Cementing the casing in place
- Removing the drill rig
- Logging the casing to ensure bonding of cement to the formation and casing and the top of the cement relative to formation depths
- Perforating the casing
- Stimulating the well if required
- Installing production tubing and surface equipment
- Production of oil or gas from the well
- Monitoring well performance and well integrity
- Reclaiming parts of the well pad no longer needed

Design and construction of wells is a critical process that needs to be both well regulated and well managed to ensure that groundwater and aquifer formations are protected and so the hydrocarbons can be produced safely throughout the life of the well.

Choosing where to drill

The level of impact of oil and gas production including hydraulic fracturing is strongly dependent on the location of the particular well – the rock structure, the location of faults and aquifers, and the proximity to those who may be affected. Subsurface geology will have a major influence in determining where a well is drilled but strong consideration is also given to surface issues such as populated areas, the natural environment, local ecology as well as existing infrastructure and access roads, water availability and disposal options. Sensitivity to these factors at this stage of development can minimise the impact of the activity on current and future land use.

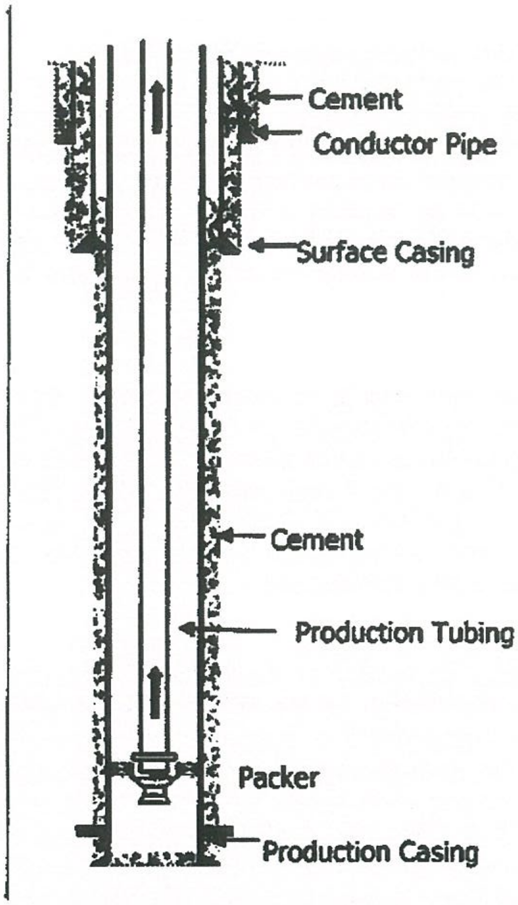
Establishing a well site

The first stage of developing any oil and gas well is to prepare the site. Santos engages in thorough discussions with the key stakeholders of the land before a site is located to ensure the concerns/activities of these stakeholders are considered. Site construction typically involves levelling of the site, if required lining of the site to minimise or prevent surface erosion, excavation of fenced pits with special impervious liners to hold drilling fluids and cuttings, and access roads for the transportation of equipment and materials to and from the site.

Drilling, casing and cementing

Drilling can take a few days or many weeks, depending on the geology, depth of the well, and whether the well is vertical or directional. As the hole is drilled, multiple layers of steel casing are inserted and cemented into place, providing a barrier between the contents of the well and the surrounding rock (see diagram below). Cement is forced down the inside of the casing and back up between the wall of the drill hole and the casing exterior, fixing it in place and sealing the gap. Cemented casing strings protect and isolate groundwater resources and aquifers from the oil or gas. The design and selection of the casing is important to ensure it is able to retain its integrity throughout the life of the well and withstand the forces it will be subject to from natural formation pressure as well as those from well completion, fracture stimulation and production operations. Wells may have from 2 to 5 casing strings that extend to different depths depending on individual well design requirements and conditions encountered. Understanding the depths of groundwater and useable aquifers is critical in the casing design of wells so that these resources are protected.

The construction aspect that is most important for well integrity is the correct composition, volume and placement of cement. The aim is to ensure that the cement binds tightly to both the steel casing and the rock, and leaves no cavities through which liquids and gases could travel. The cement serves two purposes – it provides protection and structural support to the casing while also providing zonal isolation between different formations, including groundwater and aquifers. At each casing stage the integrity of the well is tested to ensure that the steel casing and cement is able to perform the above purposes.



Establishing and maintaining the integrity of the well is critical to minimising the impact of hydraulic fracturing and future production operations on current and future land use. Wells are integrity-tested throughout their life. Santos has in place integrity management plans for all of its wells. These plans determine, based upon risk assessment, the frequency of the required well integrity testing. All wells are visited regularly for visual checks and casing annulus pressure readings and the individual well's risk rating is reviewed annually.

Hydraulic fracturing the well
When the cement and steel casing are in place and their integrity verified by both pressure testing and electric logs such as a cement bond log to validate the height and competency of the cement, the well completion process can begin. This is the final step to producing the oil or gas.

First, a perforating gun which contains a series of small specially designed shaped charges is lowered to the desired depth in the well and activated. These shaped charges create the holes through the casing and cement that connect the inside of the production casing with the geological formation containing the hydrocarbons. The producing zone is isolated both above and below by cement ensuring that hydrocarbons are unable to migrate anywhere except through the perforations and into the wellbore. Then the fracturing fluid is injected under high pressure and is forced through the casing perforations and into the rock, creating fractures.

The sheer weight of the overlying rock ("overburden") naturally limits fracture growth. Cracks are a few millimetres wide, about 30 metres high and extend anywhere from tens of metres to a few hundred metres from the well. The fractures will also vary in length due to the existence of natural faults, joints, or changes in rock type – these can either provide natural stopping points for a fracture or extend its reach.

Potential water impacts
Hydraulic fracturing could impact water quality in three ways. These are from:

- Spills and leaks at surface – of chemicals, waste, or oil and gas during transport, storage, and use. These risks are relatively easy to manage through good practice, response procedures, and personnel training.

- Migration – where oil and gas or other fluids travel up through cracks in the rock (either natural fractures or those caused by stimulation) and eventually reach aquifers. Migration of chemicals into aquifers through the cracks created during the hydraulic fracturing process is only a remote possibility. This is due to both the presence of cement above and below the hydrocarbon-bearing formation at the wellbore. The likelihood of hydraulic fracturing creating vertical pathways into aquifers is further reduced if there is an impermeable layer of rock (cap rock) above the hydrocarbon zone that will limit fracture growth and prevent migration. Gas in shale is unable to freely migrate due to the impermeability of the shale itself unless under large applied drawdowns such as those from production, in which case the migration is only toward the wellbore. Another important factor in limiting migration is the depth of hydraulic fracturing below the ground and aquifers. In tight sands and shale, the distance between the depth where hydraulic fracturing occurs and the depth of aquifers is typically large – anywhere between a thousand to many thousand metres. Extensive micro-seismic mapping of thousands of hydraulic fracture stimulation operations has taken place in North America and show that the height growth of the created fractures is limited to a few hundred meters with even the largest fracture treatments.

- Mechanical failure of the well – where the well is designed or constructed incorrectly. Wells can leak due to poor design or construction. Properly executed hydraulic fracturing in a properly constructed well does not lead to groundwater contamination.

  Most gas wells can be expected to drill through aquifers ranging from freshwater to saline and at depths ranging from very near surface (tens of metres) to deep (hundreds to thousands of metres), and are subject to well integrity regulation. In the Cooper-Eromanga Basin, in addition to surface aquifers, gas wells (whether they are seeking conventional, tight or shale gas) pass through deep aquifers of the Great Artesian Basin. To minimise the risk to this vital groundwater resource, Santos ensures that producing wells are constructed to industry best practice and meet or exceed Government regulations which stipulate which formations need to be isolated from each other to prevent cross flow and contamination. Prior to hydraulic fracturing, Santos models expected well pressures for all fluids to be pumped into the well. During the hydraulic fracturing process, Santos monitors, in real time, various well data onsite and will immediately shut down a job if a pressure signature does not match the modelled pressures.

  In order to ensure that groundwater is protected, Santos applies a number of best practices relating to shale gas production and water management before, during and after drilling and hydraulic fracturing take place:

- Prior to hydraulic fracturing, all landholders' active groundwater bores (subject to access being permitted by the landholder) in any aquifer that is within 200 metres above or below the target gas producing formation and is spatially located within a two kilometre radius from the location of the stimulation initiation point will be tested before and after hydraulic fracturing to ensure there was no impact.

- A quality assurance program is put in place to ensure that the proper well-bore design and construction practices are followed. During the life of the well, integrity testing is performed regularly.

Waste Water Management
To get the well to flow gas, the flow back of residual fluid from the fracture stimulation operation must occur first. "Flowback" water is a mixture of the original hydraulic fracturing fluid and any natural formation water – containing dissolved constituents from the shale formation itself. The disposal of this wastewater and produced water has been the cause of some concerns. Flowback from hydraulic fracturing is managed in three main ways: it is re-used, treated in a local facility or disposed through injection in deep underground wells.

Underground injection is currently the primary disposal method for wastewater from most shale projects in North America. The wastewater is discharged into deep disposal wells that are subject to individual review and permitting.

However, there will be instances where the geology is not conducive to underground injection. Therefore, some wastewater is either treated on site or transported to local treatment facilities.

Wastewater may also be recycled and re-used for hydraulic fracturing, meaning there is less need for wastewater disposal and less use of local water sources.

Wastewater can be temporarily stored in pits, tanks or evaporation ponds.

At its Cooper Basin operations, Santos produces fracture stimulation flowback water into a combination of tanks and lined pits. This ensures that surface contamination cannot occur. The water is then treated for re-use or allowed to evaporate at approved facilities.

During the flowback period, gas that flows up the well can be vented into the air or lit and flared. It is preferred to flare the gas both for safety reasons and to minimise green-house gas emission intensity. Air pollution and greenhouse gas emissions can also be effectively reduced through the use of 'green completions' – a series of processes that separate the gas from the returned water more effectively than conventional processes and allow it to be captured rather than vented or flared. Santos currently flares flow back entrained gas and is working towards implementation of "green completion" operations to further minimise emissions. Green completions require infrastructure such as pipelines to be in place during completion operations and thus may not be possible during the exploration or appraisal phases.

Seismic activity
Although there is ample evidence in Australia of induced seismic activity associated with large dams, mining operations and geothermal operations, there is currently no seismic risk data for oil and gas-related activity in Australia, such as hydraulic

fracturing operations. Overseas evidence suggests that induced seismicity of magnitude 3 to 4 can be generated by the reinjection of large volumes of produced water in deep wastewater wells or in geothermal operations, particularly at or near a critically-stressed fault, but hydraulic fracturing is unlikely to lead to damaging or felt seismic events. Overseas evidence from extensive shale gas operations documents only a few cases involving low magnitude seismic events, where the hydraulic fracturing process itself has resulted in induced seismicity. These few events have been linked to the intersection of active fault structures by hydraulic fractures. Best practice mitigation, which Santos employs, involves the identification and characterisation of local fault structures, avoidance of fracture stimulation in the vicinity of active faults, real-time monitoring and control of fracture growth through available sensing technologies and the establishment of 'cease-operation' triggers based on prescribed measured seismicity levels.

Term of Reference 1: How hydraulic fracturing may impact on current and future uses of land?

Santos' existing onshore operations, in eastern Australia, show that agriculture and natural gas extraction can coexist successfully. As the global population increases, sustainable and multiple uses of land is the best response to increased domestic, regional and global demand for food and energy. This is particularly true when both can be provided safely and sustainably from the same land.

The surface footprint of low-permeability rock oil and gas extraction is generally relatively small and temporary in nature. The exception to this is access roads and occasional infrastructure such as treatment and compressor stations, and centralised water treatment facilities. During their construction phase, wells are normally of an area of 1.5 ha or less for up to one year, and then decrease to approximately 25m by 25m, or 0.07ha for their productive life of approximately 20 to 30 years. At the end of their productive life, the wells are plugged with cement and rehabilitated, and surface facilities are removed, in accordance with Government approvals, guidelines and regulations, with effectively no surface impact remaining.

Santos understands that landholder access is one of the most important issues to address and get right on an ongoing basis as the gas industry grows. Clearly, landholders have legitimate concerns about how gas exploration and production will impact upon their existing land use, operations and property valuations. Creating respectful, mutually beneficial partnerships is a key priority for Santos. Every reasonable attempt is made to ensure that surface facilities are generally located in areas that are not visible from public roads, or homesteads, and away from the more intensively used areas of the property. Placement of wells, roads and infrastructure corridors are made in discussions with landholders so that impacts are minimised and if possible mutual benefits are realised.

Santos approaches landholders respectfully and in the spirit of a genuine negotiation, rather than with demands or a pre-determined outcome. Santos understands and acts to get the basics right by managing simple, but significant, issues such as closing property gates and preventing the spread of weeds.

Santos recognises that the impact its activities, including hydraulic fracturing, will have on the current and future use of the land depends significantly on the location of the particular well and the quality of its design and construction.

That said, it is also worth noting that the use of hydraulic fracturing may result in a smaller land-use footprint than via traditional onshore oil and gas operations as the use of hydraulic fracturing increases the economic drainage of the well resulting in less overall numbers of wells. Combined with the use of multi well pads where a number of wells are drilled directionally from a single pad further reduces the land use footprint. The U.S. Department of Energy (DOE) reports (see The International Gas Union 'Shale Gas: The Facts about the Environmental Concerns', June 2012) that just six to eight horizontal wells from one vertical location can access the same or greater shale reservoir volume as more than 16 conventional vertical wells – each requiring its own well pad, roads and pipelines.

In the Cooper Basin, multi-well pad development has resulted in a 55% reduction in surface disturbance compared to individual single well pads.

By applying best practice construction of surface and subsurface infrastructure, and by working with all stakeholders, the impact on current and future uses of land is not impacted by the use of hydraulic fracturing.

Term of Reference 2: The regulation of chemicals used in the hydraulic fracturing process

All fracturing fluids contain a small proportion of additives. These fulfil very specific purposes, such as controlling rust, reducing bacteria levels or to improve the overall productivity of the well. On average, chemical additives make up only 0.5% of hydraulic fracturing fluid and many are found in food additives, makeup and household cleaning products. The hydraulic fracturing fluid is controlled and does not come into contact with fresh water at any point in the hydraulic fracturing process due to the cement and casing surrounding the wells.

Santos is committed to keeping people well informed about our activities and supports the public disclosure of the additives (including maximum component concentrations) of the additives, such as fracfocus.org in the United States.

There are several geologic and reservoir characteristics, including mineralogy, permeability, pressure and temperature, that are considered in selecting an appropriate fracturing fluid. Service companies have developed a number of different hydraulic fracturing fluid recipes to more efficiently induce and maintain productive fractures. These solutions have unique characteristics and therefore the exact concentrations of some additives may be protected as proprietary information. Intellectual property rights are critical for businesses; these rights enable business to benefit from their investments and remain competitive in a global market place, allowing for continued innovation and hence improvement.

A potential unforeseen outcome of full disclosure, including constituent hydraulic fracturing fluid recipes, is that new, innovative and more environmentally benign products may not be used, with companies only having available older and less beneficial alternatives.

Term of Reference 3: The use of ground water in the hydraulic fracturing process and the potential for recycling of ground water

Water used during hydraulic fracturing is either taken from surface water sources (such as rivers, lakes or the sea) or from local boreholes (which will draw the water from shallow or deep aquifers) or from 'town' supply (trucked to site) pending availability and applicable regulations. Water may also be re-used from other sources, such as produced formation water from adjacent oil and gas production. Santos does this in the Cooper Basin to reduce the amount of bore water required. With advances in fluid chemistry, it is no longer required to use fresh, potable water for hydraulic stimulation.

Water is a key input for shale gas production. It can take up to about 11 million litres of water to hydraulically stimulate a well. This has raised concerns about depletion of local water supplies. But the amount of water used in shale oil and gas production needs to be viewed in context with other industrial, commercial and agricultural water uses. Typically, it is a fraction of the total usage for agricultural, industrial and recreational purposes.

Cumulative impacts assessment data was assembled by the New York City Department of Environmental Protection for the Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed and showed that the volume of water required for a single hydraulic fracturing for the life of a major gas field (3,000 wells) is in the order of 45,600 ML (45.6 GL) which, while a large amount of water, is modest when set against consumption in irrigated agriculture (see The Australian Council of Learned Academies (ACOLA) report 'Engineering Energy: Unconventional Gas Production: A study of shale gas in Australia', May 2013).

Best practice is to minimise the amount of water used in the well construction and hydraulic fracturing operations, and to re-use produced water.

Term of Reference 4: The reclamation (rehabilitation) of land that has been hydraulically fractured.

When a well reaches the end of its productive life, it has to be shut down and abandoned. Akin with initial well construction, the abandoning of oil and gas wells needs to be well regulated and managed to ensure the required end outcomes are achieved.

At abandonment, companies remove as much equipment from the well as possible before plugging the well with a number of cement plugs. The placement and verification of the integrity of these plugs is a critical step to ensure that the remaining hydrocarbons cannot leak into overlying formations and cause contamination. Casing and cementing is cut off below the surface and removed so that land can be returned to other uses. In addition, the company will disassemble any remaining buildings, tanks, and other infrastructure and will restore the land to its former state. The end goal of any abandonment program is that there should be minimal evidence that oil and gas operations have taken place.

While the operating company has tenure over the land they are responsible for all activities and to ensure that wells have integrity and do not cause cross flow contamination. Post abandonment and the relinquishment of production licence area Government regulators need to be satisfied that the abandonment operations have been carried out to required best practices so that future contamination risks are minimised.

Conclusion

The process of hydraulic fracture stimulation is not new to WA and has been applied safely to more than 780 wells since 1958. Advancements in hydraulic fracture stimulation and drilling technologies over the past decade have made the application of these processes for the production of shale and tight gas economically viable.

Currently WA's shale and tight gas industry is in the early exploration and proof of concept phases, but a significant opportunity awaits the State due to its large shale and tight gas resources. WA is estimated to contain 280 trillion cubic feet of potential shale and tight gas resources. Of this, 235 trillion cubic feet is estimated to be in the Canning basin (Kimberley and East Pilbara regions) and 45 trillion cubic feet in the northern Perth basin (Mid West region). To put this resource into perspective, WA currently consumes approximately 0.5 trillion cubic feet of domestic natural gas each year for everyday requirements such as electricity, heating, transport, manufacturing and mineral processing. If the 'shale gale' that swept through the United States in recent years (turning the nation from a major importer of gas to imminently an exporter of gas) is any example, WA is well placed to enjoy the major energy security, tax and royalty, and employment benefits that will flow from the industry's development. From Santos' experience in the Cooper Basin, the use of hydraulic fracturing does not significantly impact on the use of land by others, nor does it lead to the contamination of water aquifers. The key to addressing concerns around the impact of hydraulic fracturing on land use (in the short and long term) and aquifers lies in proper engagement with key and local stakeholders, identifying the right drill location, the quality of well design and construction (well integrity) and the protocols around testing and auditing. Employing best practice in these areas has led to safe, environmentally sustainable and successful operations for Santos in the Cooper Basin.

Yours Sincerely,

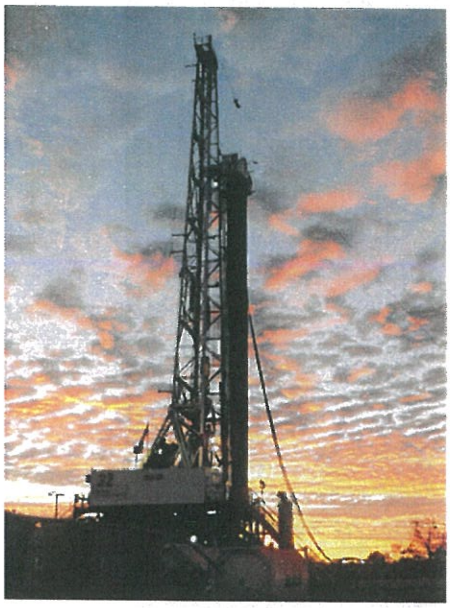
Tom Baddeley
Manager – Government and Community Relations, WA&NT
Santos

APPEA

Western Australian Onshore Gas

Code of Practice for Hydraulic Fracturing

Background



APPEA has facilitated the preparation of this Code of Practice to demonstrate what the gas industry is doing to successfully and responsibly develop significant onshore gas reservoirs in Western Australia.

The Code has been developed by a working group of industry operators based on established operating principles and leading practices in other jurisdictions that are relevant to local conditions.

Onshore gas reservoirs in Western Australia typically occur in tight sandstone and shale formations at depths of between two to four kilometres and in geological formations that are isolated from surface aquifers by significant barriers. Developing these resources can potentially deliver major environmental and economic benefits.

The shale and tight gas industry aims to assess and if feasible develop these reservoirs in a safe and environmentally responsible way consistent with regulatory requirements.

This Code was developed as part of industry input to an independent review of the regulation of these activities in WA which was released on 31 October 2011: http://www.dmp.wa.gov.au/7105_14068.aspx Western Australia's shale and tight gas industry will support these regulatory reforms to help ensure safe natural gas development, responsible water management and enhanced transparency. In addition, the industry commits to the guiding principles set out in this operating framework.

Legislation

In Western Australia, the Department of Mines and Petroleum (DMP) is the lead agency responsible for regulating unconventional gas activities. Shale, tight and coal seam gas are regulated using a similar process to conventional oil and gas activities under the Petroleum and Geothermal Energy Resources Act 1967, Petroleum Pipelines Act 1969, and the Schedule of Onshore Petroleum Exploration and Production Requirements 1991.

Proponents intending to carry out drilling and hydraulic fracturing operations must submit a number of applications to DMP, including:

- a drilling application;
- an environmental management plan; and
- a safety management plan.

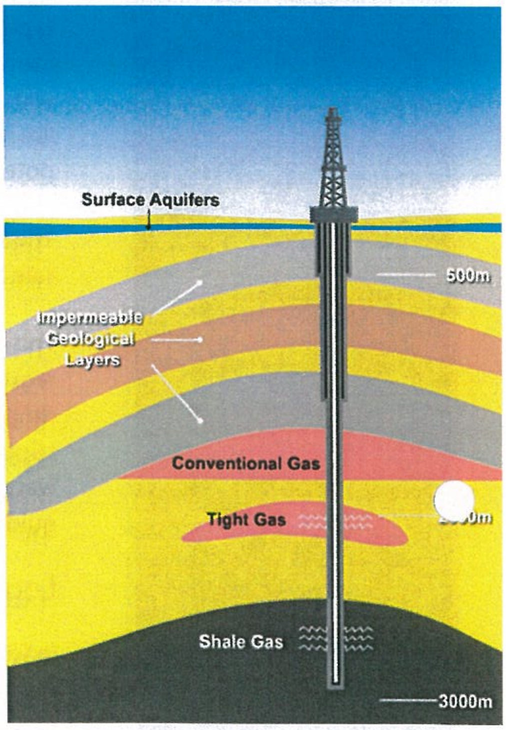
This Code of Practice has a particular focus on well stimulation given that requirements for drilling and well integrity in the broader oil and gas industry are well developed and dealt with in detail in the Schedule of Onshore Petroleum Exploration and Production Requirements 1991.

Guideline 1 – Community, landholder and stakeholder interaction

The aim of this guideline is to ensure operators communicate openly and as early as practicable with landholders, local communities and other stakeholders. This communication includes explaining how risks are being managed to minimise any potential unwanted or adverse impacts.

For example:

- Operators will work to understand and minimise potential impact of hydraulic fracturing on existing land users, the natural environment and local communities. This includes keeping activities away from dwellings or environmentally sensitive areas as per regulatory requirements.
- Operators will ensure contractors are fully informed as to the potential environmental and occupational health and safety impacts of hydraulic fracturing operations and that they comply with this Code of Practice as part of contractual arrangements.
- Operators will provide accurate, timely and current information about their hydraulic fracturing activities, including how risks are identified, assessed and managed, prior to undertaking the activity, and will provide additional significant information as it becomes available. This information will include publicly released environmental management plans.
- Landholders or occupiers of the land where hydraulic fracturing operations take place will be entitled to fair and reasonable compensation which will be arrived at by negotiation.



Guideline 2 - Protection of Aquifers

The aim of this guideline is to ensure that well design and implementation practices include protection of aquifers or groundwater that may be accessed for commercial or residential water supply ("Production Aquifers").

For example:

- During the well design and planning process, operators will identify any Production Aquifers at significant risk of being impacted by hydraulic fracturing fluids. This will include the identification of critical aquitards that protect such Production Aquifers from contamination.
- If any such aquitards have been identified, fracture stimulation activities will be designed to not breach these aquitards. As far as is reasonably practicable, monitoring will be carried out during operations with the aim of ensuring this is not occurring.
- Well design will ensure protection of all Production Aquifers from exposure to stimulation and/or resultant reservoir fluids by ensuring two independent and verified barriers in all wells.

Guideline 3 – Sourcing and Use of Water

The aim of this guideline is to protect and, where required, effectively and responsibly use groundwater resources.

For example:

- All water used in hydraulic fracturing operations will be captured and recycled for reuse as much as practical.
- Taking water from aquifers will be subject to Department of Water licence requirements. This includes demonstrating as far as reasonably practicable that the volume of water extracted will not have unacceptable impacts on aquifers, the environment or other water users.

Guideline 4 – Use of Chemicals in Hydraulic Fracturing

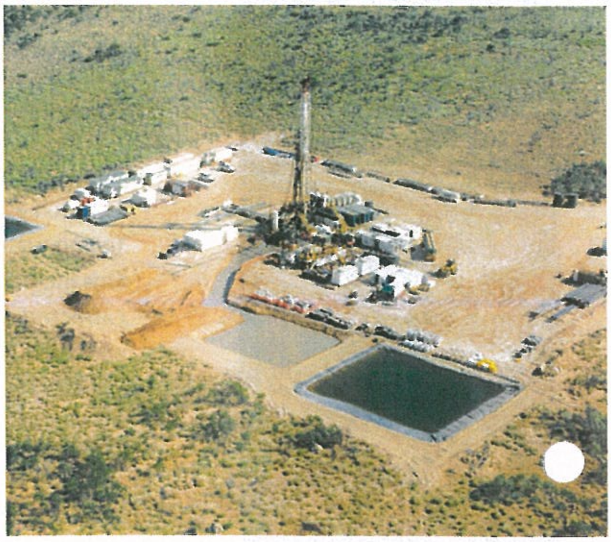
The aim of this guideline is to minimise the use of chemicals in hydraulic fracturing operations, provide clear and accurate information on any chemicals that may be used, and promote the safe and responsible use of chemicals.

For example:

- As far as practicable, fluids with the lowest toxicity will be used in hydraulic fracturing, and the concentrations used will be the minimum required to facilitate effective operations. Chemical suppliers will be required to meet these guidelines.
- Details of all fluids to be used during hydraulic fracturing operations, including information on actual usage and fluid recovery will be provided to DMP.
- The information will include relevant Material Safety Data Sheets (MSDS) and National Industrial Chemical Notification and Assessment Scheme (NICNAC) registration details and will be subject to the protections of proprietary or commercially sensitive information available under these schemes.
- Operators will support the public release of this information. This will include working with DMP through APPEA to develop a standard process including consideration of a website service such as FracFocus Chemical Disclosure
- All chemicals used for hydraulic fracturing operations will be handled and stored in accordance with appropriate International Standards Organisation standards, relevant Material Safety Data Sheets and State regulatory requirements.

Guideline 5 – Fluid flowback and produced fluids containment

The aim of this guideline is to ensure that post-fracture stimulation clean-up flowback or produced fluids cannot come into contact with Production Aquifers or pollute soil or soil substrate.



For example:

- All recovered hydraulic fracturing fluids will be isolated in sealed storage areas designed to prevent leakage.
- Recovered fluids will be recycled or disposed of through flaring, sale, evaporation or removal to an approved disposal site consistent with regulatory conditions.
  Produced hydraulic fracturing fluids may be reinjected into a suitable formation isolated from Production Aquifers in accordance with regulatory requirements.
- When no longer required for use, all sites, including any sealed storage areas, will be rehabilitated to meet regulatory or any other agreed requirements.
- Operators will comply with any legislative requirement to report any known or suspected contamination to the Departments of Environment and Conservation, Department of Health and Department of Mines and Petroleum.

Guideline 6 – Fugitive Emissions

The aim of this guideline is to ensure the fugitive emissions from stimulated wells during flowback and testing activities are minimised.

For example:

- Venting of gas to the atmosphere is to be avoided and when this is not possible for operational or safety reasons it should be kept to a minimum.
- During flowback of hydraulic fracturing fluids and extended well testing periods, gas will be separated from liquids and either be put into a pipeline for sale or when this is not possible, flared such that fugitive emissions are minimised.

Guideline 7 – Continuous improvement

The aim of this guideline is to ensure continuous performance improvement and the sharing of information with regulators and other stakeholders to reduce potential risks of hydraulic fracturing.

For example, well operators should:

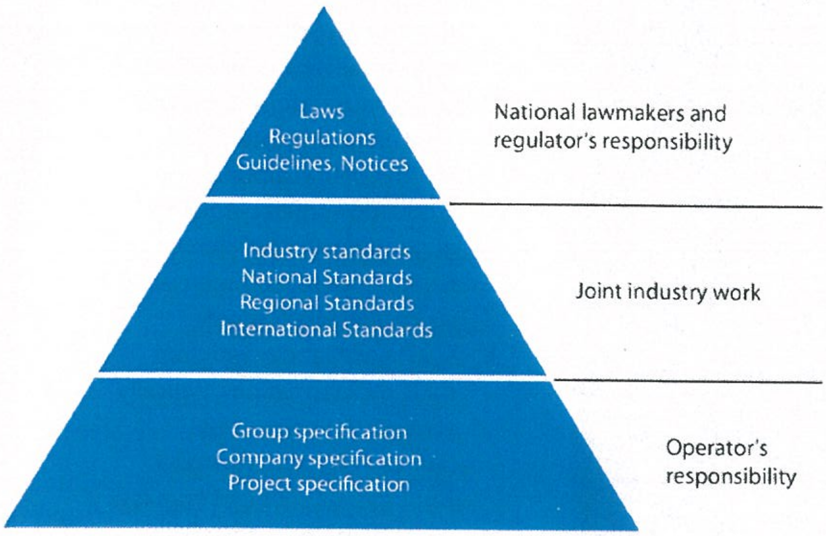
- Develop well construction procedures, environmental management plans and safety management plans consistent with regulatory requirements and the Code of Practice principles.

- Ensure full and open communication with regulatory authorities and other stakeholders in relation to industry activities and the processes of continuous improvement, including through supporting the public release of approved management plans.
- Collate and share information among the operating and services community on knowledge and experience to continuously improve operating practices.
- Contribute to building the body of knowledge within government on the appropriate management and regulation of the industry.

Industry standards and guidance, and the regulatory framework

The oil and gas industry operates under regulatory frameworks supported by many international and national standards relevant to exploration, development and operation as shown in figure 1. Further details on the standards identified in regulation and those that relate specifically to hydraulic fracturing are provided at Attachment 1.

This WA Code is a contribution to this guidance within the category of joint industry work.



Source: International Association of Oil and Gas Producers, Regulators' use of standards, Report No. 426, March 2010

Next steps

APPEA welcomes your views on the guiding principles and suggested actions in this Code of Practice. It is anticipated that a final version of the document will be issued after further consultation with regulators in relation to the regulatory reforms announced on 31 October 2011.

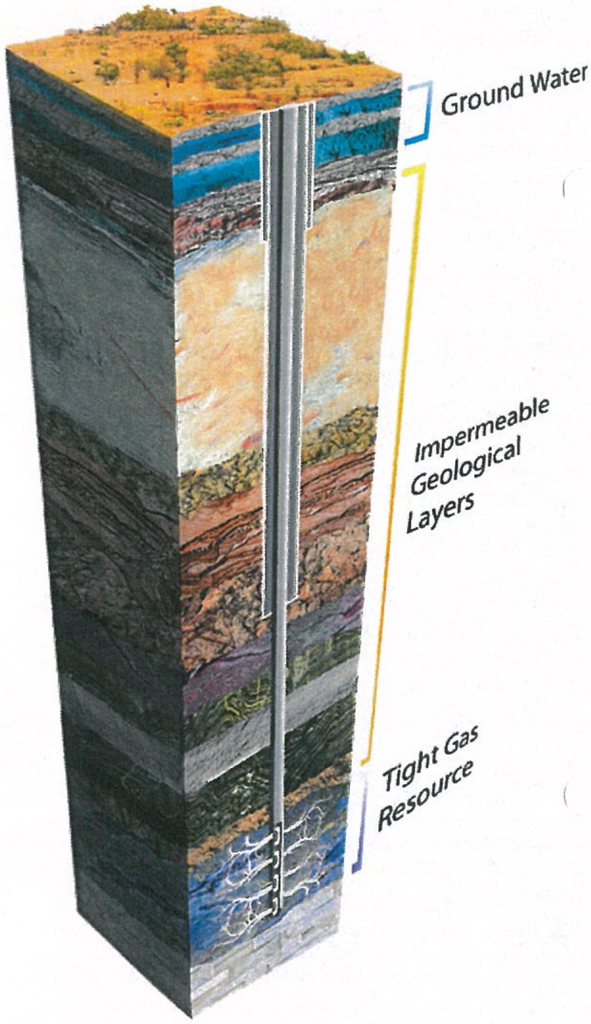
APPEA is also working with onshore gas operators in other States and Territories to consider a nationally consistent approach to a Code. This could define best practice operating principles for all onshore gas activities while also recognising that the different geology and regulatory frameworks must be considered in deciding which actions are best for local conditions.

To download the Code of Practice document or request a copy visit: www.appea.com.au

Post your comments to Onshore Gas Code of Practice, APPEA, Level 1, 190 St Georges Terrace, Perth WA 6000 or email your comments to ataylor@appea.com.au

Definitions

- Aquitard: A confining or impermeable layer that overlays or underlays an aquifer
- Coal seam gas: Gas derived from coal beds, typically at depths of between 300 and 600 metres.
- Hydraulic fracturing: Hydraulic fracturing (known in the industry as fraccing) is a process that uses the hydraulic pressure of fluid pumped into gas wells to open fractures in target formations and help increase gas production.
- MSDS: Material Safety Data Sheets provides details of the properties of a substance. They also provide details of actions that should be taken if a person comes into contact with the product.
- NICNAS: National Industrial Chemicals Notification and Assessment Scheme. NICNAS assesses all new chemicals to Australia and those already used on health, safety and environmental grounds.
- Production aquifer: Aquifers or groundwater which may be accessed for commercial or residential water supply.
- Shale gas: Gas derived from shale rock formations, typically at depths of below 2500 metres in Western Australia.
- Tight gas: Gas derived from low porosity or low permeability rock, typically at depths of below 2500 metres in Western Australia.



International Standards Employed in Western Australia for Onshore Petroleum Activities

Standards Identified in Regulation

Detailed below is a list of standards cited in Western Australia's Schedule of Onshore Petroleum Exploration and Production Requirements 1991 that relate to onshore petroleum activities under the Petroleum and Geothermal Energy Act 1967. A copy of the regulations is available on the Department of Mines and Petroleum's website at http://www.dmp.wa.gov.au/documents/PD-PTLA-TGR-248D.pdf.

Reference in Regulations	Reference	Title	Purpose
See http://www.osha.gov/SLTC/etools/oilandgas/glossary_of_terms/glossary_of_terms_a.html for a description of the typical components of a petroleum well.			
503 (a) – Equipment to conform to certain standards	API Std 4A	Specification for Steel Derricks (including Standard Rigs)	Sets standard for drilling and workover equipment
503 (a)	API Std 4D	Specification for Steel Derricks (including Standard Rigs)	This specification covers any mast structure suitable for oil-well or gas-well drilling or servicing
503 (a)	API Std 4D,	Specification of Portable Masts	
503 (a)	API Std 4E;	Specification for Drilling and Well Servicing Structures	This specification covers steel derricks, portable masts, and substructures i.e. structures suitable for drilling or well servicing
503 (b)	API Spec 7	Specification for Rotary Drilling Equipment	Sets standard for drilling and workover equipment
503 (c)	API Spec 5CT	Specification for Casing, Tubing and Drill Pipe	Specifies the technical delivery conditions for steel pipes (casing, tubing and pup joints), coupling stock, coupling material and accessory material
503 (d)	API Spec 6A	Specification for Wellhead and Christmas Tree Equipment	Specifies requirements and gives recommendations in relation to wellhead and christmas tree equipment for use in the petroleum and natural gas industries.
503 (e)	API Spec 16A	Specification for Drill Through Equipment	Includes blowout preventers, drilling spools and adapters
503 (f)	API Std 8A	Specification for Drilling and Production Hoisting Equipment	Establishes ratings for certain hoisting equipment used in drilling and producing operations
503 (g)	API Spec 9A / AS 1656	Specifications for Wire Rope	Specifies the minimum requirements and terms of acceptance for the manufacture and testing of steel wire ropes.
503 (h)	API Spec 10	Specification for Materials and Testing of Well Cements	Requirements for manufacturing eight classes of well cements and application of the API monogram, including chemical and physical testing requirements.
506 (1) - Casing	API Bull. 5C2	Bulletin on Performance Properties of Casing Tubing and Drill Pipe	Sets standard for design and placement of casing strings
506 (5)	API RP 5C1	Recommended Practice for Care and Use of Casing and Tubing	Sets standard for re-use of casing strings
508 (1) - Blow out prevention control	API RP 53	Recommended Practices for Blow-out Prevention Equipment Systems for Drilling Wells	Sets standard for installation, operation, maintenance and testing of blow out preventers.
515 (4) - Drilling fluid	API RP 13B	Recommended Practice for Standard Procedure for Testing Drilling Fluids	Sets standard for design of tests of drilling fluids
523 (1) - Fluid samples	API RP 44	Recommended Practice for Sampling Petroleum Reservoir Fluids	Sets standard for testing of recovered fluids from formation tests or non-routine production tests

Standards Specific to Hydraulic Fracturing

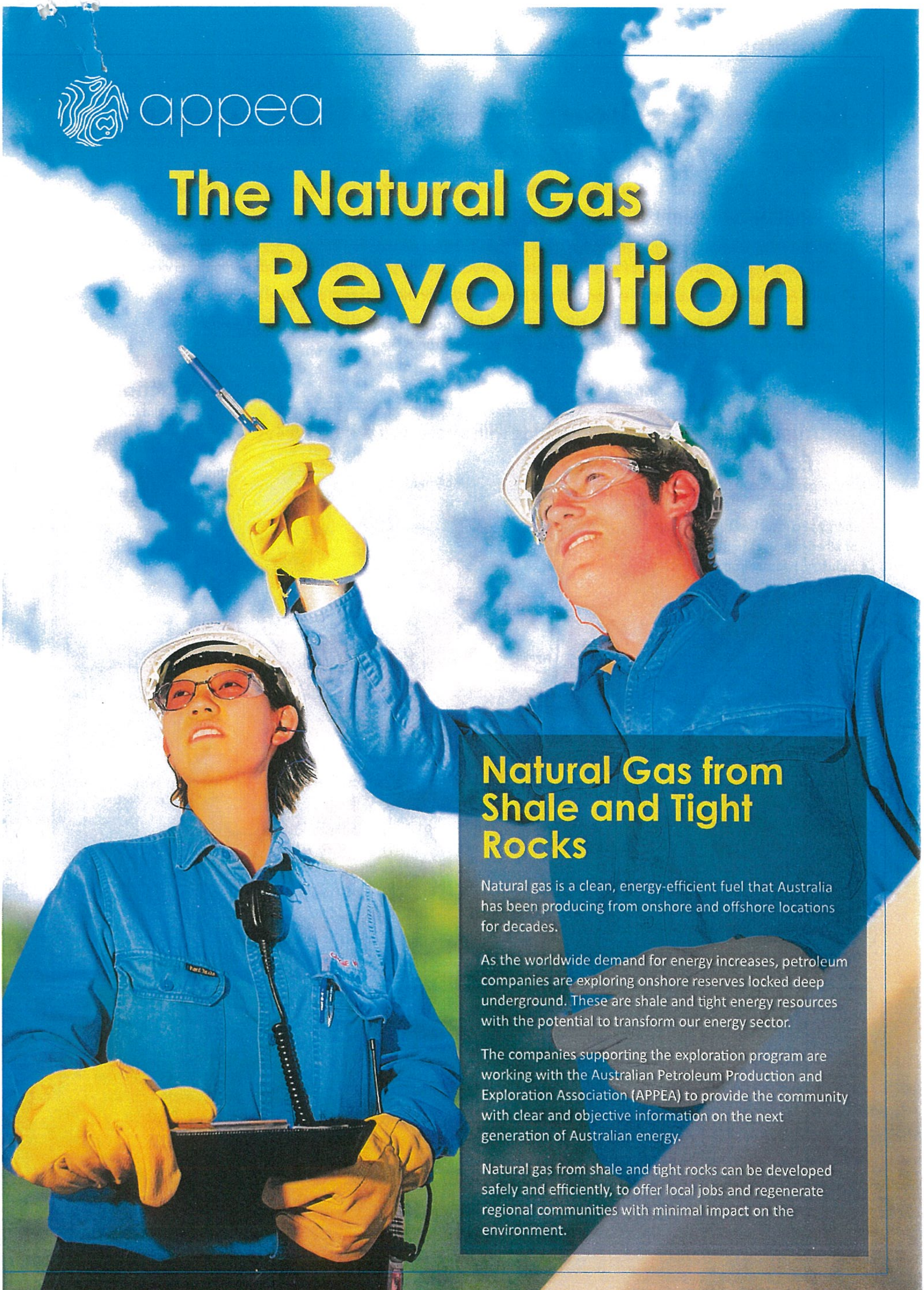
In relation to hydraulic fracturing, alignment with the following API standards would be considered good practice. Similar standards are also available from other jurisdictions.

API Reference	Title	Purpose
API HF1	Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines, 1st Edition, October 2009	• Highlights industry practices for well construction and integrity for wells that will be hydraulically fractured. • The guidance identifies actions to protect shallow groundwater aquifers, while also enabling economically viable development of oil and natural gas resources.
API HF2	Water Management Associated with Hydraulic Fracturing, 1st Edition, June 2010, (API)	• Identifies best practices used to minimize environmental and societal impacts associated with the acquisition, use, management, treatment, and disposal of water and other fluids associated with the process of hydraulic fracturing. • Focuses primarily on issues associated with hydraulic fracturing pursued in deep shale gas development, but also describes the important distinctions related to hydraulic fracturing in other applications.
API HF3	Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing, 1st Edition, February 2011, (API)	• Identifies the best practices for minimizing surface Environmental impacts associated with hydraulic fracturing operations. • Focused on protecting surface water, soils, wildlife, other surface ecosystems, and nearby communities. • Includes API's policy on chemical disclosure: - API supports transparency regarding the disclosure of the chemical ingredients;
		- States are the proper authority to determine reporting requirements and formatting of reporting and public disclosure; - Proprietary information should be protected; and - Hydraulic fracturing is effectively regulated by numerous federal, state and local requirements. Hydraulic fracturing should not be placed exclusively under the purview of the Safe Drinking Water Act (SDWA) or any other federal statute.
API Std 65 Part 2	Isolating Potential Flow Zones During Well Construction, 2nd Edition, December 2010, (API)	• Identifies best practices used to minimize environmental and societal impacts associated with the acquisition, use, management, treatment, and disposal of water and other fluids associated with the process of hydraulic fracturing. • Focuses primarily on issues associated with hydraulic fracturing pursued in deep shale gas development, but also describes the important distinctions related to hydraulic fracturing in other applications.
API RP 51R	Environmental Protection for Onshore Oil and Gas Production Operations and Leases, 1st Edition, July 2009, (API)	• Provides environmentally sound practices for domestic onshore oil and gas production operations, including fracturing. Applies to all production facilities, including produced water handling facilities. Operational coverage begins with the design and construction of access roads and well locations, and includes reclamation, abandonment, and restoration operations.

Source: http://www.api.org/policy/exploration/hydraulicfracturing/upload/Hydraulic_Fracturing_InfoSheet.pdf

Abbreviations

API - American Petroleum Institute
Bull - Bulletin
RP - Recommended Practice
Spec - Specification



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The Natural Gas Revolution

Natural Gas from Shale and Tight Rocks

Natural gas is a clean, energy-efficient fuel that Australia has been producing from onshore and offshore locations for decades.

As the worldwide demand for energy increases, petroleum companies are exploring onshore reserves locked deep underground. These are shale and tight energy resources with the potential to transform our energy sector.

The companies supporting the exploration program are working with the Australian Petroleum Production and Exploration Association (APPEA) to provide the community with clear and objective information on the next generation of Australian energy.

Natural gas from shale and tight rocks can be developed safely and efficiently, to offer local jobs and regenerate regional communities with minimal impact on the environment.

Natural Gas from Shale and Tight Sources
Benefits for Australia

Regional Development

- Studies show that developing an Australian shale and tight natural gas industry will generate significant benefits in regional areas[1], employing thousands of people in construction, operations, infrastructure and support services.
- Many companies are investing in exploration and infrastructure for the next wave of natural gas development.
- The availability of additional natural gas from shale and tight rocks will stimulate the Australian economy, generating new job opportunities across a range of industry sectors.

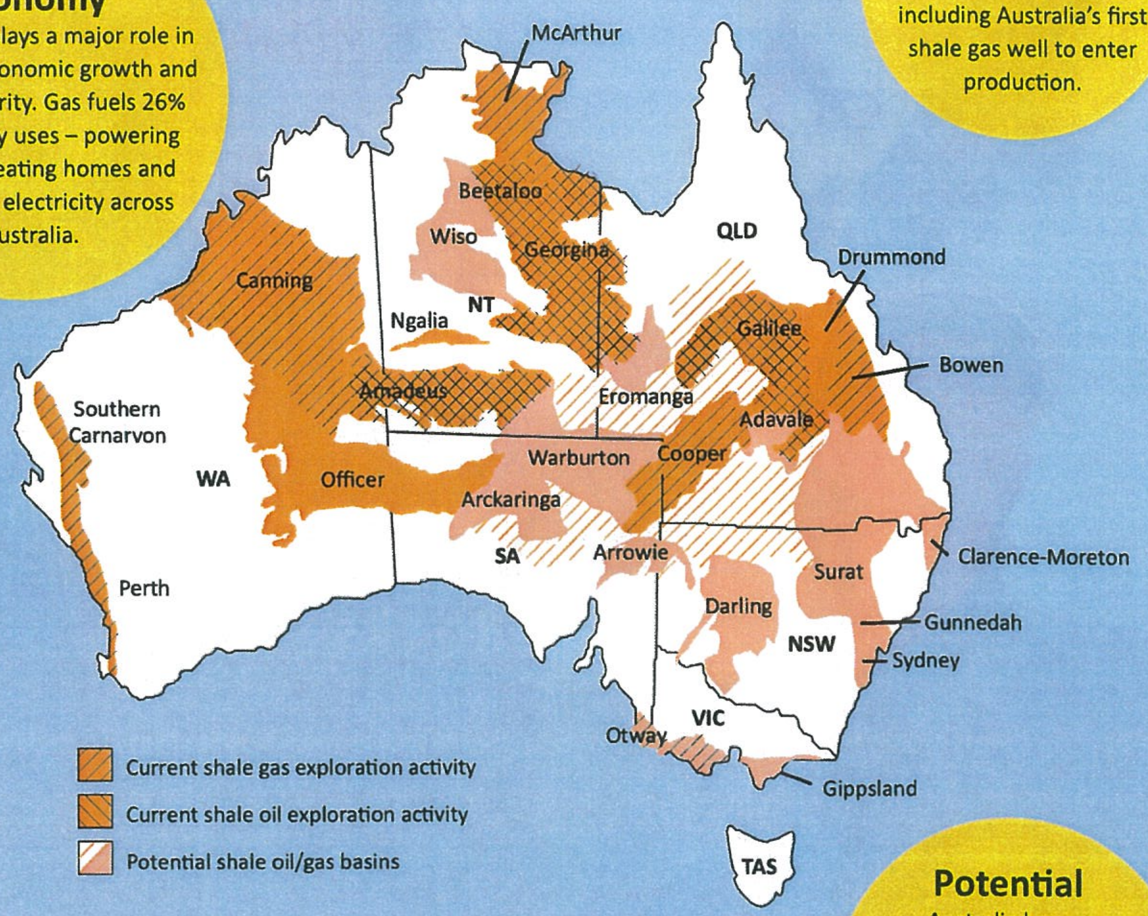
Australia's Economy

Natural gas plays a major role in Australia's economic growth and energy security. Gas fuels 26% of all energy uses – powering industry, heating homes and generating electricity across Australia.

Production

South Australia has the most advanced shale and tight gas projects, including Australia's first shale gas well to enter production.

Australian basins with shale gas potential



Potential

Australia has an estimated 437 TCF of recoverable shale gas reserves. 1 TCF is enough gas to power a city the size of Perth for 10 years.

1. Source: Engineering Energy: Unconventional Gas Production, Australian Council of Learned Academies (June 2013), Chapter 11: Community Amenity and Opportunity.

Learn more: www.appea.com.au

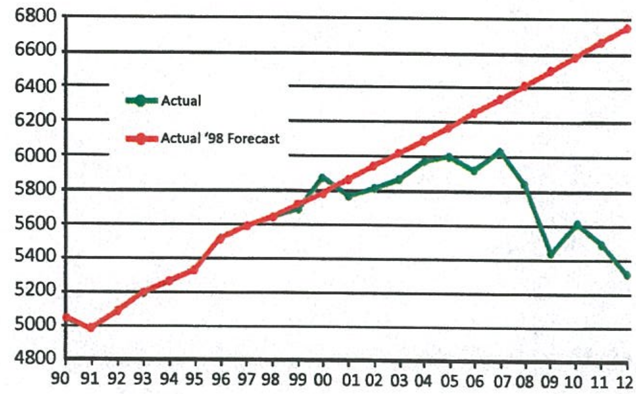
Secure Energy Supplies

- The first natural gas from shale and tight rocks in Australia is supporting the domestic market. This gas, from the Cooper Basin in Central Australia, is supplying homes and businesses in South Australia and New South Wales.
- Development of natural gas from shale and tight sources in Western Australia and the Northern Territory could also support the growing demand for domestic gas.
- Greater gas development in Australia will increase supply security and price competition as it has in the United States of America (USA).
- If the present exploration programs are successful, future development will be able to support secure and diversified domestic gas projects, with the potential to support liquefied natural gas (LNG) projects.

Clean Energy

- Natural gas currently offers the cleanest viable source of baseload and peaking power in Australia.
- Australia's natural gas resources can significantly reduce greenhouse gas emissions by replacing coal as a power fuel.
- Energy-related carbon dioxide (CO_2) emissions in the USA have dropped 12% between 2007 and 2012, their lowest level for a decade. A major factor influencing this reduction has been the increased use of natural gas, including shale gas, in place of coal for power generation.

USA Carbon Dioxide Emissions from Energy Consumption (Million Metric Tons)



Data sourced from: EIA Data by Country, Carbon Dioxide Emissions and EIA estimates from 1998 that emissions would rise by 1.5% per year through to 2020.

USA 'Shale Revolution'

A rapid increase in low-cost shale gas production has breathed new life into the US economy. As the leading global producer of shale gas, the USA has revitalised its energy sector with major investment in natural gas production.

One recent study illustrates the extent of the transformation. It found that the resurgence in onshore gas exploration and production in the USA had created at least 576,000 jobs in Texas, 102,600 jobs in Pennsylvania, 96,500 jobs in California, 78,900 jobs in Louisiana, and 77,600 jobs in Colorado, totalling 1.7 million jobs in 2012 with estimated growth to 2.5 million jobs by 2015.

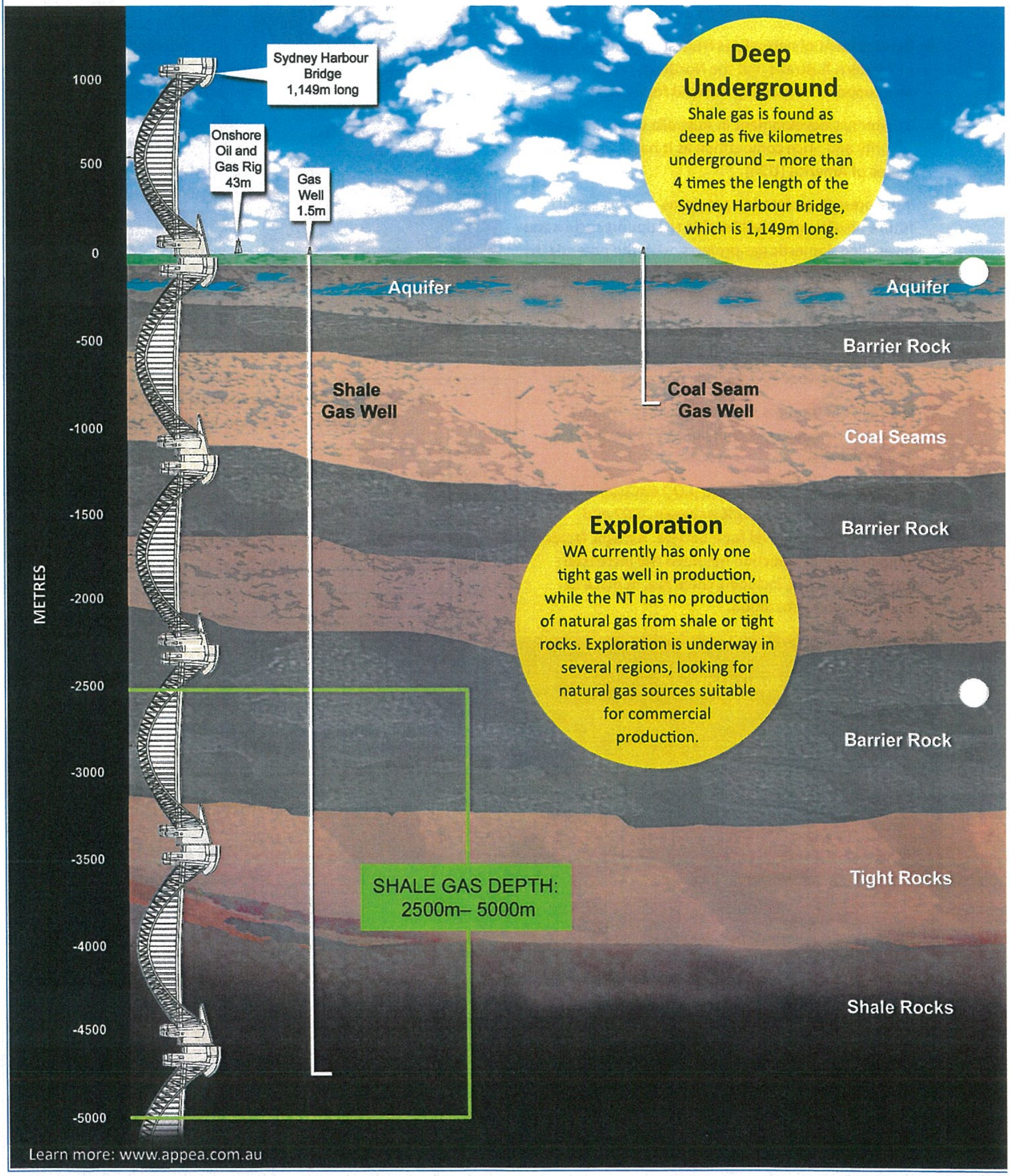
While employment has gone up, CO_2 emissions have come down.

USA Shale and Tight Gas Employment Predictions

Employment figures sourced from: IHS Global Insight - America's New Energy Future, December 2012.

New Energy Underground

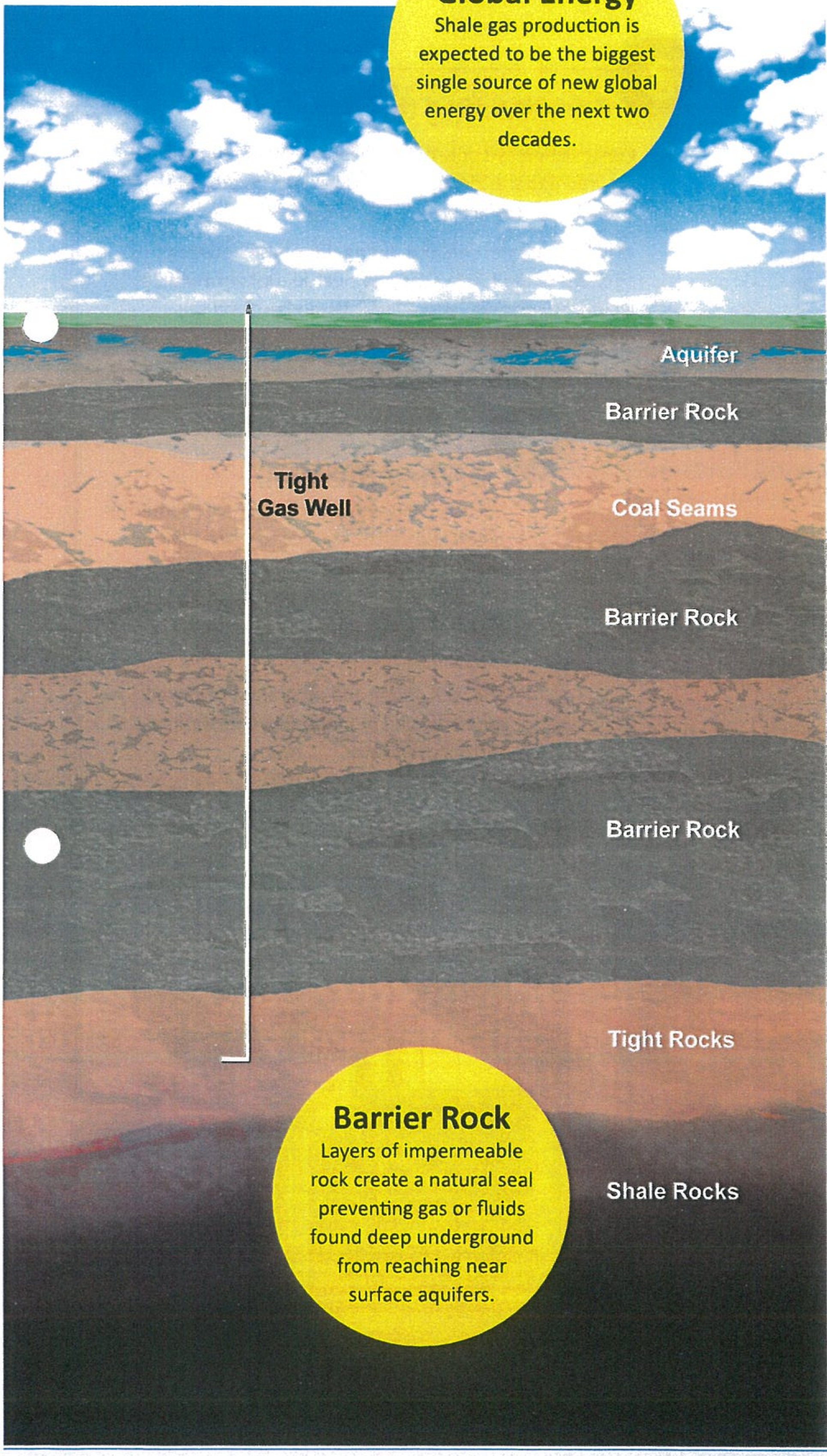
Natural gas is found in many forms of rock, including shale, coal seams and sandstone. Tight gas reservoirs are found in low permeability sandstones. Natural gas is used to fuel millions of households and businesses in Australia.



Natural Gas Resources Explained

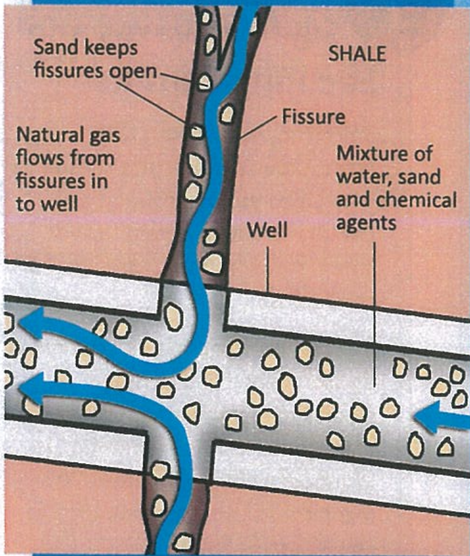
Global Energy

Shale gas production is expected to be the biggest single source of new global energy over the next two decades.



Barrier Rock

Layers of impermeable rock create a natural seal preventing gas or fluids found deep underground from reaching near surface aquifers.



Natural gas from shale and tight sources are found trapped in layers of fine-grained rocks. Shale gas in shale rocks and tight gas in low permeability sandstone, is usually found two to five kilometres underground.

Advances in drilling technology have allowed the industry to extract this trapped gas using hydraulic fracturing (also known as 'fraccing') to create tiny 3-6mm cracks in the gas-bearing rock to help with gas flow.

Coal seam gas (CSG), also known as coal bed methane, is trapped by water pressure in underground coal seams. It is found closer to the surface at depths of 400-1000 metres. Hydraulic fracturing is sometimes needed to release gas from the coal seams.

Due to the natural geology across Australia, natural gas production in the western and central regions will most likely be supplemented by shale and tight sources, while on the east coast the focus is currently on natural gas from coal seams.

Learn more: www.appea.com.au

Natural Gas from Shale and Tight Sources
Stages of Development

1 Signing Leases and Securing Permits

Before any activity can take place, industry must first consult with pastoralists and Traditional Owners to obtain access to the land for exploration under agreed conditions.

Exploration companies also conduct environmental and heritage studies to identify areas for special management. This information is included in plans submitted for regulatory approval ahead of any industry activity.

3 Constructing the Well Site

Construction can only begin once regulatory approval is secured and the location for the well pad is agreed by the company, pastoralists and Traditional Owners.

Well pads vary in size, but during this phase between 2-5 hectares of land will usually be cleared. Drilling multiple wells from one well pad minimises land use and the number of roads needed.

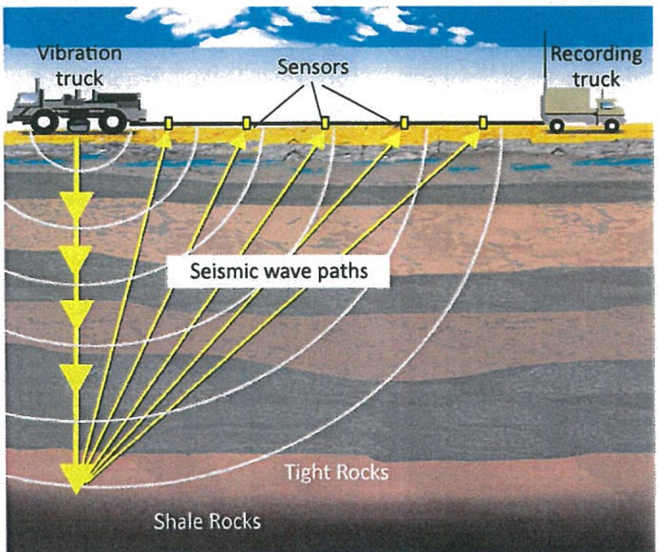
Many Uses

Hydraulic fracturing can also be used to stimulate groundwater wells to improve flow and is essential to produce energy from geothermal "hot rock" systems.

2 Gathering Seismic Data

Seismic imaging is used to help understand what lies beneath the earth. Soundwaves are bounced off underground rock structures and the echoes reveal possible oil- and gas-bearing formations.

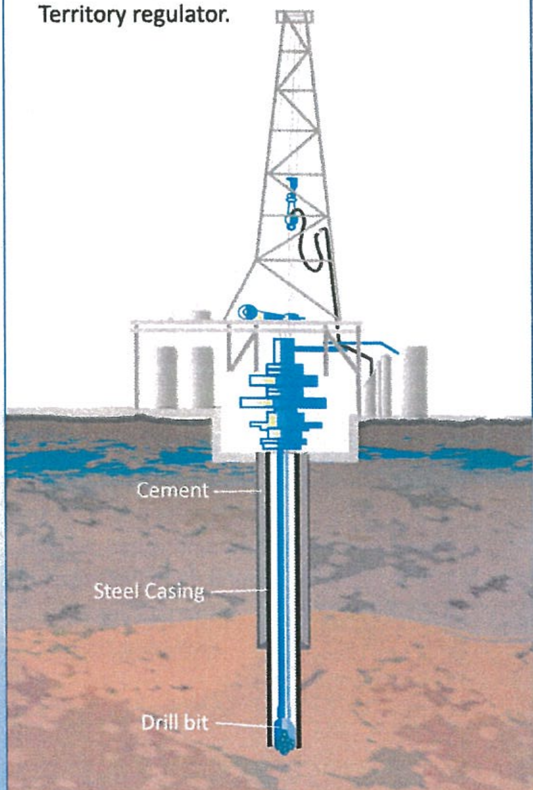
Earth scientists study the echoes to determine the best location for drilling and minimise the number of wells needed.



4 Drilling the Well

Vertical wells are drilled up to five kilometres below the earth's surface to reach tight or shale resources. To maximise access to the resource the wells may then be drilled about 600-2000 metres horizontally into the layer of rock containing the gas.

The well design and program is reviewed, approved and monitored by the State or Territory regulator.

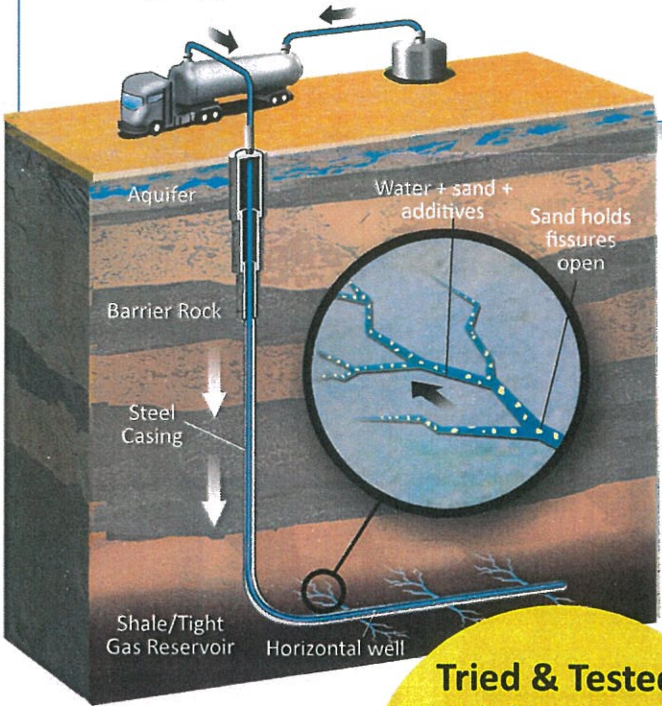


Learn more: www.appea.com.au

5 Hydraulic Fracturing

Before hydraulic fracturing can occur the program is reviewed by the regulatory authority.

If approved the operator will pump a fluid – typically 99.5% water and sand, and 0.5% chemical additives (see page 10) – down the well at a high pressure. This creates a network of tiny cracks in the rock. The sand helps to hold the cracks open, allowing trapped natural gas to flow to the well.



Tried & Tested

Hydraulic fracturing has been used in Western Australia since the 1950s. More than 780 petroleum wells have been fractured in WA with no known adverse effects on the environment, water sources or public health.

6 Testing

Once the well is in place and it can safely produce natural gas, an extended testing program may take place. These tests provide the operator with important information about the resource.

7 Building Natural Gas Pipelines

If the testing period is successful, a pipeline will be installed from the new well to an existing network. This natural gas is processed and can then be used for power generation, heating and cooking in homes and to meet a wide range of industrial energy needs.

Decades of Production

Natural gas wells that produce from shale and tight sources are expected to have a long production life spanning several decades.

8 Low Impact Production

It can take up to a year to build the well site, drill and complete the well. Throughout the well development process, the regulatory agency ensures compliance through regular inspections.

When the development of the well is complete, the company works with the pastoralists and Traditional Owners to restore the land around the well head back to its original state.

9 Producing Natural Gas for Decades

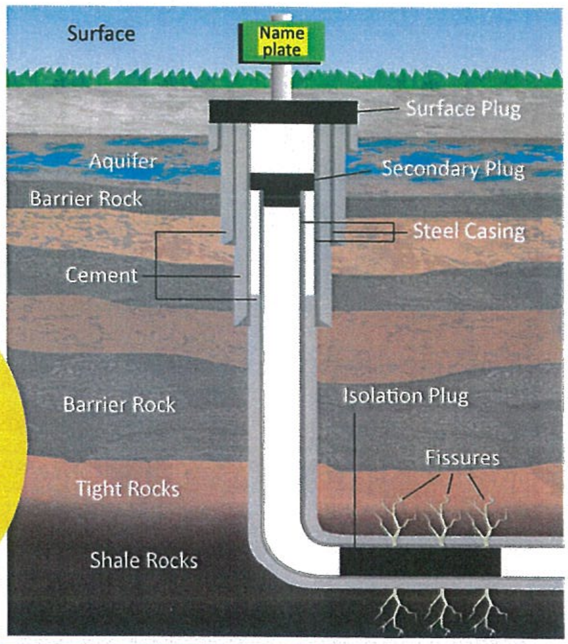
After the land at the well site is restored a small cleared area around each well head remains. The area includes a well head, a gas processing unit and one or two water tanks.

Wells typically produce gas for many years with little surface activity other than regular environmental checks.

10 Decommissioning of Wells

When a well is no longer required it is permanently sealed off by a series of cement plugs – a process called abandonment. This cement is a specially formulated mixture designed to be long-lasting and withstand high pressures.

The abandonment process is subject to strict conditions and is reviewed and approved by the State or Territory regulator.



RESPONSIBLE DEVELOPMENT
Sound environmental management

Protecting Groundwater

The industry is committed to safe and responsible operations and ensuring long-term groundwater protection. One of the most important groundwater protection measures is safe and effective well-design and construction. Other measures include independent research to understand underground fresh-water systems and the safe storage and treatment of fluids recovered at the surface.

The rigorous engineering standards are supported by continuous monitoring to make sure the controls are working effectively.

Hydraulic Fracturing

The same concept of high-standard engineering and ongoing monitoring is the basis of well-managed hydraulic fracturing, the process used to increase the production of tight and shale gas.

For shale and tight rocks hydraulic fracturing or 'fraccing' takes place between two and five thousand metres below the surface – that's up to five times the length of the Sydney Harbour Bridge (1,149m). The gas zone is separated from fresh water aquifers by hundreds of metres of impermeable rock – creating a natural barrier and preventing gas or fraccing fluids from leaking into shallow freshwater aquifers.

Water Use

Most of the water for tight and shale gas production is used in the hydraulic fracturing process. The International Gas Union estimates about 11 million litres of water – equivalent to four Olympic swimming pools – is used in this process. This is much less than is required for many pastoral and industrial uses.

About a third of this water will flow back to the surface with the initial gas production. This can be recycled and used to hydraulically fracture other wells.

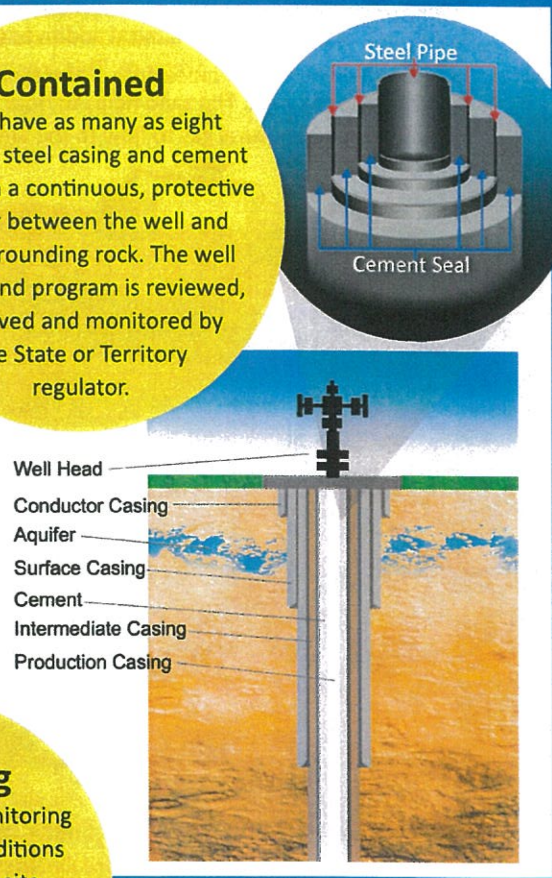
Water that cannot be recycled is placed in specially designed ponds for evaporation, leaving a small residue. This residue is tested and if necessary is safely removed and taken to a licensed disposal facility.

Water Management

The amount of water used for shale or tight gas operations is a small fraction of the water used for agriculture, industry or recreation.

Contained

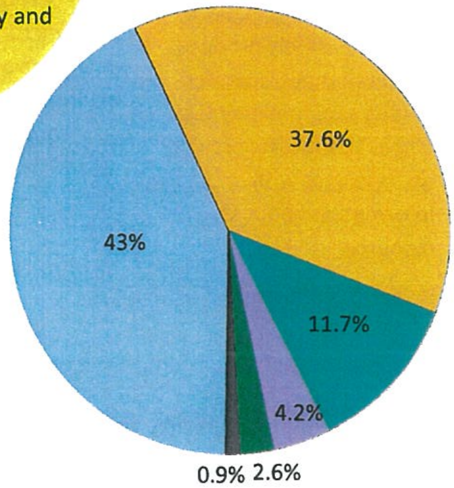
Wells have as many as eight layers of steel casing and cement that form a continuous, protective barrier between the well and the surrounding rock. The well design and program is reviewed, approved and monitored by the State or Territory regulator.



Monitoring

Regulators require monitoring and management conditions appropriate to each site during and after production. This includes monitoring the local groundwater quality and levels.

Water Usage



Water volumes sourced from: Australian Bureau of Statistics – Australian Water Account, 2010-11

Air Quality

Reducing emissions from natural gas operations is a high priority for the industry. Wells are designed, constructed and operated to minimise emissions.

Several scientific studies agree that greenhouse gas emissions from shale gas-powered electricity – including the life-cycle emissions – are significantly lower than those from coal-fired power[1]. All natural gas production facilities in Australia, including wells and pipelines, are tightly controlled and monitored to minimise the risks of leakage.

CSIRO Research

Research into air quality and emissions from coal seam gas production is being undertaken by the CSIRO and the Federal Government. More information can be found on the CSIRO website.

Limited Surface Impact

Onshore tight and shale gas developments are designed to minimise impact on the ground surface and land use.

Horizontal drilling has helped reduce the footprint for shale and tight gas developments by allowing multiple wells to be drilled and operated from a single drilling pad, significantly reducing the surface footprint. Using this approach, producers can develop a field with one drill every 1-4 kilometres. Most of these drill pads can then be connected to a central processing facility by underground pipes.

Setting High Standards

Industry operators set and meet high standards, and strongly support government regulations that also expect high standards for shale and tight gas development. These high standards are expressed in the 'Golden Rules for the Golden Age of Gas' published by the International Energy Agency.

APPEA has developed or contributed to several codes of practice. These codes provide best-practice guidelines, reflect industry priorities for working with communities and are intended to improve the transparency of all the essential elements of the assessment and monitoring of industry activity.

Cleaner Energy

The US Environment Protection Authority states that: "Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides at the power plant."[2]

Small Footprint

A multiple well pad, averaging between 4-8 well heads, would cover less than the size of a standard house block after land rehabilitation.

1. Source: Shale Gas: the facts about the environmental concerns, International Gas Union (June 2012), Section 7: Air emissions

2. Source: US Environmental Protection Agency, www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

Learn more: www.appea.com.au

RESPONSIBLE DEVELOPMENT

Sound environmental management

Access to information

The industry is committed to open and transparent disclosure of the chemical additives used in exploration or production.

Planning for each well involves preparing an environmental plan management plan with details of any chemicals used in hydraulic fracturing and management strategies in place to protect the environment throughout the full lifecycle of a project. The industry supports disclosure and many companies make this information available on their websites.

Chemicals management

The fluid used in hydraulic fracturing is mostly made up of water and sand (approximately 99.5 per cent). The remainder is a mixture of chemical additives used to thicken the fluid to help carry the sand or beads (known as "proppants") which hold open the tiny hair-like fissures allowing the gas to flow more easily into the well. The chemicals reduce friction, remove bacteria and prevent scale from building up in the well.

Most of the chemical additives used are found in familiar household products.

Understanding Fracturing Fluid

The fluid from the hydraulic fracturing process is nearly 99.5% Water and Sand

90% WATER + 9.5% Sand + 0.5% Chemical Additives

Some typical additives used in fracturing fluid and common household items

Guar Gum 0-0.15%
Concentration in ice-cream **approx. 1%**

Acetic Acid 0-0.1%
Concentration in vinegar **5%**

Sodium Chloride 0-0.005%
Concentration in table salt **99%**

pH Stabilizer (MEA Borate) 0-0.1% Concentration in cosmetics **0.5%**

Disinfectant (Sodium Hypochlorite) <0.02%
Concentration in bleach 5%

Chemical Controls

The chemical additives in the hydraulic fracturing fluids are subject to the same strict regulations applying to responsible chemical use on farms or in factories.

Transparency

Companies must submit detailed plans for approval by the State or Territory government ahead of any hydraulic fracturing activity.

Common Chemicals

Many of the chemicals found in hydraulic fracturing fluids are also found in common household and commercial applications. They include guar gum used in jelly sweets, table salt, detergents and antiseptics – all of which are used in extremely low concentrations.

Learn more: www.appea.com.au

RESPONSIBLE DEVELOPMENT
Community partnerships

Working Together

The oil and gas industry recognises that success depends on long-term relationships built on integrity, transparency, fairness and respect.

The partnerships between communities and the industry have achieved important benefits, including:

- economic growth;
- local employment (including jobs for farmers and Traditional Owners);
- regional and indigenous business development;
- training;
- community development; and
- infrastructure.

Through co-operative community relationships and informed discussion, the industry and the government are ensuring the right approach is being taken to unlock the industry's potential and provide significant benefits to regional areas.

A partnership approach

Industry, government and CSIRO have jointly hosted community information workshops in Western Australia and Northern Territory. This important collaboration aims to work with local communities – listening to and addressing their concerns – and identify sources of information they can trust.

In South Australia the industry has been working closely with all stakeholders, in particular the South Australian Government, through the Roundtable for Unconventional Gas.

Science

The International Gas Union (IGU) has provided a good compilation of peer-reviewed science and best practices in relation to common environmental concerns. You can read more in the shale gas booklet available for download at http://www.igu.org/gas-knowhow/publications/igu-publications/

A Queensland Farmer's Story

Farmer Simon Drury has been on a journey with the coal seam gas (CSG) industry in Queensland for more than a decade. With his wife, Kylie, and four sons he owns and operates a 2,300 hectare property on the western Darling Downs. The farm grows various grains and supplies grain-fed beef to the domestic and international markets.

In 1997, Mr Drury was elected as local councillor to the Murilla Shire Council, this experience revealed to him that 10 years of continuous drought was taking its toll. Local businesses were struggling and many locals were sending their kids to the city to get a job. The local towns were shrinking.

In the early 2000s there was talk of CSG in the area. The Shire invited the industry to speak to them about the pros and cons of having CSG operations on their doorstep. Mr Drury said: "Of course, we had many questions, you know, what would it do to the aquifers that we all depended on for our stock, and domestic, and irrigation, landowners rights, would it devalue our land, etcetera."

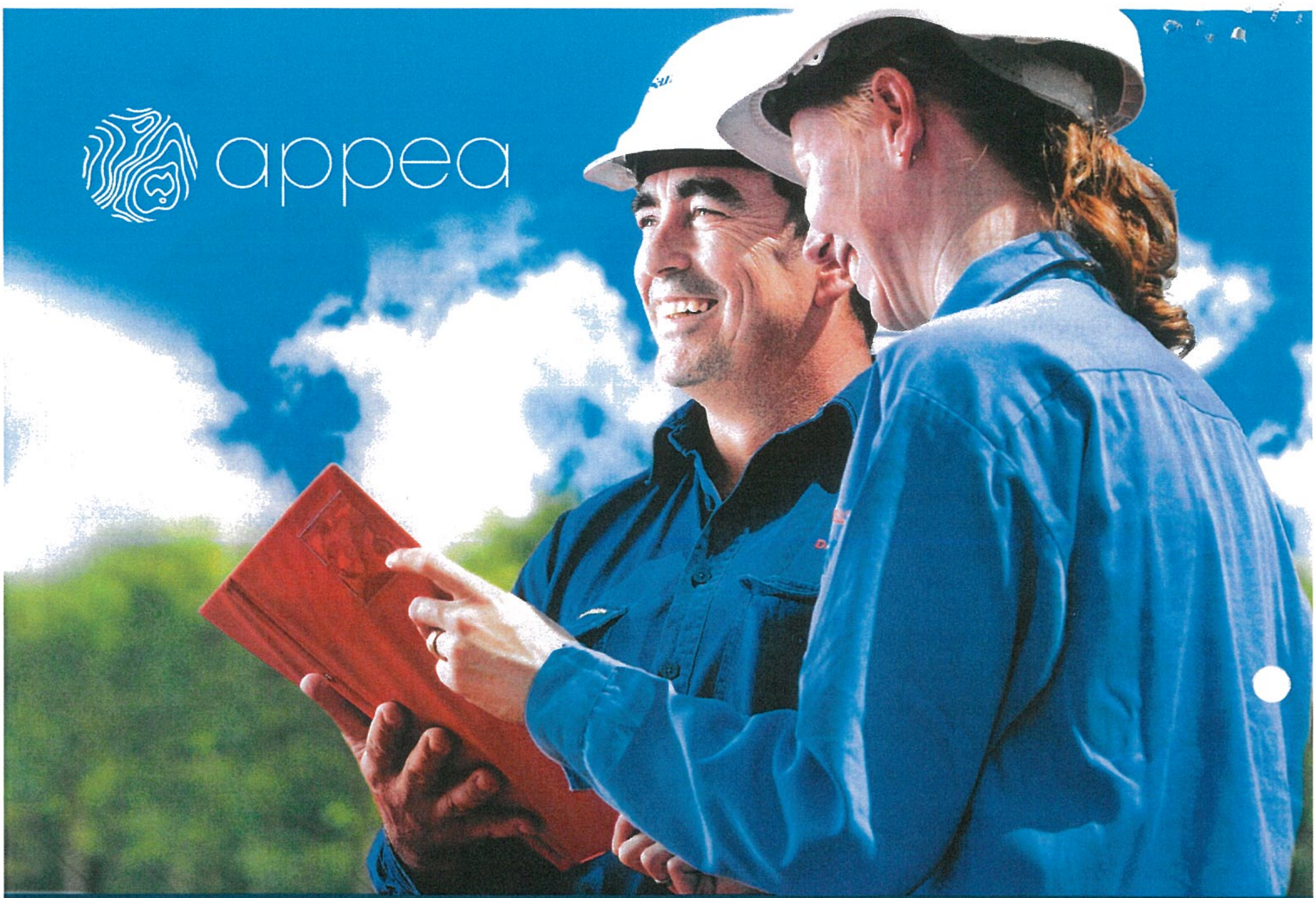
A few years later Mr Drury agreed to allow Origin Energy to have access to his land to build four wells and an evaporation pond. The relationship between the farm and Origin grew, with the family taking part in the Working Together program, designed to allow farmers to monitor their wells on their own property. As part of the program Origin put the farm's staff through first aid, ChemCert and 4WD training, as well as a general gas induction.

Mr Drury said: "In the beginning, I was questioned by neighbours as to the wisdom of embracing CSG on our property. Now, I'm receiving more queries from landholders about how CSG could possibly benefit them.

"We were quite naive and didn't realise how big the scale of this development would be, not only on our property, but in the whole district.

"Our journey with CSG has been a positive one. We have seen doors open up, and at the end of the development, our business will be better for it."

To read more about the CSG industry see: www.naturalcsg.com.au



Find Out More

Below is a small selection of some useful reports and websites where you can learn more about natural gas from shale and tight rocks.

Websites

www.appea.com.au
www.csiro.au
www.waonshoregas.info

www.dmp.wa.gov.au
www.dmitre.sa.gov.au
www.minerals.nt.gov.au

www.gisera.org.au
www.iea.org
www.igu.org

Science

Shale Gas

Engineering Energy: Unconventional Gas Production, Australian Council of Learned Academies (June 2013)

Golden Rules for a Golden Age of Gas: Full Report, International Energy Agency (November 2012)

Shale Gas: the facts about the environmental concerns, International Gas Union (June 2012)

Hydraulic Fracturing

Shallow Groundwater Quality & Geochemistry in the Fayetteville Shale Gas-Production Area, US Geological Survey (April 2012)

Fact-Based Regulation for Environmental Protection in Shale Gas Development, University of Texas (February 2012)

Energy and Climate Change Committee Report on shale gas - Update, UK House of Commons (January 2012)

Energy and Climate Change Committee Report on shale gas, UK House of Commons (May 2011)

Health Impacts

Health Watch Study – a three-decade study of occupational health in the oil and gas industry, Monash University (Ongoing)

Water Management

Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area, Queensland Government (July 2012)

Namoi Catchment Water Study – Independent expert final study report (July 2012)

appea the voice of australia's oil and gas industry

Submission

October 2013

APPEA Submission: Environment and Public Affairs Committee 'Inquiry into the Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas'

Submission

CONTENTS

appea the voice of australia's oil and gas industry

Submission

TERMS OF REFERENCE

a) How hydraulic fracturing may impact on current and future uses of land;
b) The regulation of chemicals used in the hydraulic fracturing process;
c) The use of ground water in the hydraulic fracturing process and the potential for recycling of ground water; and
d) The reclamation (rehabilitation) of land that has been hydraulically fractured.

EXECUTIVE SUMMARY

The technology, operational experience and regulation already exist to enablethe safe and sustainable extraction of Western Australia's significant natural gas resources from shale and tight rocks. With growing demands for natural gas globally and in Western Australia, and the increasing cost and technical barriers to developing offshore resources, these resources will play a key role in delivering security of natural gas supplies for the State. Accessing these resources on a commercial basis has become possible through the combination of two well-tried technologies – multistage hydraulic fracturing and horizontal drilling.

The development of these previously uncommercial sources of natural gas will deliver significant economic and environmental benefits for Western Australia – through job creation, industry stimulation and lowering of greenhouse emissions. In the United States the uptake of shale gas has seen a fall in carbon emissions of between 200 and 400 million tonnes (as a result of natural gas replacing coal-fired electricity) and led to a 'manufacturing renaissance' from lower cost feed stocks. The development of onshore natural gas industries in Queensland has also led to the creation of thousands of jobs.

Realisation of these benefits will require a foundation of community confidence. This will be achieved through safe and responsible operator practices, robust regulation, and early and open communication.

Fortunately, companies are able to transfer decades of experience and operational practices in pursuing offshore natural gas developments to pursuing extraction of these previously uncommercial natural gas sources. In particular, the knowledge obtained from the use of hydraulic fracturing more than 700 times in Western Australia since 1965 provides a significant advantage with ensuring sustainable operations. Companies currently focus significant efforts on protecting the environment, including through extensive monitoring, construction of wells to exacting standards, and the use and disclosure of low impact chemicals.

Current early exploration efforts are overseen by a regulatory framework that has proven capable of managing the same techniques and technologies for nearly 50 years and adapting to new ones as they emerge. The effectiveness of this framework and the ability for risks to be managed effectively has been recognised through several reviews by independent experts which are referred to throughout this submission. The management of projects as they advance past early-stage exploration may require the regulatory framework to adapt, and industry is working closely with government to ensure robust and efficient regulation.

Industry and government has also been working to ensure that fact-based information reaches the community, including through independent third parties such as CSIRO, to enable informed discussion and decision making. This is an important means of countering the misinformation

that has been spread by groups ideologically opposed to natural gas, who ignore the extensive body of science proving it poses negligible environmental and health risks.

While there are challenges ahead, the considered pace and manner in which the industry is approaching exploration (and potentially development) provides time to face these challenges head on.

APPEA would be pleased to provide further information to the Inquiry at the Committee's convenience.

RECOMMENDATIONS

- Planning for multiple land uses to ensure coexistence of potential shale gas activities with existing activities will be very important to industry and landowners. In this regard, implementation of the Standing Council on Energy and Resources Multiple Land Use Framework, discussed further at Attachment 2, should be pursued across government to deliver shared benefits to all stakeholders. This Framework should be integrated into planning documents such as the State Planning Strategy and any strategic frameworks relating to the development of an onshore gas industry in Western Australia.

- Development of a regulatory disclosure protocol to enable the use of leading practice and environmentally benign chemicals in hydraulic fracturing should be pursued. This would enable the newest technologies to be used in Western Australia without intellectual property concerns resulting from public disclosure.

- A better understanding of local environments, particularly in relation to water resources, is required in many areas and the commitment of the State Government to develop an environmental database will be very useful in consolidating and communicating this information.

- The Australian Council of Learned Academies (ACOLA) report, 'Engineering Energy: Unconventional Gas Production', is referred to throughout this submission and should play a larger role in the discussion in Australia. Released in May 2013, APPEA would commend the document to the Environment and Public Affairs Committee.

appea the voice of australia's oil and gas industry

Submission

ONSHORE NATURAL GAS IN WESTERN AUSTRALIA

About APPEA

The Australian Petroleum Production and Exploration Association is the peak national body representing Australia's oil and gas exploration and production industry. APPEA has more than 85 full member companies exploring for and producing Australia's oil and gas resources. These companies currently account for around 98 per cent of Australia's total oil and gas production and the vast majority of exploration. APPEA also represents over 240 associate member companies providing a wide range of goods and services to the industry.

The Inquiry

APPEA welcomes the opportunity to input into the Environment and Public Affairs Committee's Inquiry into the Implications of Hydraulic Fracturing for Unconventional Gas. APPEA hopes that the Inquiry will provide the clarity required to properly inform the public on both the benefits and perceived risks of hydraulic fracturing and onshore natural gas in Western Australia. This submission should be read in conjunction with submissions from APPEA's members which will provide further technical detail in relation to shale and tight gas developments.

APPEA believes that the key technical issues at the centre of the Inquiry are being managed effectively by the petroleum industry in the way the exploration programs have been planned and developed. The critical issues identified by the terms of reference have been considered in detail by ACOLA.[1]

The science indicates that, with appropriate monitoring and robust and transparent regulation in place, shale and tight gas resources can be developed safely and effectively as an economically important additional energy source which could significantly reduce Australia's greenhouse gas emissions.[2] Other impacts in relation to health, cumulative impacts, seismicity, fugitive emissions, social impacts, groundwater contamination and best practice regulation for onshore natural gas have also been considered extensively by the existing literature.[2]

The industry has the technical capability to develop shale and tight gas resources but acceptable development of the industry will rely on community confidence.[3] This confidence will require robust regulation, responsible operator practices and early and effective communication with stakeholders. APPEA's submission seeks to demonstrate how the industry has worked across these three areas to build confidence.

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[1] Cook, P, Beck, V, Brereton, D, Clark, R, Fisher, B, Kentish, S, Toomey, J and Williams, J (2013). *'Engineering Energy: Unconventional Gas Production.'* Australian Council of Learned Academies (ACOLA), www.acola.org.au.

[2] These issues have been covered in detail in publications by ACOLA, the International Gas Union and International Energy Agency.

[3] *'Golden Rules for a Golden Age of Gas'*, International Energy Agency (2012), www.iea.org

WHY WE NEED ENERGY

Natural gas will continue to play a critical role in meeting the world's demand for energy. The US Energy Information Administration recently projected demand would increase by 52 per cent between 2010 and 2040.[4] While nuclear and renewable sources will provide increased contributions (2.5 per cent per annum), fossil fuels are expected to supply nearly 80 per cent of world energy needs through to 2040.[5]

Much of this demand will come from non-OECD (Organisation for Economic Cooperation and Development) countries, which are expected to increase their energy demand by 90 per cent during this period (compared to 17 per cent in OECD countries).

Similarly, Australia's energy demand is expected to increase by 29 per cent between 2008 and 2035. Petroleum products, which represented 39 per cent of energy consumption in 2011-12, will meet most of this demand. Into the future natural gas will continue to supply energy to various industries (e.g. mining), households (e.g. hot water, stove tops) and sectors such as transport (e.g. Transperth's compressed natural gas bus fleet).

Driven by the economy and lifestyles, Western Australia is the most gas-dependent jurisdiction in Australia with natural gas supplying 55 per cent of energy consumed in the State.[6] This gas is primarily supplied by the North West Shelf Project and Apache's Varanus Island facility and consumed in large quantities by the mining, manufacturing and electricity generation sectors.[7] The recently released *WA Gas Statement of Opportunities* (GSOO) found that forecast average

[4] 'EIA projects world energy consumption will increase 56% by 2040', US Energy Information Administration, (2013) http://www.eia.gov/todayinenergy/detail.cfm?id=12251 [Accessed 17/09/13].
[5] *Ibid.*
[6] 'Energy in Australia 2012', Bureau of Resources and Energy Economics (2012), http://www.bree.gov.au/documents/publications/energy-in-aust/energy-in-australia-2012.pdf [Accessed 17/09/13]; WA Office of Energy, 'Strategic Energy Initiative Directions Paper', http://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/WAs_Energy_Future/Strategic+Energy+Initiative+Directions+Paper_web.pdf (2011), [Accessed 17/09/13].
[7] 'Energy White Paper 2012', Department of Resources, Energy and Tourism (2012), http://www.ret.gov.au/energy/Documents/ewp/2012/Energy_%20White_Paper_2012.pdf, P. 160 [Accessed 17/09/13].

annual growth for domestic gas demand is expected to be 1.1 per cent per annum.[8] Under a constrained scenario this will lead to an increase in gas demand of about nine per cent in 2022, a rate similar to the average growth of the domestic gas market between 2003 and 2012.

Given the prominent role of natural gas in Western Australia, continued access to secure, reliable and competitively priced energy is critical.[9] With the increasing challenges and cost of offshore gas developments, it is likely that onshore gas fields will become more prominent sources of natural gas supply for Western Australia's domestic consumption. In addition to reinforcing the State's energy security, onshore natural gas has the potential to provide significant benefits to regional areas within the proximity of activities.

WHY ONSHORE NATURAL GAS

There is no material difference between the composition of natural gas retrieved from conventional sources (e.g. from the North West Shelf project) and natural gas from shale or tight rock sources.

Shales are fine-grained sedimentary rocks formed from the compaction of silt and mud. 'Tight' rocks are typically limestone and sandstone. Both shale and 'tight' rocks have very low levels of permeability and are found deep underground, typically at depths of between two and five kilometres.

Estimates from the US Energy Information Administration have suggested that Australia could possess recoverable resources of 17.5 billion barrels of shale oil and condensate and 437 trillion cubic feet of shale gas.[10] These equate respectively to the sixth and seventh largest global reserves of shale oil and gas.

Western Australia has been identified as one of the largest potential supplies of natural gas from shale rocks in the world. These resources are typically located at depths of between two and four kilometres below the ground and separated from near-surface freshwater aquifers by at least a kilometre of virtually impermeable rock.

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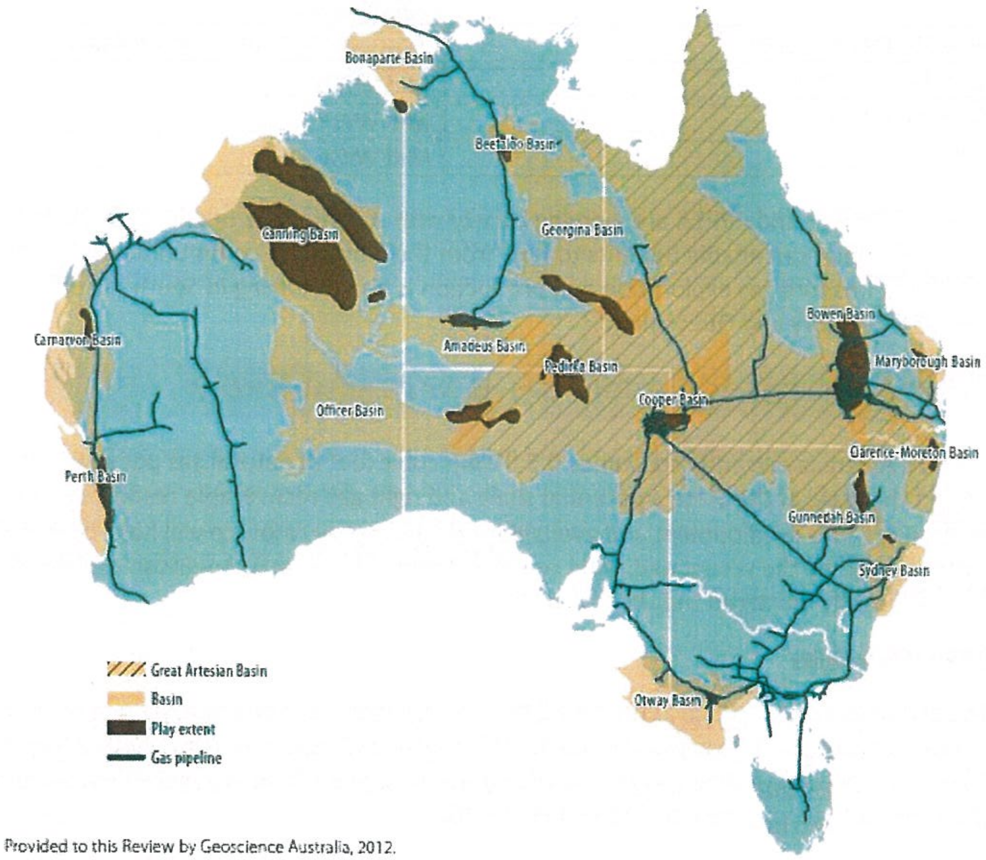
[8] 'Gas Statement of Opportunities', Independent Market Operator (2013),http://www.imowa.com.au/GSOO [Accessed 17/09/13].

[9] 'Strategic Energy Initiative: Energy 2031', Public Utilities Office (2012), http://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/WAs_Energy_Future/Strategic_Energy_Initiative_Energy2031_Final_Paper.pdf [Accessed 17/09/13].

[10] Based on the risked recoverable levels of the Georgina, Beetaloo, Maryborough, Canning and Cooper Basins. See 'Technically recoverable shale oil and shale gas resources', US Energy Information Administration (2013), http://www.eia.gov/analysis/studies/worldshalegas/ [Accessed 17/09/13].

Figure 1. Australia's Assessed Prospective Shale Gas and Shale Oil Basins



Source: ACOLA

Western Australia's share of these resources is significant, with recoverable gas resources estimated to be in the order of 32 trillion cubic feet from the Perth Basin (Mid West) and 235 trillion cubic feet from the Canning Basin. These Basins are also estimated to hold approximately 10 billion barrels of recoverable shale oil and condensate resources.[11] However, low levels of historic exploration means that these areas remain largely underdeveloped and are considered frontier or 'green field' exploration zones, which are typically recognised as more challenging to access. In addition, some areas are distant from markets and infrastructure which adds additional hurdles to development.

Despite the potential of shale and tight gas, there is no significant production in Western Australia at present. A small number of APPEA members are in the early stages of exploration for these resources in Western Australia, as outlined in Figure 3 below.

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[11] 'EIA/ARI World Shale Gas and Shale Oil Resource Assessment', US Energy Information Administration (2013), http://www.eia.gov/analysis/studies/worldshalegas/pdf/chaptersi_iii.pdf?zscb=395186, [Accessed 17/09/13], P. III-4.

Figure 2. Onshore Operators and Regions of Exploration in Western Australia

OPERATOR	PRIMARY EXPLORATION FOCUS
Buru Energy	Canning Basin
Hess	Canning Basin
New Standard Energy	Carnarvon Basin, Canning Basin
Latent Petroleum	Mid West
Norwest Energy	Mid West
AWE	Mid West

These companies and APPEA are working closely with stakeholders to ensure sustainable coexistence that can enable benefits to flow from the industry to communities. It should be noted that onshore gas exploration and production is also occurring in South Australia, the Northern Territory and Queensland.

THE DEVELOPMENT OF ONSHORE GAS IN WESTERN AUSTRALIA

Western Australia currently consumes 0.5 trillion cubic feet of natural gas per year, which puts in context the scale of the State's potential shale and tight gas recoverable resources of 267 trillion cubic feet.[12] The development and availability of this energy resource will have broad benefits, as demonstrated by the recent and rapid transformation of the North American energy sector which has significantly bolstered the US economy.

Economic Benefits

The global forecaster IHS recently found that the resurgence in onshore gas and oil in the US had created at least 1.7 million jobs across the US in 2012 with estimated growth to 2.5 million jobs by 2015.[13] In the US the shale gas industry has generated $63 billion in government revenues and this is expected to increase to $113 billion by 2020.

Notably, the US experience has demonstrated that benefits can flow to adjacent states that have little or no production in addition to those that host the industries. Large economic contributions have been seen through the delivery of critical goods and services that are vital to the oil and gas supply chain.[14] This has created a 'manufacturing renaissance' which is expected to support 460,000 jobs by 2020.[15] In addition, lower energy costs and feedstock prices directly resulting from unconventional gas production are expected to increase industrial production by $258 billion in 2020. Taking into account these broader benefits, estimated jobs created by unconventional gas development would total 2.1 million in 2013 increasing to 3.3 million in 2020.[16]

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[12] 'Natural Gas from Shale and Tight Rocks Fact Sheet', Department of Mines and Petroleum (2013), http://www.dmp.wa.gov.au/documents/Shale_and_tight_gas_and_WA_future_energy_security.pdf [Accessed 17/09/13].
[13] 'America's New Energy Future – The Unconventional Oil and Gas Revolution and the US Economy', IHS Global Insight (2013), http://www.ihs.com/info/ecc/a/americas-new-energy-future-report-vol-2.aspx, [Accessed 17/09/13]
[14] *Ibid.*
[15] 'U.S. Unconventional Oil and Gas Revolution to Increase Disposable Income by more than $2,700 per Household and Boost U.S. Trade Position by More than $164 billion in 2020', IHS (2013), http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270, [Accessed 17/09/13].
[16] *Ibid.*

A similar success story has been seen in Australia. In Queensland the coal seam gas industry has been identified as a significant contributor to the Queensland economy through job creation. Data obtained from APPEA members indicates that more than 27,000 people were employed in Queensland's CSG industry in Q4 2012.

Between January 2011 and Q4 2012 economic flows from the CSG industry to Queensland communities was valued at over $97 million. While offshore LNG projects are generally an order of magnitude beyond a shale or tight gas project in terms of scale, they do provide an indication of the community benefits likely to flow from energy developments.

The offshore oil and gas sector has been operating and supporting local communities in Western Australia's north-west for over 25 years, including significant investment in community infrastructure and social initiatives across the region.[17] For example, the North West Shelf project currently spends approximately $600 million per annum with Australian-based businesses for operational activities. Similarly, the Apache-operated Devil Creek domestic gas project has reported annual payments to Australian-based businesses of $1.4 billion.[18]

In New Zealand, Todd Energy's Mangahewa shale gas project has added $400 million to national GDP and provided 1,360 jobs over seven years.

In addition to the economic activity generated from these projects, the energy sector also has a history of supporting projects within the communities in which they operate, including investment in infrastructure, education and research (e.g. health and environmental).

The development of a shale and tight gas industry in Western Australia would have significant social and economic benefits. The magnitude of social and economic impacts of a development will vary depending on the activities, location, speed, scale, duration and configuration.[19] The ACOLA Report notes that economic diversification that leverages energy projects is the best way of contributing to the long-term wellbeing of a region, though a planned approach to regional development is important. The Western Australian onshore gas industry is currently discussing how to maximise the local benefits of shale and tight gas production through incentives for regional contractors, farm-friendly working conditions, community development programs and fair compensation payments.

Environmental Benefits

The development of a shale and tight gas sector holds potential to provide a number of positive environmental benefits. In June 2013, the International Energy Agency (IEA) released a report noting that emissions from the United States had fallen by 3.8 per cent (200 million tonnes) over the previous year. In total, US emissions have fallen between 400 and 500 million tonnes – twice the reduction achieved in the rest of the world as a result of the Kyoto Protocol.

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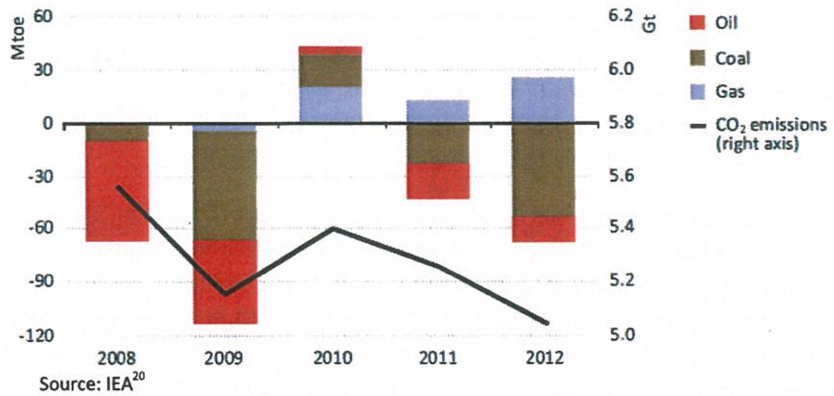
[17] 'The wider contribution to Australia of the Oil and Gas Industry', Australian Venture Consultants (2012), P. 15.
[18] *Ibid.*, P. 19
[19] ACOLA. P. 153

The IEA attributed this fall to the increased uptake of natural gas, in particular from shale sources, which replaced coal in power generation, as indicated in Figure 4 below.

Figure 3. Change in fuel consumption and total energy-related CO_2 emissions in the US



Source: IEA[20]

Natural gas currently offers the cleanest viable source of baseload and peaking power in Australia. This is supported by the evidence out of the US, discussed in the case study above, which highlights the US experience with falling carbon emissions as a result of the uptake of shale gas. Within Australia it is expected that increased access to shale and tight gas would likely decrease the contribution of coal-fired generation (as happened in the US) to the electricity mix.[21] This conclusion has also been supported by a recent study from the UK Department of Energy and Climate Change and the ACOLA report in Australia, as illustrated in Figure 5 below.[22] Natural gas is therefore the cleanest source of energy available at this time after renewables.

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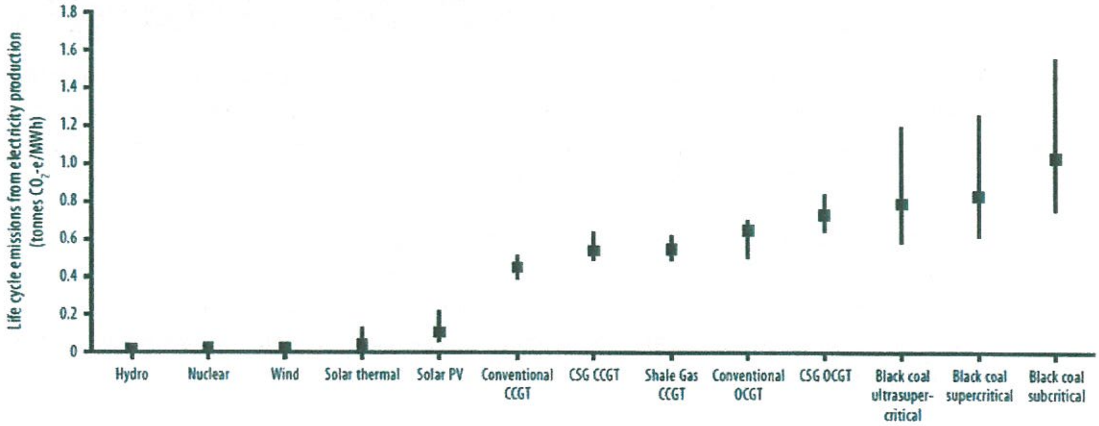
[20] 'Redrawing the energy-climate map', International Energy Agency (2013), http://www.worldenergyoutlook.org/media/weowebsite/2013/energyclimatemap/RedrawingEnergyClimateMap.pdf, [Accessed 17/09/13].

[21] ACOLA. P. 17

[22] MacKay, D, Stone, T, 'Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use', Department of Energy and Climate Change (2013), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/237330/MacKay_Stone_shale_study_report_09092013.pdf, [Accessed 17/09/13].

Figure 4.– The range of life cycle emissions for electricity generation (tonne CO_2e/MWh)



Source: ACOLA

Many critics of natural gas, in particular the increased use of shale and tight gas, have made clear their opposition to the industry because it delays the transition to renewable energy.[23] This argument is grounded in ideology and does not account for the evidence, which shows that natural gas provides the quickest, most economically efficient and most reliable opportunity to reduce Australia's carbon emissions.

Distribution of Benefits

The scale and benefits of shale and tight gas developments will vary from region to region but will need to be supported by effective strategic planning (through tools such as the State Planning Strategy) to ensure benefits are maximised and coexistence is maintained.

APPEA has been involved in a similar strategic approach to the development of the shale and tight gas industry in South Australia, through the Roundtable for Unconventional Gas hosted by the Department of Manufacturing, Industry, Trade, Resources and Energy. Such planning, when supported by communication, information sharing and transparency, ensures that the benefits to the community from a potential industry are maximised (including in relation to components of projects such as surface infrastructure).[24]

[23] "There's no contest: we shouldn't be burning either gas or coal. Instead, we should leave them in the ground, and move towards renewable sources of energy." 'Climate Change and Fracking', Clean Water Health Land (2013), http://cleanwaterhealthyland.org.au/content/climate-change, [Accessed 17/09/13].
[24] ACOLA. P. 154

SAFE AND RESPONSIBLE OPERATOR PRACTICES

The industry is focussed on carrying out all aspects of its activities safely and in a sustainable manner and this section outlines current practices to achieve this. In particular, the industry understands and agrees that conservation and protection of ground water is a top priority. Key factors which protect the environment during natural gas production include:

- Exacting construction standards and well planning to protect aquifers;
- Isolation of all fluids that might have a detrimental impact;
- Well designs that ensure numerous failsafe levels of protection; and
- Full disclosure and consultation with communities and Government agencies before, during and after all activities.

Many of these practices are detailed in the industry's voluntary Code of Practice for Hydraulic Fracturing in Western Australia.[25] It should be noted that these are broader than the Inquiry's Terms of Reference but are important chapters in how the industry is able to protect the environment.

The industry supports the findings of ACOLA that resources can be extracted in a manner and in locations that do not compromise agriculture, water resources, alternative land uses and landscape function.[26]

THE USE OF HYDRAULIC FRACTURING IN A SAFE AND SUSTAINABLE WAY

The use of multi-stage hydraulic fracturing represents best practice within the industry for accessing shale and tight reservoirs on a commercial basis. Provided in Attachment 1 is an outline of how the process works and detailed below are the ways in which the industry uses it safely and sustainably.

When combined with horizontal drilling, multistage hydraulic fracturing techniques are prime examples of the importance of innovation in the oil and gas industry to overcome technical challenges. These techniques and technologies have been developed over decades of research, trial and testing and are safe and sustainable ways of developing resources when best practice is followed by operators.

Hydraulic fracturing has also been used extensively within Australia. In South Australia, the technique has been used for conventional petroleum extraction more than 685 times over the last 40 years. This is the same technique that, according to the former WA Minister for Mines and Petroleum Hon. Norman Moore, has been used more than 734 times on Barrow Island since

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[25] 'Code of Practice for Hydraulic Fracturing', Australian Petroleum Production and Exploration Association (2011), http://wa-onshoregas.info/sites/wa-onshoregas.info/files/APPEA_Code_of_Practice.pdf, [Accessed 17/09/13].
[26] ACOLA P. 98

1965.[27] Located off the coast of Western Australia, Barrow Island has been identified as an 'A' Class nature reserve – the highest level of environmental protection afforded in the State.

On mainland Western Australia, hydraulic fracturing has been used 21 times at the Dongara gas field in the Perth Basin (Mid West) since 1974. Other examples of hydraulic fracturing for tight and shale gas in Western Australia include:

Figure 5. Historic Hydraulic Fracturing for Tight and Shale Gas in WA

FIELD	LOCATION	YEAR
Gingin Field	Gingin	1971
Whicher Range	Mid West	1982 (WR-3), 1997 (WR-1 & WR-4), 2003 (WR-5)
Warro	Mid West	2009 (W-3), 2011 (W-4)
Yulleroo	Canning Basin	2011
Arrowsmith	Mid West	2012
Senecio	Mid West	2012
Woodada	Mid West	2012

It is noted that hydraulic fracturing can also be used in geothermal energy production and to stimulate water flows.

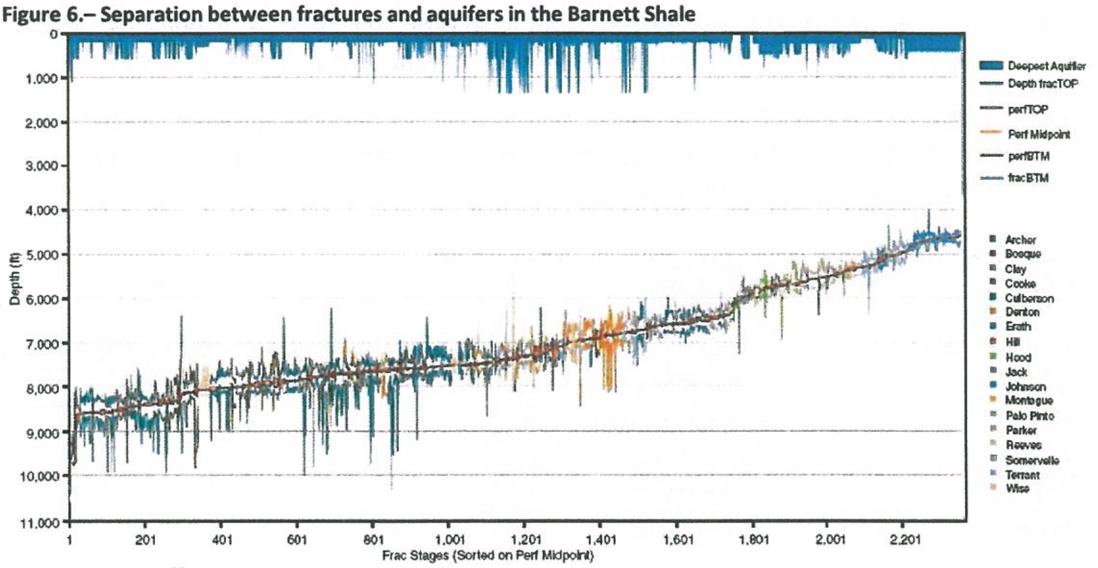
One of the key concerns relating to the use of hydraulic fracturing is that it will penetrate aquifers, however this is highly unlikely. The process of hydraulic fracturing is monitored to confirm the extent of the rock fractures is tightly controlled during fracturing events. In all but one per cent of cases, the maximum penetration of fractures into the surrounding rocks is 350 metres, with a separation from ground water (typically within 1500 metres of the surface) by one or two kilometres in Western Australia.[28]

Extensive research on hundreds of wells in the US has conclusively demonstrated that the fractures induced by the process are normally confined to the rocks close to the zone of interest. The following chart shows the relative separation of aquifers from fractures, with the maximum extent of the induced fractures and their relation to the aquifers.

[27] Xamon, A, 'Question on Notice No. 4510', Western Australian Parliament (2011), http://www.parliament.wa.gov.au/parliament/pquest.nsf/a02db76382427ad84825718e0018e9c9/168b5dba6804dbd3482578ee002c46d9?OpenDocument, [Accessed 17/09/13].

[28] 'Durham's Richard Davies speaks at Geological Society Briefing on fracking and hydraulic fractures', Durham University (2012), https://www.dur.ac.uk/dei/news/?itemno=14865 , [Accessed 17/09/13].

Figure 6.– Separation between fractures and aquifers in the Barnett Shale



Source: FracFocus[29]

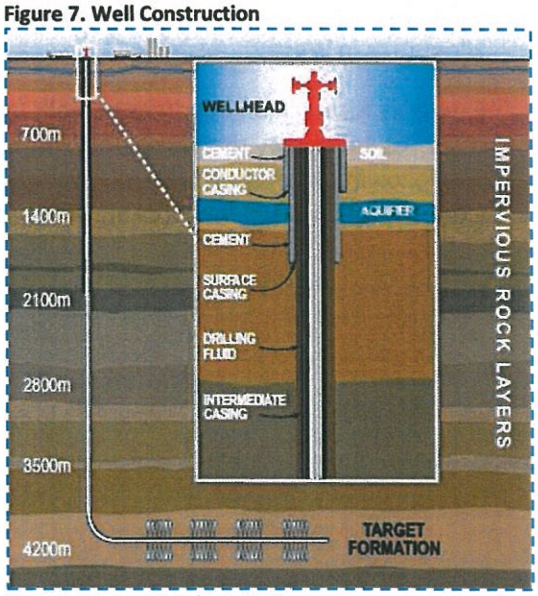
The industry believes there is clear evidence that the technology has been and will continue to be applied safely and sustainably in Western Australia.

CONSTRUCTION OF WELLS TO EXACTING STANDARDS

Petroleum producers construct wells to the appropriate standards to ensure that gas is kept within the well and water is kept out. Responsible companies will have in place standards relating to well design, well construction, well integrity management and well abandonment that adhere to practices published by organisations such as the American Petroleum Institute. These commonly meet or exceed expectations of the regulator and are subject to review and audit.

As demonstrated in Figure 6, multiple layers of steel and cement, along with extensive surface safety equipment, are used to keep the gas inside the well and under control. The design, construction and completion of a well to the highest standards is recognised as one of the most important ways of ensuring that the

Figure 7. Well Construction



Source: International Gas Union

[29] 'Hydraulic Fracturing: The Process', FracFocus, http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process [Accessed 17/09/13].

environment is protected throughout operations. When a well is properly constructed it provides a strong, long lasting seal that isolates the well and deep gas formations from aquifers.

Research by the US Ground Water Protection Council has found that rates of well leakage can be between 0.01 and 0.03 per cent.[30] Most of these occurred in the 1980s and 1990s before improved cement formulas and regulations were in place. Similar to performing a service on a car, these wells required routine maintenance on the casing or cement. More recent research published in the journal *Science* has estimated well leakage rates at between one and three per cent.[31]

Importantly, there have been no cases where hydraulic fracturing has been identified as the cause of groundwater contamination.[32]

Ensuring that well integrity is maintained throughout the life of operations is critical to safety and the protection of the environment. The risk of a well casing failure in Australia is low because the industry is committed to ensuring that wells are constructed and maintained to the highest standards.[33]

The industry will continue to keep gas in and water out of wells by ensuring that they are constructed to the highest standards. This includes taking advantage of innovation in cements to continue to improve the construction of new wells and the durability of casings. The industry is also committed to monitoring and fixing any wells that are not functioning to the standards required.

MONITORING EVERY RELEVANT ASPECT OF THE ENVIRONMENT FOR CHANGE

Companies use extensive monitoring to detect any possible changes in the environment as a result of operations. Before, during and after activities commence, monitoring is put in place to measure the potential impact on the environment. Before drilling a well, it is standard practice that companies undertake extensive surveys (including 3D seismic over time) to fully understand the environment.

Technicians and engineers use a range of monitoring techniques based on seismic, pressure-testing and water sampling technology to show that the production process is working safely and effectively. Standard forms of monitoring include:

- Water sampling (e.g. surface water, groundwater)
- Air quality (e.g. gas, dust and noise)

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[30] Kell, S, 'State Oil and Gas Agency Groundwater Investigations And their Role in Advancing Regulatory Reforms', Ground Water Protection Council (2011), http://www.gwpc.org/sites/default/files/event-sessions/05Kell_Scott_0.pdf [Accessed 27/09/13].

[31] Vidic, R, Brantley, S, Vandenbossche, J, Yoxtheimer, D, Abad, J, 'Impact of shale gas development on regional water quality', Science (2013), https://n-1.cc/file/download/1708283 [Accessed 27/09/13].

[32] Peterson, J, Hamilton, H, 'No contamination from Fayetteville Shale Exploration Found in Sampled Wells', United States Geological Society (2013), http://www.usgs.gov/newsroom/article.asp?ID=3489#.UjfgtEqQ-70 [Accessed 17/09/13] ; 'EPA's Lisa Jackson on Hydraulic Fracturing', EnergyInDepth YouTube, http://www.youtube.com/watch?v=_tBUTHB_7Cs [Accessed 17/09/13].

[33] ACOLA P. 120

- Vegetation and flora (e.g. weed infestations)
- Fauna (e.g. for conservation species)
- Seismicity (e.g. potential seismic events)
- Well head (e.g. pressure changes within the well)
- Soils/topography (e.g. for erosion)
- Social (e.g. impact on communities)
- Cultural (e.g. disturbance of cultural sites)

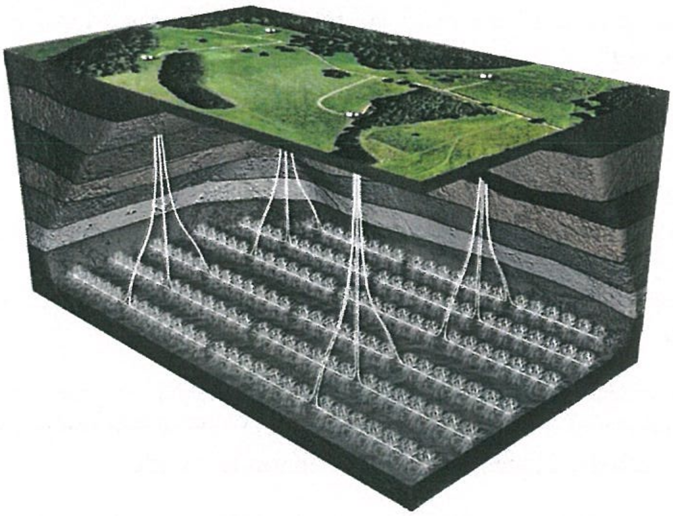
Where required, monitoring will be adapted to ensure that all changes to the environment as a result of activities are watched closely.

A more detailed understanding of the environment in areas prospective for natural gas, particularly in relation to water resources, is required in many areas and the commitment of the State Government to develop an environmental database will be very useful in consolidating and communicating this information.

MINIMISING IMPACTS ON THE LANDSCAPE

This section relates to Terms of Reference 1.1(a).

Figure 8.– Multiple wells drilled from central pads



Source: Statoil[34]

Companies are committed to working with landowners to identify where an activity can be located that causes the least amount of land use disturbance.

The cost of drilling a shale or tight gas well in Western Australia is very expensive, often around $20 million, and operators are therefore very careful in how they plan and execute drilling. In the current early stage of exploration companies will primarily rely on vertical wells. As the industry moves towards commercial production, producers will use some horizontal drilling. This will improve the efficiency of the operations and allow for the use of widely spaced drill pads limiting the potential for surface land disturbance.

[34] 'Statoil strengthens US shale gas position', Statoil (2010), http://www.statoil.com/en/newsandmedia/news/2010/pages/26marmarcellus.aspx [Accessed 27/09/13]

Horizontal drilling describes the process of drilling vertically to a target depth and then turning and drilling horizontally, usually to a distance of 1-3 kilometres. This increases the amount of rock in contact with the well and increases the gas production rate, thereby decreasing the number of wells required. Typically 6-12 horizontal wells can be drilled from a single surface location or 'pad', which concentrates all activities into an area of approximately a hectare, thereby minimising surface disturbance.

As noted by the International Gas Union (IGU), shale gas production requires a much smaller land use footprint than conventional natural gas drilling and other forms of energy production.[35] While pads containing multiple wells are likely to require more land than a pad for a single well, it has been found that this extra land use would more than offset the fewer well pads required overall. A pad containing between four and eight wells is expected to cover less than the size of a standard house block after land rehabilitation. In a development where multiple pads were required to commercialise a field, these pads would be placed between one and four kilometres apart.

As noted by ACOLA, "overall, there clearly is a smaller total area of land disturbance associated with horizontal wells for shale gas development than that for vertical wells."[36] These levels of land disturbance are also expected to be lower than those associated with agriculture or urban development.[37] Strategic planning for coexistence of industries should seek to take into account the impact of all activities and how they can minimise their total land disturbance.

After a well is established and a project moves from exploration to production, most of the land is rehabilitated around each well pad and the associated infrastructure. Each well head will have a two metre tall 'Christmas Tree' – or valve assembly – to control the gas production. These well pads would typically be spaced between one and three kilometres apart across a production area. The number of wells and well pads will depend on the nature of the reservoir rocks identified by exploration programs and production history of the wells.

Planning for multiple land uses to ensure coexistence of potential shale gas activities with existing activities will be very important to industry and landowners. It will also be an important way of ensuring that the maximum benefit is obtained from potential developments, with surface infrastructure in remote locations such as the Canning Basin potentially also serving to assist with unlocking these regions.

In this regard, implementation of the Standing Council on Energy and Resources Multiple Land Use Framework, discussed further at Attachment 2, should be pursued across government to deliver shared benefits to all stakeholders. This Framework should be integrated into planning documents such as the State Planning Strategy and any strategic frameworks relating to the development of an onshore gas industry in Western Australia.

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[35] 'Shale Gas: The Facts About Environmental Concerns', International Gas Union (IGU) (2012), http://www.igu.org/gas-knowhow/publications/igu-publications/UG20120064_IGU_ShaleBooklet_Final_forWeb1.pdf, [Accessed 17/09/13].
[36] ACOLA P. 103
[37] ACOLA P. 104

USING LOW IMPACT CHEMICALS AND DISCLOSING AS MUCH AS POSSIBLE

This section relates to Terms of Reference 1.1(b).

During hydraulic fracturing a fluid is used to carry 'proppants' which hold the rock fissures open and allow the gas to flow more easily into the well. The fluid is mostly made up of water and sand (approximately 99.5 per cent). The remainder is a mixture of chemical additives, which are added at very low concentrations and controlled by the cement and steel well casing. A typical fracture treatment will use three to 12 additive chemicals, depending on the characteristics of the water and the formation being fractured.

Figure 9. Typical proppant used in hydraulic fracturing

Source: Todd Energy[38]

Each chemical serves a specific engineering purpose[39] and ensures the operation is carried out safely and the long term integrity of the well is assured.[40] These chemicals are found in familiar household products including ice cream, vinegar, table salt, cosmetics and antiseptics.

The industry strongly supports transparent practices and companies publish details of their activities and environmental protection methods. Since the introduction of the State's *Petroleum and Geothermal Energy Resources (Environment) Regulations 2011*, APPEA and its members have incorporated the new requirements into operations and demonstrated a shared commitment to transparency and best practice operating standards and regulation.

The outcome of this process has been a decision by the WA Department of Mines and Petroleum (DMP) to use a systems-based method for chemical disclosure and an environmental risk assessment approach to assess product and chemical use on a case-by-case basis using the chemicals disclosure information and guidelines. APPEA believes this approach, when combined with environmental risk assessments, will allow the safe use of the chemicals needed in Western Australia.

Development of a regulatory disclosure protocol to enable the use of leading practice and environmentally benign chemicals in hydraulic fracturing should be pursued. This would enable the newest technologies to be used in Western Australia without intellectual property concerns resulting from public disclosure.

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[38] Todd Energy, P. 36
[39] Including to reduce friction, remove bacteria and algae and prevent the formation and build-up of scale
[40] IGU P. 30

MINIMISING WATER USE AND RECYCLING WHERE POSSIBLE

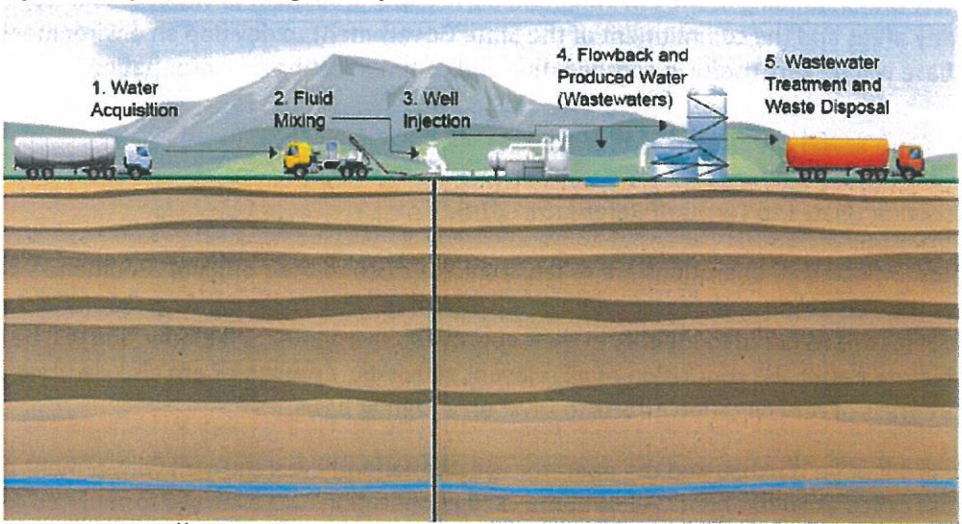
This section relates to Terms of Reference 1.1(c).

Most of the water used in tight and shale gas production is used in the hydraulic fracturing process and quantities vary depending on local geological conditions, such as depths, porosity and the length and number of horizontal wells.[41] Water is generally obtained within the vicinity of operations and is typically brackish (i.e. not potable).

Companies are committed to minimising their footprint and all water used in hydraulic fracturing operations will be captured and reused where possible. As part of the approvals process, a company must also demonstrate that the taking of water will not have unacceptable impacts on aquifers.

The IGU estimates that between 11 and 19 million litres of water – equivalent to four Olympic swimming pools – is required to fracture a well.[42] The ACOLA Report notes that while water requirements might be large when considered independently, they are "modest when set against consumption in irrigated agriculture."[43] In Western Australia, the annual expected water requirement of a typical tight gas development is equivalent to the annual irrigation needs of about seven hectares of carrots or 38 hectares of olive trees.

Figure 10.– Hydraulic fracturing water cycle



Source: Todd Energy[44]

After hydraulic fracturing has been completed and the pressure from pumping is reduced, water begins to flow back to the wellhead. This 'flow back' is a mixture of the original hydraulic

[41] ACOLA P. 113
[42] IGU P. 28
[43] ACOLA P. 113
[44] Todd Energy P. 89

fracturing fluid – containing less than one per cent of chemical additives – and any natural formation water – containing dissolved constituents from the shale or tight formation itself.[45]

About a third of this water will flow back to the surface with the initial gas production, with the rest remaining in the formation. This can be recycled and used to hydraulically fracture other wells. The quantity of water being recycled is increasing as companies become more familiar at handling waste onsite and water treatment technologies become more readily available.

Water that cannot be recycled is placed in specially designed ponds for evaporation. The residue from this process is tested and, if required, safely removed to a licensed disposal facility. At no point does this water contact or contaminate groundwater sources.

With appropriate well design and protection in place, risks and mitigation in relation to impacts on water from shale gas should primarily focus on reinjection and impacts at the surface.[46] These activities are strictly regulated by DMP and companies are required to address the management of water at the surface and disposal in an Environment Plan.

In maximising the sustainability of operations, the industry constantly evaluates the ability for water used in operations to be recycled or reinjected into reservoirs. Reinjection involves pumping the water deep underground into approved aquifers, provided it does not degrade the quality of the groundwater.

A better understanding of the environment, particularly in relation to water resources, is required in many areas and the commitment of the State Government to develop an environmental database will be very useful in consolidating and communicating this information.

REHABILITATION OF LAND IMPACTED BY PETROLEUM ACTIVITIES

This section relates to Terms of Reference 1.1(d).

All sites impacted by operations are rehabilitated as close to their original condition as possible. As per the *Petroleum and Geothermal Energy Resources (Environment) Regulations 2011,* companies are required to identify in their approved Environment Plan how land will be rehabilitated after the conclusion of all relevant activities. Companies are also required to report the progress of rehabilitation efforts to DMP on a regular basis.

Once production is exhausted the operator will permanently seal the well with cement plugs – a process called abandonment. All cements used in operations are specially formulated to withstand high pressures and last for decades.[47] The abandonment process is subject to strict conditions and a company's process is reviewed and approved by DMP.

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[45] IGU P. 28
[46] ACOLA, P. 129.
[47] ACOLA, P. 128.

EARLY, OPEN AND MEANINGFUL COMMUNICATION

Trust is central to building community confidence and the industry invests significant time and effort in engaging with communities and key stakeholders.[48] The industry also recognises that it is important for the public to be informed by credible third party sources and the industry has worked successfully with CSIRO (and DMP) to deliver a series of community workshops in the Mid West.[49]

APPEA and its members work closely with key stakeholders (affected landholders, Traditional Owners, shires, government representatives and other interest groups) in the area of operations to ensure they are provided with all relevant information in relation to activities. Companies are required to work with landowners prior to the commencement of activities to agree compensation for loss of income, disturbance and distraction. Further examples of how companies work with landholders is available in APPEA's Code of Practice for Hydraulic Fracturing.[50]

Working with regional communities and the agriculture and pastoral sectors

APPEA is working with peak farming and pastoral industry bodies and directly with regional communities to address some of the concerns about development of natural gas production on private land including concerns about water management and farmers' and pastoralists' rights.

The petroleum sector recognises that good communication and trust-building is necessary to underpin successful coexistence of the two industries in the future. On this basis, APPEA is working with WAFarmers and the WA Pastoralists and Graziers Association to establish a shared understanding of how science and cooperation can help in resolving technical issues and concerns about petroleum exploration activities.

These discussions have primarily focussed on the areas where activity is proposed or underway including the Canning Basin, the north Perth Basin and the Carnarvon Basin. The Mid West exploration areas include established farmland where some property owners have raised concerns about the implications of the industry's future development. The Carnarvon Basin includes some irrigated horticultural land about 30 kilometres from an exploration zone and the Canning and Carnarvon Basins include some pastoral stations.

The key concerns raised by farmers with APPEA include:

- Groundwater protection and competition for water use;
- Impact of petroleum exploration on pre-existing activities;
- Land access, compensation arrangements and farmers rights; and

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[48] ACOLA, P. 26.

[49] For further information see the CSIRO report from this process. Taylor, B, Stone, P, 'Dongara Mid-West onshore gas community workshop – 24 October 2012', CSIRO Ecosystem Sciences (2012), http://www.dmp.wa.gov.au/documents/Report_Onshore_gas_workshop.pdf [Accessed 27/09/13].

[50] APPEA Code of Practice.

- Uncertainty about the scale, nature and timing of future industry and regulatory action.

APPEA is in talks with farmers' and graziers' representatives to develop a set of protocols and commitments which would:

- Protect the viability and amenity of farm and pastoral land;
- Ensure that rural property owners and leaseholders are well resourced and represented in negotiations with petroleum companies;
- Protect the environment – particularly water supplies; and
- Maximise the benefits of petroleum developments to local communities.

The process will include a joint workshop to identify the issues and ways to resolve them. The work will set objectives which are based, in part, on examples from other jurisdictions and reflect WA-specific requirements. The workshop is expected to establish a joint working group to prepare a draft agreement. The CSIRO will be involved as a technical advisor to identify the key scientific issues which would need to be addressed in any agreement.

The outcomes of the process are expected to complement recently updated regulations and guidelines for the control and management of the industry's development.

Products to come from this joint industry work could include a code of practice, an information website, a reference booklet and a set of guidelines for communication, negotiations and activities on private and pastoral lease land.

Working with Traditional Owners

Shale and tight gas exploration companies working with Traditional Owners in Western Australia have made it a priority to engage with Aboriginal communities. As the projects move from exploration to commercial development, Traditional Owners will emerge as key beneficiaries of the onshore petroleum industry.

Two companies with close links to Aboriginal communities are Buru Energy (operating in the Canning Basin) and New Standard Energy (exploring in the Canning and Carnarvon Basins). Both companies are working closely with Traditional Owners to build relationships based on mutual respect and confidence.

One of Buru's first major initiatives was to hand back exploration tenements in the Roebuck Bay area near Broome to the Yawuru Traditional Owners in 2011. The commitment has ensured that the Yawuru People are able to exercise their traditional roles as the custodians of Roebuck Bay without intrusion from oil and gas exploration. In relinquishing the tenements, Executive Director Eric Streitberg said the company's relationship with the community was founded on a respect for traditional country, culture and values.

Since then, Buru has developed a comprehensive program involving:

- Potential Indigenous training;
- Commitments to operations training and employment - if the projects go ahead on a commercial basis;
- Cross cultural training;
- Heritage protection;

- Support for independent expert advice; and

New Standard Energy has adopted an inclusive approach to its program from the start of its exploration programs. Traditional Owners have been extensively consulted prior to any operational activities (from seismic to civil works to drilling) and the company values their input.

The input isn't confined to mandated consultation periods, but is part of an ongoing two-way flow of information.

All of New Standard's exploration permits are covered by native title and the company is committed to protecting sites of cultural significance, while providing opportunities for Traditional Owners in return for access to their traditional lands. From the cultural awareness programs the company has implemented to its ethos of fairness and respect, New Standard is working to achieve mutually beneficial relationships with Traditional Owners.

THE IMPORTANCE OF A FACT-BASED DISCUSSION

It is APPEA's view that the strength of regulatory approaches and the industry's ongoing commitment to continuous improvement are often lost within the onshore gas debate. This debate has often seen fact and science-based evidence diluted by extremist claims from "ideological crusaders"[51] seeking to spread misinformation rather than engage in a constructive dialogue. In this regard, Attachment 4 provides details of 'Frequently Asked Questions' and responses that APPEA previously distributed to State Members of Parliament to clarify a number of inaccurate statements made by the Conservation Council of Western Australia.

However, it is noted that APPEA has also had positive engagement with conservation groups in other jurisdictions where there is an appetite to discuss the issues and how activities can be better managed.

APPEA strongly believes that trust is critical to building community confidence and where there are legitimate landowner concerns they must be addressed by the industry. Industry should at all times be transparent, open and undertake early engagement with stakeholders.

Where possible within the broader debate, the industry continues to rely on peer-review science-based information.

Case Study: Informing the Discussion with Independent Third Parties

APPEA, DMP and CSIRO have jointly developed an initiative to provide information and advice on shale and tight gas production to community groups in Western Australia. The initiative is helping to provide an objective and effective basis for consultation during the planning and development of a natural gas industry based on shale and tight rock formations in Western Australia. The key objectives of the initiative are to

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[51] Potter, B, "Demand to sort out `ideological crusaders'", *Australian Financial Review*, 9 September 2013.

- Provide a source of credible, objective and expert information to the community;
- Facilitate and inform engagement with stakeholders and the community; and
- Address some of the misinformation surrounding the onshore gas industry

APPEA has been working with the WA State Government, particularly the DMP, on some of the key aspects of the partnership development.

The need for quality independent advice became evident during a series of community meetings and information workshops during 2012. Local residents had trouble reconciling the conflicting information from industry and anti- gas campaigners. A number of community leaders asked the CSIRO to become involved to provide trusted information.

On this basis, CSIRO participated in community meetings and contributed to the design of a community workshop. CSIRO observers prepared a report on the proceedings. Some of the key recommendations were

- Introduction of engagement processes for a diverse range of stakeholders
- Provision of information from independent and trusted sources
- Appropriate engagement for different stages of development
- Better coordination of information flows, and engagement processes
- An enhanced role for local government as an engagement hub.
- Provision of additional information to reflect:
  - local as well as national and international experiences and cases
  - existing and best-practice circumstances
  - the range of future development options, risks and scenarios e.g. identifying the low, mid and high development scenarios for the region as "possible futures"

Some of these initiatives are being implemented, and others will be put in place after further consultation with local community leaders and government agencies. As part of this process, APPEA has started discussions with peak farm bodies to develop protocols for exploration on private land (building on experience in other jurisdictions).

In the Canning Basin, the key players are reviewing the options for engagement with Traditional Owners and community groups. State Government and APPEA participated in some meetings with TOs involving a world expert on shale gas, Professor Peter Styles earlier this year to inform development of a suitable engagement model. The exploration companies are liaising with indigenous leaders on the most appropriate consultation strategies.

In the Northern Territory, CSIRO participated in June in an initial stakeholder meeting involving the NT Cattlemen's Association. APPEA is working with the NT Government and CSIRO in relation to further public meetings. .

The purpose of these meetings is to discuss:

- Provision of expert advice to community groups on initiatives such as planned round table discussions with farmers
- Design of effective community engagement processes in the Kimberley communities
- A technical information audit and gap analysis – looking at scientific data applicable to

shale and tight gas development in WA, NT and South Australia

- Access to independent on-line information
- Participation in community reference groups

The costs of the present activities are shared equally between APPEA, DMP and CSIRO. APPEA is currently preparing a funding plan for member companies, government agencies and CSIRO.

CONTINUOUS IMPROVEMENT

The industry is constantly seeking ways to improve its performance, including through innovation in technology and adapting techniques that further improve the sustainability of activities. Codes of practice are used to unite and demonstrate the industry's commitment to environmental and social sustainability. Australian and international studies inform and improve the way the industry does business and protects the environment.

The industry recognises that setting and adhering to high operating standards in relation to onshore natural gas operations is essential in maintaining and building a reputation which ensures that the industry is a welcome part of the Australian economy and communities.

This is particularly challenging with the wide variety of regulatory regimes and industry participants across Australia. Community and media attention has also made the challenges quite public and widely debated across a broad range of stakeholders.

Industry has therefore agreed to develop and promote leading Operating Principles and Practices. These will be used to:

- Set an appropriate expectation of leading practices;
- Encourage a consistency in approach across the industry;
- Provide a basis for harmonised, or at least consistent, laws and regulations across the jurisdictions; and
- Promote the responsible and sustainable practices of the industry with stakeholders.

The Australian Council of Learned Academies Report, 'Engineering Energy: Unconventional Gas Production', is referred to throughout this submission and should play a larger role in the discussion in Australia. Released in May 2013, APPEA views this document as the most comprehensive study of the industry and its potential impacts in Australia and would commend the document to the Environment and Public Affairs Committee.

THE DELIVERY OF ROBUST AND EFFICIENT REGULATION

Effective regulation is an important means of providing the public with confidence that activities are assessed and approved to standards of sufficient rigour that they mitigate risk. Industry is confident that robust regulation already exists in Western Australia and will continue to work with government to evolve the regulatory framework as required.

Continuous improvement and the maintenance of an objective-based regulatory framework will be important to address environmental impacts – a key requirement that government and industry must continue to meet in order for the benefits of shale and tight gas to be accessed.

REGULATING EXPLORATION-STAGED ACTIVITIES

All petroleum activities in Western Australia, and waters and islands within three nautical miles, are specifically regulated through the *Petroleum and Geothermal Energy Resources Act 1967 (PGERA),* overseen by DMP. This legislation has been tried and tested in Western Australia and has successfully managed petroleum activities for decades, including the use of hydraulic fracturing.

This legislative framework is supported by subsequent regulations which specifically address in detail issues such as the construction and maintenance of petroleum wells and the environmental impact of petroleum activities. The industry can also be subject to safety, health and water legislation.[52] This framework has recently been through a rigorous assessment by an independent expert which found that it is more than sufficient to manage shale and tight gas activities.

Review of Shale and Tight Gas Regulation in Western Australia

In July 2011, DMP released a review by Dr Tina Hunter (currently based at the University of Queensland) titled '*Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia*'. The Review considered the state of Western Australia's regulations and their ability to manage the development of tight and shale gas exploration.

While finding the existing regime robust, the Review led to the development and implementation of new environment regulations in 2012 with an increased focus on issues such as management of produced water. Further recommendations to strengthen the regulatory framework relating to management of well operations (including construction and maintenance of wells) are expected to be reflected in a new set of resource management regulations to be released in 2013.

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[52] Including, amongst others, the Petroleum and Geothermal Energy Resources (Occupational Safety and Health) Regulations 2010, the Health Act 1911 and the Rights in Water and Irrigation Act 1914.

Environmental Protection Authority

Where activities justify a higher level of assessment, they are elevated and assessed through the *Environmental Protection Act 1986* (*EP Act*) which is overseen by the Environmental Protection Authority (EPA). In September 2011, the EPA released a Bulletin following the assessment of three hydraulic fracturing proposals and "emerging community interest".[53] The EPA noted that:

- in deciding whether to assess a proposal the EPA will determine the significance of the environmental impact; and
- DMP is the lead agency for regulating the development of the gas industry.

The EPA identified areas of focus associated with these activities as:

- water use;
- storage and disposal of produced water;
- potential chemical contamination of groundwater and surface waters;
- disruption to aquifer connectivity;
- fugitive greenhouse gas emissions;
- changes to land use and associated infrastructure development; and
- clearing of native vegetation.

The EPA determined that there was no need to assess current small scale 'proof of concept' exploration proposals, as they were not likely to have a significant impact on the environment. Importantly, the EPA noted that any potential impacts could be managed through the DMP's existing processes.

The EPA noted that it will assess future projects on a case-by-case basis and formal assessment will only occur if projects are likely to have a significant effect on the environment (as per the significance test outlined in the EPA's *Environmental Impact Assessment (EIA) Administrative Procedures 2010*). APPEA has worked with DMP to consider the stage at which a project might be referred to the EPA and the characteristics of a project that will require formal assessment under the *EP Act*.

The history of the industry and the reviews of the regulatory framework's ability to manage shale and tight gas activities clearly indicates that risks are effectively managed and mitigated.

REGULATING ACTIVITIES AS THEY ADVANCE

APPEA has been working with DMP to clarify the stage at which projects might progress past a 'proof of concept' stage and require further consideration by the EPA. This work supplements the independent expert reviews of regulation referenced throughout this submission that have been conducted within Western Australia and Australia.

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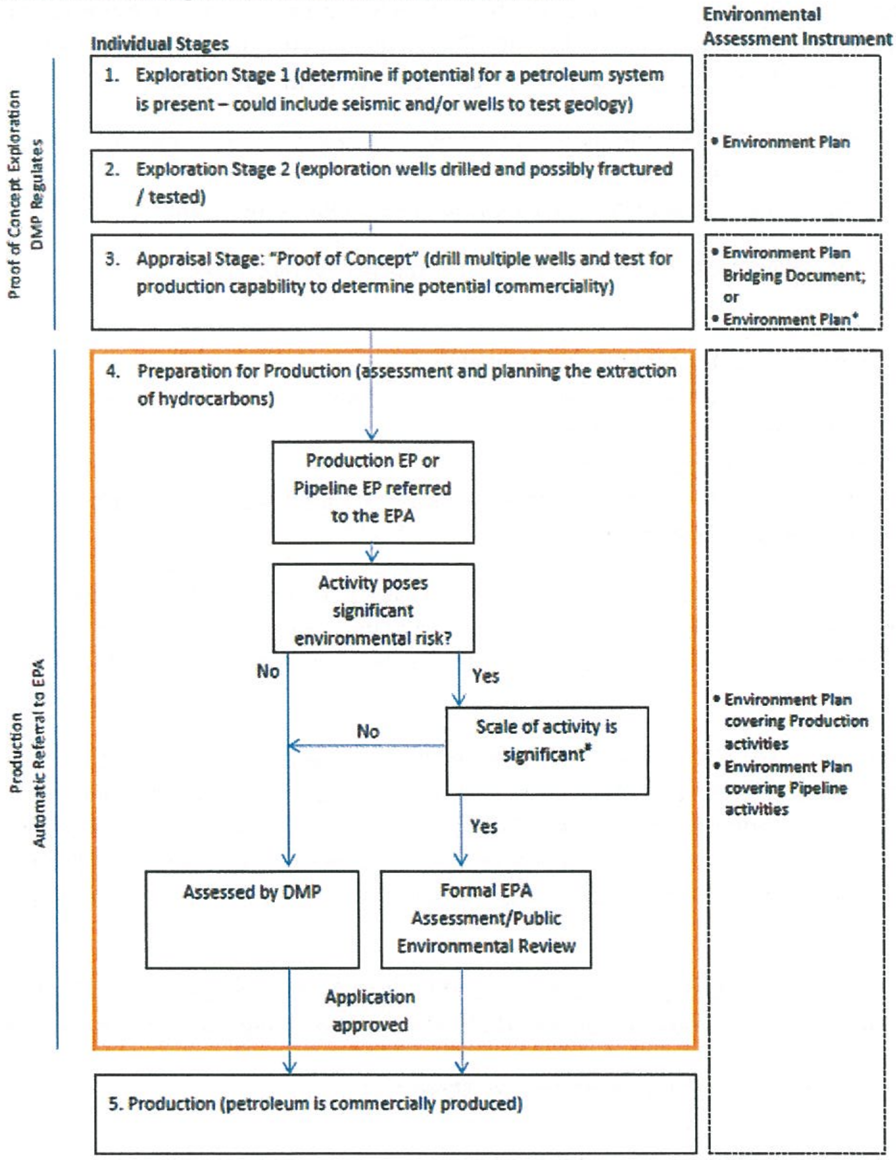
[53] 'Environmental Protection Bulletin No. 15: Hydraulic fracturing of gas reserves', Environmental Protection Authority (2011), http://www.epa.wa.gov.au/EPADocLib/EPB%2015%20Fracking%20050911.pdf, [Accessed 17/09/13]

As per the diagram below, industry believes that commercial production is an appropriate trigger for these higher level assessments.

Figure 11. Shale and Tight Gas Assessment and Referral Process



Notes:

Advice from DMP is that the scale of projects, including whether they are significant, can only be determined by the EPA after it has become familiar with assessing onshore projects.

* A new Environment Plan may be required if activities, such as extended well testing, have not been described sufficiently in the original EP

Source: APPEA

ADVANCING THE INDUSTRY

This submission has discussed the three ingredients that industry believes are required for community confidence in the industry to be achieved – best practice from operators, robust regulation and effective communication.

The industry has enormous potential to be an economically important additional energy source which significantly reduces Australia's greenhouse gas emissions.

ACOLA notes that development would require great skill, persistence, capital and careful management of any impact on ecosystems and related natural resources. It will also need an informed and supportive community, transparent and effective regulations and companion codes of practice.

Case Study: IEA Golden Rules for a Golden Age of Gas

In 2012 the International Energy Agency released a set of 'Golden Rules' to guide government and industry in relation to shale gas extraction. These rules were established to manage the social and environmental concerns that have emerged alongside the industry. In particular, the IEA noted:

> *The technologies and know-how exist for unconventional gas to be produced in a way that satisfactorily meets these challenges, but a continuous drive from governments and industry to improve performance is required if public confidence is to be maintained or earned.*[54]

The full detail of the Golden Rules can be accessed through the IEA website, but points of note include:

- Measure, disclose and engage: Engage with stakeholders (local communities and residents etc.), establish baseline data for key environmental indicators, gather and disclose baseline data on water use and minimise disruptions during operations.
- Watch where you drill: Choose well sites that minimise impacts (including on local community and heritage etc.), properly survey sites (including for seismicity) and monitor to ensure propagation of fractures does not leave the target reservoir.
- Isolate wells and prevent leaks: Establish robust rules to ensure well integrity (e.g. proper cementing and integrity testing), consider minimum depth limitations on hydraulic fracturing, take action to prevent and contain surface spills and leaks from wells and

[54] IEA Golden Rules

ensure any waste fluids and solids are disposed properly.

- Treat water responsibly: Reduce freshwater use, store and dispose of produced and waste water safely, and minimise use of chemical additives and promote the use of environmentally benign alternatives.
- Be ready to think big: seek opportunities for realising economies of scale and coordinated development of local infrastructure that can reduce environmental impacts. Take into account the cumulative and regional impacts of multiple drilling, production and delivery activities.
- Ensure a consistently high level of environmental performance: ensure the level of activity is matched by resources and political backing for robust regulatory regimes, sufficient permitting and compliance staff, and reliable public information. Balance prescriptive and objective based regulation, pursue continuous improvement of regulation and operating practices and recognise the case for independent evaluation and verification of environmental performance.

APPEA views these rules as important considerations for industry and government in building community confidence.

The industry in WA is currently at a very early stage with small companies at the forefront of exploration efforts. However, the development of the industry in Western Australia will have a strong foundation as a result of:

- The petroleum sector's ability to bring to bear decades of experience;
- The State's tried and tested regulation having been assessed and endorsed for its ability to manage current shale and tight gas activities; and
- Significant efforts by government and industry to engage with communities, including through initiatives with independent third party groups such as CSIRO.

Strategic planning will be an important way of combining the State's advantages to capitalise on the industry's potential. The Committee has an opportunity to use the Inquiry to facilitate the delivery of fact-based information to the public so that the community can have a constructive conversation about the future of the industry.

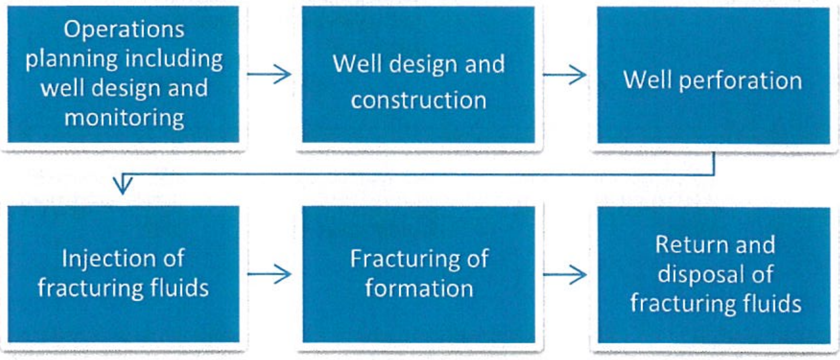
However, even building from this base, the industry's success is not guaranteed. Cost pressures for natural gas projects in Australia are very high and there are a number of projects worldwide, and within Australia, that are seeking to export into the global gas market. In this environment of high costs and competition, the continuation of Australia's resources boom and energy supply cannot be taken for granted. Successful development of a shale and tight gas industry will rely on targeted, coordinated and transparent regulation. For example, monitoring of water supplies needs to have an environmental benefit – the risk of contamination is highest at the surface and expensive monitoring of deep water saline aquifers does not represent the best allocation of resources to protect the environment.

While there are challenges ahead, the considered pace and manner in which the industry is approaching exploration and potentially development provides sufficient time to face these challenges head on.

ATTACHMENT 1 – HYDRAULIC FRACTURING

Like the natural movement of the Earth's crust, hydraulic fracturing of rocks releases trapped fluids or gasses. In the context of petroleum operations, hydraulic fracturing is used to increase the flow of oil and gas to a well, therefore increasing production and reducing the total number of wells needed to develop a resource. It allows commercialisation of low permeability (shale or tight gas) reservoirs in which oil and gas do not easily flow. It can also be used with other natural resources such as to access geothermal energy and to increase water production.

The hydraulic fracturing process is outlined below:



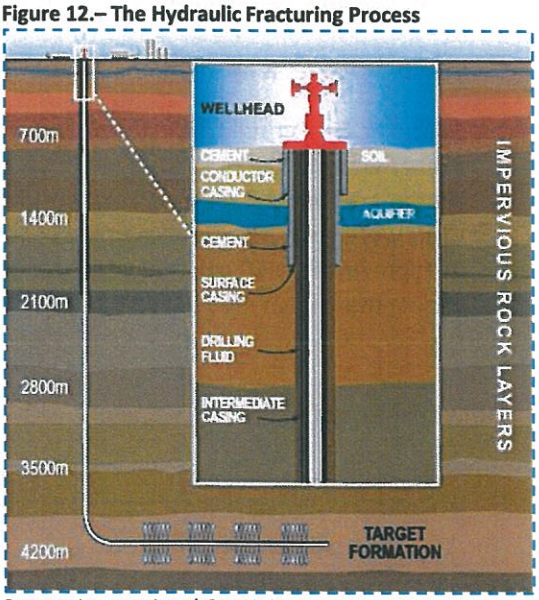
1. After a well has been drilled, including any horizontal pathways, it is cased in multiple layers of steel (casing) and concrete.

2. A perforating tool is then used to create small holes in the lowermost well casing within the target zone (i.e. the depth at which gas is expected to be located) so that fluid can only enter within a certain section of the well.

3. Hydraulic fracturing is then used, which involves pumping a fluid down the well at high pressure to open tiny cracks in the target rock reservoir. This fluid contains 'proppants', such as sand or tiny ceramic beads, which are used to hold the fissures open and improve the flow of gas or oil. Most fluid contains a small percentage – less than one per cent – of chemical additives to make the technique more efficient.

All recovered fluids are isolated in sealed storage areas designed to prevent leakage, including specially designed and constructed dams or above-ground holding tanks. Depending on regulatory conditions, these fluids are then reused in subsequent well stimulation activities, treated for other uses or disposed of through an approved facility.

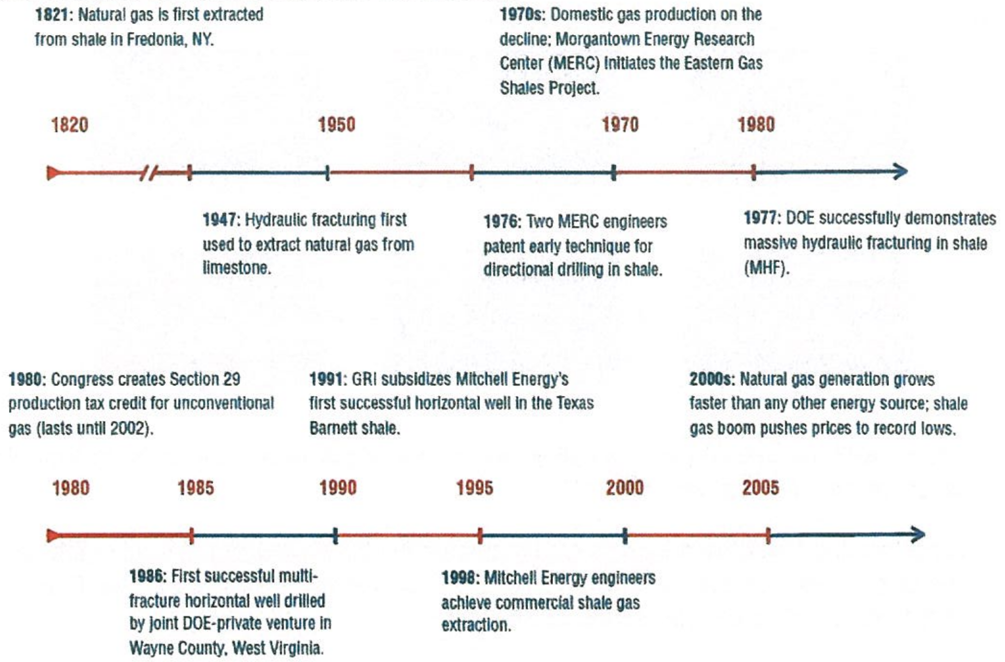
Figure 12.– The Hydraulic Fracturing Process



Source: International Gas Union

Reviews of the emergence of shale gas development in the US have found that a number of factors converged in the early 2000's to make it profitable for firms to produce large quantities of gas. As outlined below in Figure 14, this includes public-private partnerships into research and commercialisation and federal government support for commercialisation. Hydraulic fracturing technology took time to develop but ultimately resulted in cost-effective production of natural gas from shale rocks. [55] Ultimately, government support and the development and implementation of multistage hydraulic fracturing and horizontal drilling techniques enabled shale resources to be accessed on a commercial basis.

Figure 13. Shale Gas Development in the US: A Timeline



DOE = US Department of Energy; GRI = Gas Research Institute
Source: Breakthrough Institute[56]

The Development of Hydraulic Fracturing

Hydraulic fracturing was first used commercially in 1949 in Stephens County, Oklahoma, and Archer County, Texas, to increase flow rates from tight hydrocarbon reservoirs and has since been used more than 2.5 million times worldwide. Within the first year of its implementation, 332 wells were treated with an average production increase of 75 per cent. It is now reportedly used in approximately 60 per cent of all petroleum wells drilled and, as at 2010, was credited with adding more than nine billion barrels of oil and 700 trillion cubic feet of gas to US reserves

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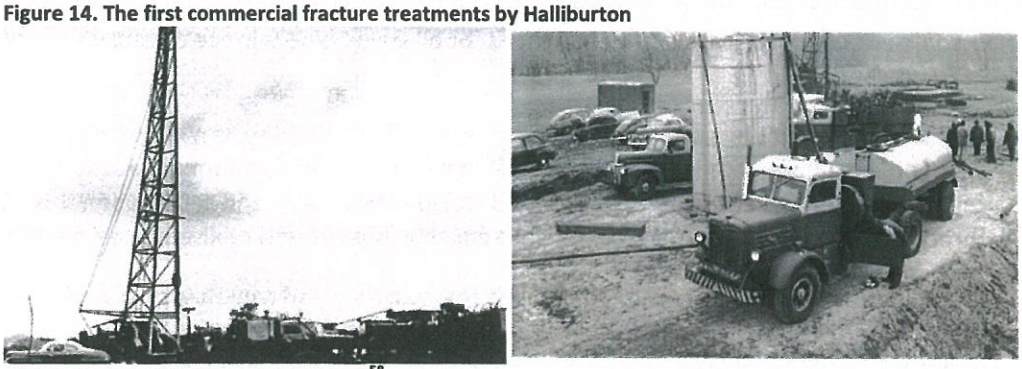
[55] Wang, Z, Krupnick, A, 'A Retrospective Review of Shale Gas Development in the United States: What Led to the Boom?', Resources for the Future (2013), http://www.rff.org/RFF/documents/RFF-DP-13-12.pdf, [Accessed 17/09/13].
[56] Trembath, A, Jenkins, J, Nordhaus, T, Shellenberger, M, 'Where the Shale Gas Revolution Came From', Breakthrough Institute (2012), http://thebreakthrough.org/blog/Where_the_Shale_Gas_Revolution_Came_From.pdf, [Accessed 17/09/13].

alone.[57] In general, fracturing is considered to have increased US oil and gas reserves by at least 30 per cent and 90 per cent respectively and is expected to move the country towards levels of energy security it hasn't experienced in decades.

Figure 14. The first commercial fracture treatments by Halliburton



Source: Society of Petroleum Engineers[58]

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[57] Montgomery, C, Smith, M, 'Hydraulic Fracturing: History of An Enduring Technology', Society of Petroleum Engineers (2010), http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf, [Accessed 17/09/13].
[58] *Ibid.*

ATTACHMENT 2 – MULTIPLE LAND USE FRAMEWORK

APPEA supports and has engaged with the process by the Standing Council on Energy and Resources (SCER) to develop the Multiple Land Use Framework (MLUF). Achievement of the below outcomes would provide clear shared benefit for all stakeholders in the development of onshore gas industry:

- Shared commitment by government, industry and the community to multiple and sequential land use - Minimise incidences of land use conflict by improved ability to recognise differing needs and benefits to all stakeholders early, and acting upon this through a risk - based approach to mitigate adverse impacts and realise mutual benefits.

- Better informed public discourse - Increased transparency and consistency in land use decisions, provision of easy access for the public to relevant and factual information, improved understanding of land access regulations relevant to each activity, as well as recognising benefits of coexistence and collaboration through multiple land use approaches.

- Merit based land use decisions - Ensure land is not arbitrarily excluded from other uses without fully understanding the consequences. Providing certainty for industry and improved community confidence in land use decisions.

- Deliver acceptable outcomes for affected communities and landholders - Demonstrate and facilitate that multiple and sequential land use approaches can be accommodated in a manner that is beneficial to all stakeholders and engender greater confidence in, and positive engagement by, communities and land holders impacted by industry developments

ATTACHMENT 3 – CODE OF PRACTICE FOR HYDRAULIC FRACTURING

At the end of 2011, APPEA and its onshore gas members released a Code of Practice for Hydraulic Fracturing to demonstrate what the gas industry is doing to successfully and responsibly develop significant onshore gas reservoirs in Western Australia.

The Code was developed by a working group of industry operators based on established operating principles and leading practices in other jurisdictions that are relevant to local conditions. The document can be viewed in full at www.wa-onshoregas.info and includes a number of points relevant to the Inquiry, in particular:

- Guideline 1 – Community, landholder and stakeholder interaction. The aim of this guideline is to ensure operators communicate openly and as early as practicable with landholders, local communities and other stakeholders. This communication includes explaining how risks are being managed to minimise any potential unwanted or adverse impacts.
- Guideline 3 – Sourcing and use of water. The aim of this guideline is to protect and, where required, effectively and responsibly use groundwater resources. For example, all water used in hydraulic fracturing operations will be captured and reused where possible and a company needs to demonstrate that the taking of water will not have unacceptable impacts on aquifers.
- Guideline 4 – Use of chemicals in hydraulic fracturing. The aim of this guideline is to minimise the use of chemicals in hydraulic fracturing operations, provide clear and accurate information on any chemicals that may be used, and promote the safe and responsible use of chemicals. This includes by supporting the public release of information and using chemicals with the lowest toxicity to facilitate operations.
- Guideline 5 – Fluid flowback and produced fluids containment. The aim of this guideline is to ensure that post-fracture stimulation clean-up flowback or produced fluids cannot come into contact with Production Aquifers or pollute soil or soil substrate. This includes sealed storage and recycling where possible of all recovered hydraulic fracturing fluids.
- Guideline 7 – Continuous improvement. The aim of this guideline is to ensure continuous performance improvement and the sharing of information with regulators and other stakeholders to reduce potential risks of hydraulic fracturing.

ATTACHMENT 4 – LETTER CIRCULATED TO MEMBERS OF PARLIAMENT, 'APPEA's position on concerns raised by CCWA'

An Approach Based on Facts & Science, Not Fiction or Fear

Shale and tight gas is natural gas – the fuel Western Australians have been using in homes and businesses for more than a generation. It's clean and efficient, producing about half the greenhouse gas of coal in generating electricity.[59] The development of gas resources located offshore Western Australia has been overwhelmingly positive for the State. The further development of natural gas from shale and tight rocks in the Mid West and Canning Basin could be equally important in generating jobs, building infrastructure, providing income and energy security. The industry supports high operational and regulatory standards based on science, transparency, stakeholder involvement, predictability and consistency.

What is Happening Around the World?

Worldwide shale gas production is expected to be the biggest single source of new global energy over the next two decades. The US EIA has estimated that shale gas production will increase from 34 per cent in 2011 to 50 per cent in 2040.[60] The International Energy Agency estimates that natural gas will account for 20 per cent of world total primary energy supply by 2035.[61]

The USA is leading the world in development of the shale gas industry with significant economic and environmental benefits. The recent and rapid transformation of the North American energy sector based on natural gas from its shale resources highlights the potential for these benefits. One recent study illustrates the extent of the transformation. It found that the resurgence in onshore gas and oil in the US had created 1.7 million jobs in 2012.

The UK Government is encouraging petroleum companies to step up drilling programs for shale gas in Britain. Britain has significant potential for shale gas, with a number of groups looking at how these resources can replace ageing, coal-fired power stations.

China and Canada are expected to become major shale gas producers as global energy consumption increases by more than 50 per cent in the next two decades.[62]

What is Happening in Western Australia?

There is no significant shale or tight gas production in Western Australia at present. Most of the State's existing supplies of natural gas come from offshore reserves. However, the State has extensive exploration areas showing potential for shale and tight gas production.

[59] US Environmental Protection Agency, 'Natural Gas', http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html.
[60] US Energy Information Administration. 'Annual Energy Outlook 2013', http://www.eia.gov/forecasts/aeo/MT_naturalgas.cfm
[61] IEA, http://www.iea.org/publications/freepublications/publication/kwes.pdf
[62] US Energy Information Administration, 'International Energy Outlook 2011', http://www.eia.gov/forecasts/ieo/

The most advanced exploration projects are in the Canning Basin in the State's North West and the North Perth basin around the Mid West region. Most of the exploration projects are in the early or proof-of-concept stages. Exploration is governed by a tested framework of regulation and operating practices which focus on reducing risks to the environment, ensuring safe operations and supporting open and transparent engagement with local residents.

If commercial development goes ahead, the gas would be used initially for domestic markets, delivering secure long term supplies of gas at competitive prices for homes and industry. The industry has the potential to underpin a new phase of Western Australia's strong economic performance and promote economic and social development in regional areas.

What are the Facts About the Environmental Concerns?

The process of hydraulic fracturing

The process of hydraulic fracturing – pumping fluid into deep geological zones to release the gas into production wells – is one feature of tight and shale gas production. It has been used in the oil and gas industry in WA since the 1950s with some 780 petroleum wells drilled and fractured with no adverse effects on the environment, water sources or public health according to the WA Department of Mines & Petroleum. It is a tightly controlled and highly regulated process.[63]

The regulations covering the industry are stringent and comprehensive. An explanation of the process can be found on the websites of the Department of Mines and Petroleum and APPEA.[64]

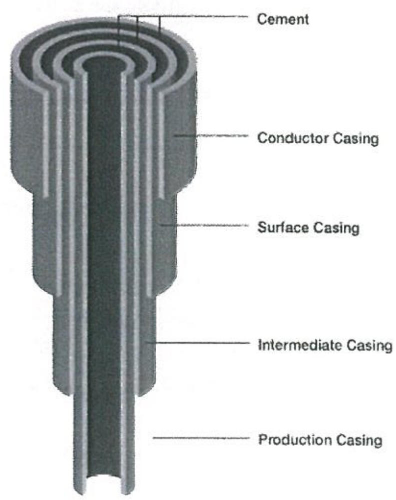
Protection of groundwater

The industry recognises the conservation and protection of ground water is a top priority. Key factors which protect groundwater during natural gas production are:

- The strength of the wells

Reinforced steel and concrete casings are designed to keep the gas inside the well. The diagram to the right is a cross section of a typical shale or tight gas well, reinforced to keep gas in and water out.

Typical Well Casing Diagram
(Not to Scale)



An August 2011 report from the US Ground Water Protection Council examined more than 34,000 wells drilled and completed in the state of Ohio between 1983 and 2007, of which a total of 0.03

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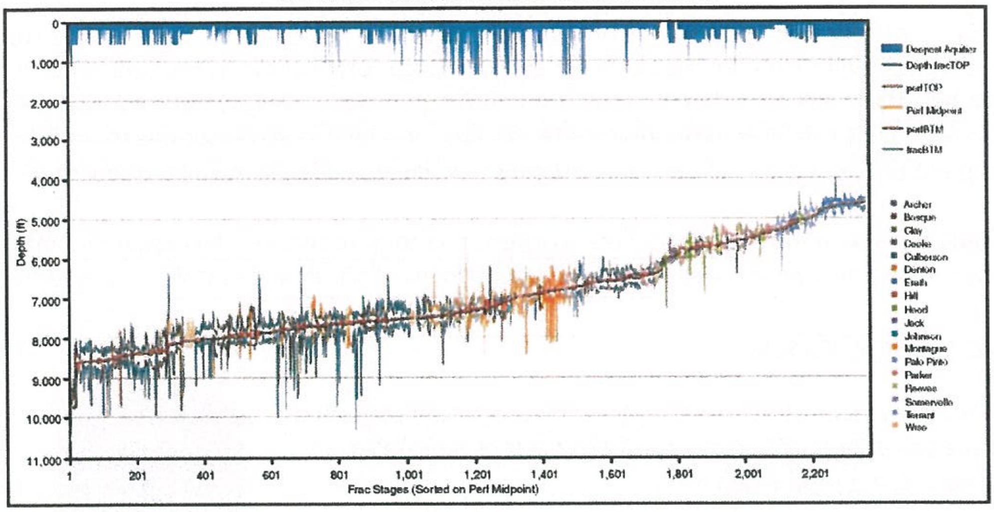
[63] More detail is available at http://www.youtube.com/watch?feature=player_embedded&v=BEH4M7EulsU
[64] DMP: http://www.dmp.wa.gov.au/15136.aspx ; APPEA: http://wa-onshoregas.info

per cent had failures of casing or cement. Most of those incidents (more than 80 percent) occurred in the 1980s and 1990s before modern technology and regulations. A similar study of 187,000 wells in Texas found that 21 incidents (0.01 per cent) related to well integrity.

- The depth of the gas-bearing rock

Shale and tight gas resources are typically between two and four kilometres below the ground, separated from near-surface freshwater aquifers by a least a kilometre of impermeable rock. The process of hydraulic fracturing is monitored to confirm that the extent of the rock fractures remain separated from ground water, typically by one to two kilometres of rock in WA. Extensive research on hundreds of wells in the US has conclusively demonstrated that the fractures induced by the process are confined to the rocks close to the zone of interest. The following chart shows the depth of the process, the maximum extent of the induced fractures and the relation to the aquifers.

Barnett Shale Mapped Fracture Treatments (TVD)



- Effective monitoring programs

Highly trained technicians use a range of monitoring techniques based on seismic, pressure-testing and water sampling technology to show that the production process is working safely and effectively. Information from the monitoring is available to the public. These monitoring programs are closely regulated by various Government agencies.

- Limited water usage

The hydraulic fracturing process uses about 11 million litres water – equivalent to the contents of four Olympic swimming pools. Ongoing production involves a minimal water use – much less than most horticultural properties.

- Surface water management

Once the well begins to produce natural gas, about a third of the fluids used during the fracturing process flow back to the surface. These fluids are stored in lined pits or in steel tanks until they can be reused in future fracturing jobs. When they are no longer needed, the fluids are placed in specially designed ponds for evaporation, leaving a small residue. This residue is tested and can then be safely removed and taken to a licensed disposal facility.

- Use of chemicals

The hydraulic fracturing fluid used to improve gas and oil production is typically comprised of more than 99.5 per cent water and sand and 0.5 per cent chemical additives. Many of the chemicals used are also found in common household and commercial applications. They include guar gum used in jelly sweets, salt, detergents and antiseptics - all of which are used in extremely low concentrations.

The chemical additives are assessed, fully disclosed and managed according to strict regulations. Monitoring ensures they remain in a closed process system – and don't contact fresh water.

Landscape Impacts

Opponents of natural gas production from shale and tight rocks have made wildly exaggerated claims about the number of wells which could be drilled if a WA. They have also used photographs of gas fields in the US which are very different in design and scale to the projects which might be developed in WA.

A WA shale and tight gas development is expected to be based on multiple horizontal wells from one well pad. This allows for higher natural gas production from one location and a smaller land use footprint.

After a well is established and a project moves from exploration to production, most of the land is rehabilitated, leaving a small area around the well head and the associated infrastructure. Each well head will have a two metre tall "Christmas Tree" – or valve assembly – to control the gas production. These well pads would be spaced between one and three kilometres apart across a production area.

The number of wells and well pads will depend on the success of current exploration programs – and the development of gas markets, will be far less than the unfounded claims being made.

The Gaslands Myth

Gaslands, a movie which has been used by groups opposing onshore natural gas development, was produced in the style of a documentary by filmmaker Josh Fox, who now makes a successful living from anti-gas campaigning.

A number of US authorities have followed up the allegations in his film and have found the majority to be untrue. For example, the signature scene is a "flammable faucet" segment in which a Colorado householder claims that gas producers have polluted his water supply with methane. He demonstrates this by lighting a match next to a kitchen tap which bursts into flames.

Tests by the State of Colorado Oil and Gas Conservation Commission on this location showed the gas was naturally occurring and not the result of commercial gas production activity.[65] The household bore had intersected a natural methane accumulation – a common local phenomenon reported long before the gas producers arrived on the scene. Mr Fox was provided with this information but chose not to use it in the film.

A more complete analysis of the film can be found at Energy in Depth.[66]

Calls for a Moratorium

WA Parliament has previously rejected requests for a moratorium on shale and tight gas exploration.

A halt to exploration would be counter-productive and unnecessary given the regulatory assessment and guidance offered by the Department of Mines & Petroleum and the Environmental Production Agency. The information from exploration programs is being used to provide important data for the effective management and regulation of a future industry.

The moratorium would stop this flow of information and delay the introduction of shale and tight gas - without improving the level of local knowledge. This knowledge will be important in developing operational and regulatory approaches which can ensure that the State's shale and tight gas resources are developed in an environmentally responsible manner.

A Partnership Approach

APPEA has partnered with the State Government and CSIRO to provide public meetings and workshops in regional communities intended to provide access to information people can trust and to create a dialogue with regulators and exploration companies. The Western Australian industry believes that this partnership represents a proactive, innovative and responsible approach for delivering local background information to support national and international scientific studies.

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