19 March 2018

Dr Tom Hatton
Independent Scientific Panel Inquiry
Locked Bag 33
Cloisters Square
PERTH WA 6850

Dear Dr Hatton

RE Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia 2017

The Chamber of Minerals and Energy of Western Australia (CME) welcomes the opportunity to provide comment for the independent scientific panel inquiry (Inquiry) into hydraulic fracture stimulation in Western Australia (WA). This Inquiry, announced on 5 September 2017, is being conducted by a panel under section 25 of the *Environmental Protection Act 1986* in response to an election commitment by the new WA Labor Government to impose a hydraulic fracturing moratorium on most of Western Australia[1]. The recommendations from the Inquiry are to be used by the new WA Labor Government to inform future policy.

CME is the peak resources sector representative body in WA and is funded by its member companies who are responsible for most of the State's mineral and energy production and are major employers of the resources sector workforce in the State. This include members with petroleum interests who have been, or may be in future, involved in the extraction of unconventional gas through hydraulic fracture stimulation.

Western Australia has already completed a Parliamentary Inquiry into the "Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas"[2]. CME made a submission to this 2013-2015 Parliamentary Inquiry which is attached for your reference. The recommendations from this previous submission are still relevant for the current Inquiry, namely:

- R1: Ensure the regulatory environment is conducive to the sustainable development of Western Australia's unconventional gas resources.
- R2: Recognise current Western Australian regulatory philosophy remains best practice.
- R3: Recognise regulation and industry best practice minimise the impact on current and future uses of land, and implement the Multiple Land Use Framework.
- R4: Recognise current regulations and industry best practice standards for chemicals used in hydraulic fracturing are adequate.
- R5: Recognise the interaction between groundwater resources and hydraulic fracturing is adequately managed by current regulations and industry best practice standards.
- R6: Recognise full and safe land reclamation and rehabilitation is standard practice and a regulated activity.

CME supports the submission being made by the Australian Petroleum Production and Exploration Association Limited (APPEA) for this Inquiry[3]. APPEA's submission provides a detailed review of WA's oil and gas sector, the history of the industry specifically in WA, the existing WA regulatory environment and potential impacts and their mitigation in WA.

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[1] The new WA Labor Government imposed a ban on hydraulic fracturing in the Perth, Peel and South West regions in addition to a moratorium on all other areas of WA. The defined ban region is not subject of the Inquiry.

[2] The report from the 2013-2015 Parliamentary Inquiry is available at: http://www.parliament.wa.gov.au/Parliament/commit.nsf/(Report+Lookup+by+Com+ID)/74E61E739E39E57748257EF9002150FE/$file/ev.fra.151117.rpf.042.xx.pdf

[3] APPEA Submission dated March 2018.

As documented in APPEA's submission, potential impacts associated with hydraulic fracturing (a practice which has occurred in WA since the 1950s) are well understood and can be adequately managed through good regulation. The Inquiry's own publication "The Regulatory Environment"[4] as well as APPEA's submission provide an up-to-date summary of WA's regulatory regime, demonstrating its robustness and best practice features.

As demonstrated by APPEA's submission and from past inquiries (including WA's 2013-15 Parliamentary Inquiry) the science indicates that, with appropriate monitoring and robust and transparent regulation in place, unconventional gas resources can be developed safely and effectively in WA.

Should you have any further queries on the above matters, please contact Bronwyn Bell, Manager – Natural Resources, on [redacted]

Yours Sincerely

Nicole Roocke
Deputy Chief Executive

Attachments:

Submission for the Chamber of Minerals and Energy Western Australia to Parliamentary Inquiry into the Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas

[4] Available at: https://frackinginquiry.wa.gov.au/sites/default/files/3_regulatory_environment.pdf

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

Submission for the Chamber of Minerals and Energy Western Australia

September 2013

The Chamber of Minerals & Energy of Western Australia [redacted]

CONTENTS

Acronyms

BCM	Billion Cubic Metres
CSG	Coal Seam Gas
DMP	Department of Mines and Petroleum
EPA	Environmental Protection Agency
Gj	Giga joules
Ml	Megalitres
MMBTU	Million British Thermal Units
TCM	Trillion Cubic Metres
Tj	Tera- joules

Executive Summary

The Parliament of Western Australia Standing Committee on Environment and Public Affairs (the 'Committee') has commenced an inquiry into the implications for Western Australia of hydraulic fracturing for unconventional gas (the 'Inquiry').

The Committee has identified the following specific issues it will investigate as part of the Inquiry:

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

The Committee has invited written submissions to the Inquiry from interested persons, which are to be submitted to the Committee by 20 September 2013. The Chamber of Minerals and Energy Western Australia has been granted an extension by the Committee to 4 October 2013.

This submission to the Inquiry provides information and comment to the Inquiry in four parts. Firstly, the submission provides important factual information pertaining to the geological, geographical, social, environmental and economic context in which hydraulic fracturing would take place in the development of a future unconventional gas industry in Western Australia.

Secondly, the submission provides a fact based discussion on the four key issues that are being addressed by the Inquiry, as outlined above.

Thirdly, the submission discusses the extent to which the current regulatory framework and industry best practice for hydraulic fracturing of unconventional gas wells in Western Australia is appropriate and effectively manages risk.

Finally, the submission makes a series of recommendations to the Inquiry, summarised below:

R1: ensure the regulatory environment is conducive to the sustainable development of Western Australia's unconventional gas resources

The Western Australian Government should ensure the regulatory environment pertaining to the development of Western Australia's shale and tight gas resources is transparent, efficient and does not create any unnecessary obstacles to the environmentally and socially responsible development of Western Australia's shale and tight gas resources.

R2: recognise current Western Australian regulatory philosophy remains best practice

The existing processes used by the Department of Mines and Petroleum for assessing and managing the occupational health and safety, environmental and resource management risks associated with the development of Western Australia's unconventional gas resources are best practice, providing industry with a robust and practical approvals and project management framework.

R3: recognise regulation and industry best practice minimise the impact on current and future uses of land, and implement the Multiple Land Use Framework

The source of impacts on current and future land uses is the overall unconventional gas development process, rather than the hydraulic fracturing process itself. Current regulation, conventional negotiation processes and industry standards ensure a consultative approach is undertaken with relevant

stakeholders and that land use impacts from unconventional gas developments are optimally minimised.

R4: recognise current regulations and industry best practice standards for chemicals used in hydraulic fracturing are adequate

Western Australian regulations mandate full disclosure of the chemical composition of hydraulic fracturing fluids. This represents best practice. In addition industry standards relating to the minimisation of chemicals used in hydraulic fracturing fluids are also considered best practise.

R5: recognise the interaction between groundwater resources and hydraulic fracturing is adequately managed by current regulations and industry best practice standards

Risk of depletion or contamination of groundwater resources from hydraulic fracturing activities is substantially mitigated by competent well design and construction and best practice fracturing fluid and flow-back water management and handling systems. The case for recycling groundwater used in the hydraulic fracturing process should continue to be assessed on a case-by-case basis, based on the content of the flow-back water, local climatic and hydrogeological settings and project economics.

R6: recognise full and safe land reclamation and rehabilitation is standard practice and a regulated activity

The safe and secure decommissioning of petroleum wells and the restoration of land to its natural state or a form suitable for other productive purposes (such as agriculture) has been standard industry practice for many years and is a condition of production licenses.

The Chamber of Minerals and Energy Western Australia

The Chamber of Minerals and Energy of Western Australia (CME) is the peak resources sector representative body in Western Australia.

Having been in operation since 1901, the role of CME is to champion the Western Australian resources sector (minerals and petroleum) and assist it in achieving its vision to lead the world in sustainable practice through innovation and to underpin Australia's position in the global economy.

CME strives to be a persuasive industry voice, adding value to our member companies in a dynamic and increasingly complex operating environment.

In order to achieve this, CME strives to:

- Lead policy development on issues impacting on the resources sector;
- Promote the value of the sector to the community;
- Represent the views and advocate the needs of our members; and
- Provide an avenue through which members and stakeholders are able to collaborate.

With policy expertise spanning industry and research activities, occupational safety and health, education and training, the environment, exploration, Aboriginal affairs, workforce development, infrastructure, economics and tax, CME provides stakeholders and members with an avenue for undertaking extensive collaboration on all industry matters.

The Western Australian resources sector is diverse and complex covering exploration, processing, downstream value adding and refining of over 50 different types of mineral and energy resources. Besides being the largest private employer in regional and remote Western Australia, the sector is also the largest private sector employer of indigenous Australians.

CME represents companies directly involved in the resources sector or those providing services to it. CME's member companies generate 95 percent of all mineral and energy production by value and employ more than 80 percent of the resources sector workforce in the state.

CME's member companies are the foundation of its operation with their valuable contributions helping to build and prioritise the organisation's agenda. Their efforts and expertise enables CME to lead policy development on issues impacting on the resources sector and promote the sector's value to Western Australian and national communities.

CME produces a range of publications, including the State Growth Outlook, the third iteration of which was released at the end of 2012, and is referenced in this submission. The State Growth Outlook provides data on the expected demand arising from growth in the resources sector through to 2023, where possible identifying implications for international competitiveness, government investment and planning and liveability. CME will be releasing the next iteration of the State Growth Outlook, which will provide updated forecasts, in 2014. A copy of the 2013 State Growth Outlook is attached and available at www.cmewa.com.

The Potential for Development of Unconventional Gas in Western Australia

What is Unconventional Gas?

Conventional versus Unconventional Gas Resources

Historically, natural gas has only been technically and/or economically recoverable from conventional resources, which are geological reservoirs comprised of sandstone or carbonate rocks that by virtue of their natural porosity and permeability, allow contained natural gas to flow freely into a well drilled into the reservoir. Unconventional natural gas resources, on the other hand, are geological formations comprised of rocks that lack natural porosity and permeability and as such require hydraulic stimulation to assist the contained natural gas to flow to the well.

The natural gas produced from unconventional resources is comprised primarily of methane (CH_4), with smaller components of ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). This is the same naturally occurring hydrocarbon gas produced from conventional resources.

Key Technologies Used in the Development of Unconventional Gas Resources

The technical and economic feasibility of recovering natural gas from unconventional resources at a large scale has been rendered possible over the past two decades by advancement in a number of technologies including micro-seismic imaging, horizontal drilling and multi-stage hydraulic fracturing[1].

Types of Unconventional Gas Resources

The term 'unconventional' refers collectively to three different types of gas:

- **Coal Seam Gas**
  Known in other parts of the world as Coalbed Methane, Coal Seam Gas (CSG) is natural gas contained in the solid matrix of naturally occurring coal seams. The unconventional gas industry in Queensland and New South Wales has revolved around CSG resources. The solid matrix of a coal seam is typically less dense than that for shale and tight gas resources and as such, CSG resources do not always require flow stimulation intervention. Western Australia is currently not prospective for CSG.

- **Shale Gas**
  Shale gas is natural gas contained within a commonly occurring rock classified as shale. Shale formations are rich in organic matter and are often (but not always) the source of gas that is trapped in conventional reservoirs. Due to the fine grained nature of the original sediments, shale formations are characterised by low permeability and porosity. As such, wells drilled into shale gas resources typically experience sub-economic flow rates without the assistance of stimulation technologies, primarily hydraulic fracturing. A future Western Australian unconventional gas industry will likely revolve around deep shale gas resources.

- **Tight Gas**
  Tight gas is a general term used to describe natural gas hosted by other rock formations characterised by low permeability and porosity which cannot produce economically without flow stimulation technologies. Western Australia has tight gas resources.

[1] Editor (2013), ' Unlocking the potential of unconventional gas', *Pipeline and Gas Journal,* March Edition

Process for Development of Unconventional Gas: An Overview

Hydraulic Fracturing and its Application in the Development of Unconventional Gas Resources

Because shale gas and tight gas formations are characterised by low permeability and porosity, they almost always require the application of a flow stimulation method known as hydraulic fracturing to facilitate economic recovery of the contained gas. Hydraulic fracturing, or 'fraccing', as it is commonly referred to, is a process designed to increase the total amount of hydrocarbon that can be recovered from a resource and the rate at which the hydrocarbon is recovered.

As the facilitation of hydraulic fracturing needs to be factored into the design and construction of a well, the decision to hydraulically fracture a well is typically made prior to well development based on the interpretation of geological and geophysical data generated during the exploration phase of the project. The well design and the fracturing process are based on extensive modelling of the formation and the proposed hydraulic fracturing process.

In all wells, a combination of steel casing and cement in the well provides an essential barrier to ensure high-pressure gas or liquids from deeper down the well cannot escape into shallower rock formations or aquifers. In a well that is to be hydraulically fractured this barrier is designed to withstand the cycles of stress the well will endure throughout the hydraulic fracturing process.

As with conventional wells, wells used for hydraulic fracture stimulation will have the steel casing perforated at intervals down the well. These perforations are conducted at significant depths within the well and are positioned according to geotechnical studies that have determined the geological formations requiring fracturing.

The proper sealing of annular spaces with cement creates a hydraulic barrier to both vertical and horizontal fluid migration. These barriers are verified by geophysical logs such as Cement Bond Logs (CBL) and Variable Density Logs (VDL) and by pressure testing during and after any well activity to ensure seals and barriers are effective.

Once the well has been installed and tested, the hydraulic fracturing process involves pumping hydraulic fracturing fluid, which is comprised primarily of water and sand (which acts as a proppant) with a very small portion of chemical additives (see Regulation of Chemicals section) down the well at pressures typically in excess of 8,000psi[2]. This causes the hydraulic fracturing fluid to enter the geological formation through the perforations in the well casing, fracturing the shale formation directly surrounding the well, with fractures that are typically between two and six millimetres wide. These fractures increase the surface area exposed within the formation.

When the injection process is complete a portion of the fracturing fluid (primarily the proppant) remains *in-situ*, where it serves to hold the fractures open and as a vector for the contained gas to flow to the well. Excess fracturing fluid returns to the surface as 'flow-back' where it is captured, treated and processed for re-use (see Use of Groundwater in Hydraulic Fracturing section).

In most unconventional well development a common hydraulic fracture stimulation technique known as multi-stage hydraulic fracturing is used. Multi-stage hydraulic fracturing involves a series of fractures created at set intervals, one after the other, approximately every 100 metres along a horizontal well bore.

[2] Hunter, T. (2011), *Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia: An Analysis of the Capacity of the Petroleum and Geothermal Energy Act 1967 (WA) to Regulate Onshore Gas Activities in Western Australia,* Bond University

In some instances operators may elect to repeat the hydraulic fracturing process several years later in the life of a producing well through a process known as re-fracturing. This is more common in vertical wells than in horizontal wells, for example less than 10 percent of horizontal shale-gas wells in the United States requiring re-fracturing[3].

History of Hydraulic Fracturing

Worldwide, hydraulic fracturing has been a standard operational practice for the conventional oil and gas industry since the late 1940s[4], although its application has increased dramatically over the past decade as a result of the development of unconventional resources, particularly in the United States, and advances in horizontal drilling technology. It is estimated that since it was first used in a commercial application in 1947, there have been over 2.5 million hydraulic fracturing operations conducted worldwide on conventional and unconventional resources[5]. In the United States thousands of unconventional wells are hydraulically fractured every year[6].

Hydraulic fracturing has been widely used in Australia by the geothermal and gas industries. Hydraulic fracturing to stimulate petroleum flow from a formation from an onshore well has been conducted in most states of Australia, with the most significant activity undertaken in Queensland and South Australia.

Hydraulic fracturing for the purposes of stimulating CSG wells has been carried out mostly in New South Wales and Queensland since the 1990s. Since exploration began in the Cooper Basin in South Australia, over 700 oil and gas wells have been hydraulically fractured. A reasonable number of these wells would be classified as tight gas. Hydraulic fracturing in the Cooper Basin has occurred without incident.

In Western Australia, hydraulic fracturing has been used extensively to assist with the recovery of gas from conventional resources with an estimated 800 wells having been hydraulically fractured since 1958[7]. Indeed, the micro fracturing process has been utilised to recover oil reserves from the environmentally sensitive Barrow Island since the 1970s[8]. As an A Class reserve, Barrow Island has the highest environmental regulations in the state, and industry activity there has been conducted safely and responsibly for many years.

The use of hydraulic fracturing to stimulate flow from shale and tight gas resources in Western Australia is less common due to the lack of development of these resources in Western Australia to date. Nevertheless, hydraulic fracturing operations have been undertaken in Western Australia for the past 50 years without incident.

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[3] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

[4] CSIRO (2012), *What is Hydraulic Fracturing*

[5] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

[6] Editor (2013), ' Unlocking the potential of unconventional gas', *Pipeline and Gas Journal,* March Edition

[7] Department of Mines and Petroleum, *Gas Fact Sheet: Hydraulic Fracture Simulation,* Government of Western Australia

[8] Department of Mines and Petroleum, *Gas Fact Sheet: Hydraulic Fracture Simulation,* Government of Western Australia

The Development Environment for Coal Seam, Shale and Tight Gas is Different

In assessing the impact of the development of unconventional resources, it is critically important to make the distinction between the CSG resources which have been the focus of development in Queensland and New South Wales, and Western Australia's shale and tight gas resources.

The key differences are summarised in Table 1 below.

Characteristics	Implication for CSG	Implication for Shale and Tight Gas
Porosity/Permeability	**Relatively more permeable and porous.**	**Relatively more dense formations**
Water Production	**Naturally occurring water has to be removed from the coal seam for gas to be produced.**	**Water has to be pumped into the formation to effect hydraulic fracturing.**
Depth	**Occur at relatively shallow depth (100 to 1,000 metres).**	**Occur at relatively deep depth (1,000 to 3,000 metres).**

TABLE 1 - KEY DIFFERENCES BETWEEN COAL SEAM GAS AND SHALE GAS DEVELOPMENT

The Nature of Unconventional Gas Resources

Global Unconventional Gas Resources

It is estimated the world's total technically recoverable natural gas resources equate to approximately 692 TCM, of which unconventional resources account for almost 40 percent, approximately two thirds of which are shale gas resources. This is illustrated in Figure 1below.

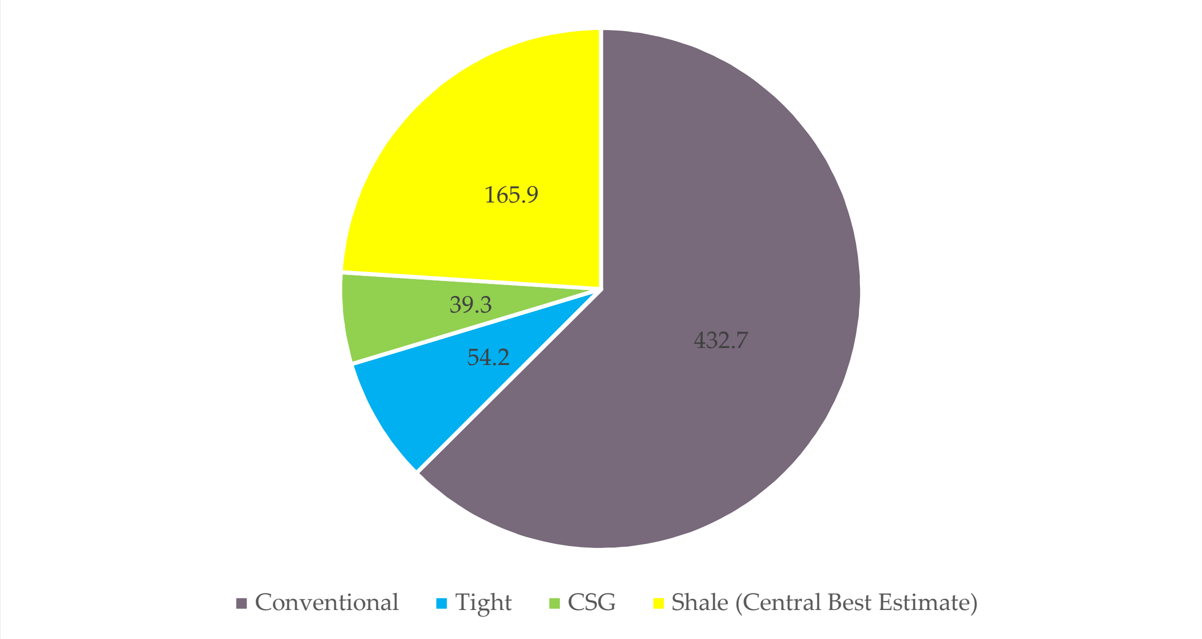

FIGURE 1 - GLOBAL RESOURCES OF TECHNICALLY RECOVERABLE CONVENTIONAL AND UNCONVENTIONAL GAS (TCM) [9]

Shale is ubiquitous in sedimentary basins. As shale is typically drilled through in conventional resource exploration and development, the main organic-rich shale have been identified in most regions of the world. Furthermore, in most cases there is adequate knowledge pertaining to the geological history of existing organic-rich shales to identify which shales are likely to contain gas. However, the precise volume of shale and tight gas and its recoverability is relatively unknown in many regions, including in Western Australia. In this sense the exploitation of shale and tight gas resources around the world is less of an exercise in exploration and more an exercise in field development and engineering.

[9] McGlade, C., Speirs, J. and Sorrell, S. (2012), *Unconventional Gas – A Review of Estimates,* Imperial College Centre for Energy Policy and Technology

As illustrated in Figure 2 below, known technically recoverable unconventional gas resources comprise a significant component of the total natural gas resources in many regions.

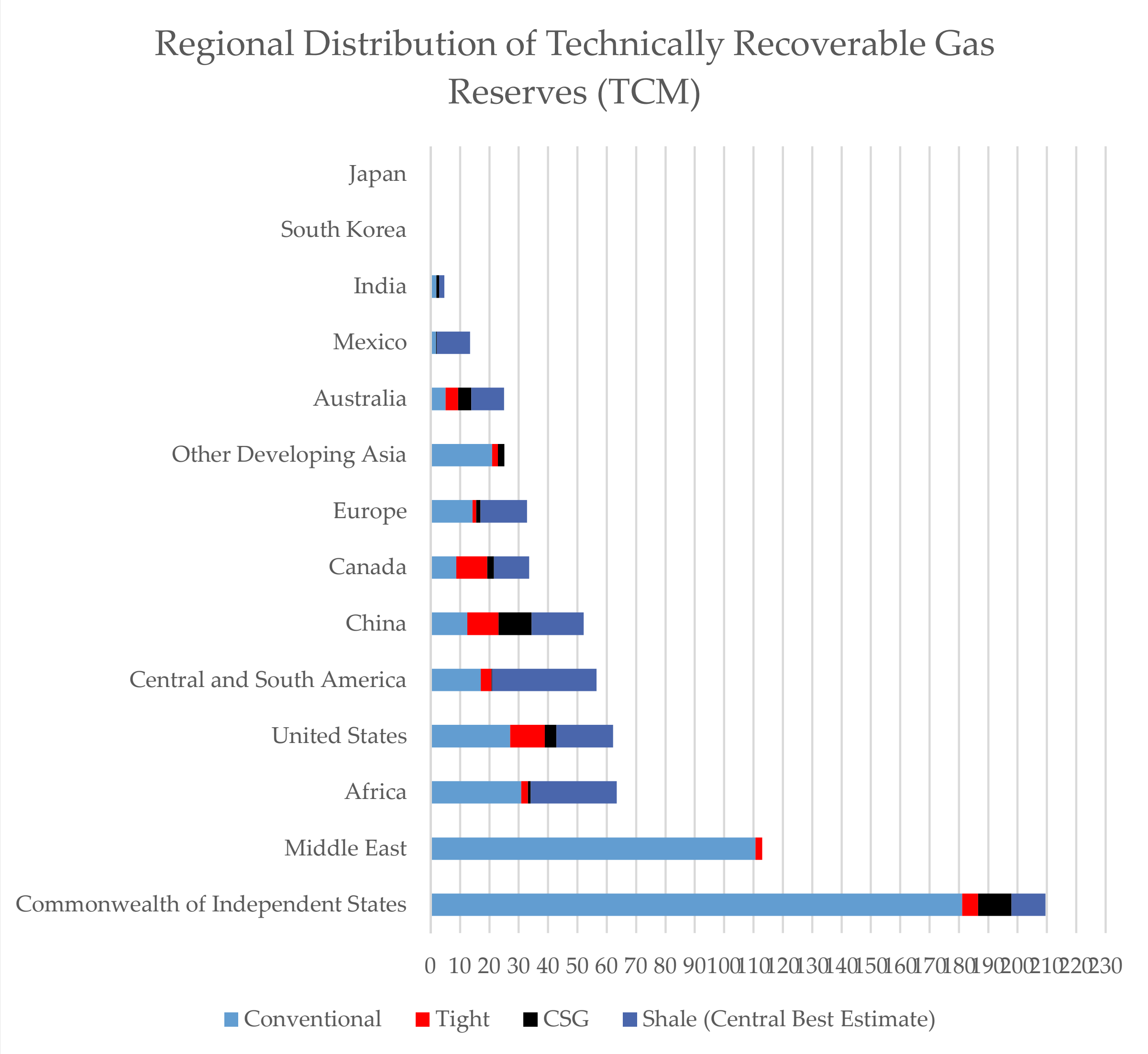

FIGURE 2 - REGIONAL DISTRIBUTION OF CONVENTIONAL AND UNCONVENTIONAL GAS RESOURCES (TCM) [10]

Profitable production of shale gas was pioneered in the United States in the 1990s by the successful extraction of gas from the Barnett Shale Formation in Texas. Rapid development of shale gas resources in the United States saw shale production in the United States grow from 36.2 BCM in 2007 to 223.8 BCM in 2011.[11].

The total shale gas resource in the United States is estimated to be 24.4 to 49.4 TCM. At current rates of production of about 0.6 TCM per annum, these reserves are adequate to provide a gas supply for

[10] McGlade, C., Speirs, J. and Sorrell, S. (2012), *Unconventional Gas – A Review of Estimates,* Imperial College Centre for Energy Policy and Technology
[11] U.S Energy Information Administration (2013), *Shale Gas Production, http://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm*

the next 41 to 82 years, with some estimates suggesting over 100 years[12]. This has and will continue to substantially reduce the United States' dependency on energy exports from other regions.

The dramatic impact the shale gas industry in the United States has had on energy security and cost for domestic residential and industrial energy consumers there has generated considerable interest in other nations, including Australia, to develop their own substantial unconventional resources.

Western Australia's Unconventional Gas Resources

Western Australia is not currently prospective for CSG. However, the Canning and Perth Basins in Western Australia are highly prospective for tight and in particular, shale gas. Indeed, Western Australia's onshore shale gas reserves are estimated to be 7.5 TCM, which is approximately double the State's known offshore conventional resources[13].

It is important to note the shale gas resources in the Canning and Perth Basins are deep, occurring at between 1,500 and 3,000 metres.

The Socio-economic Value of Western Australia's Unconventional Gas Resources

Unconventional Gas and Greenhouse Gas Emissions

Since the production of energy accounts for approximately 65 percent of current anthropogenic greenhouse gas (GHG) emissions[14], the composition of a jurisdiction's energy generation mix is a key determinant of that jurisdiction's GHG footprint.

Natural gas has the lowest carbon emissions content per unit of energy of all fossil fuels and is abundant, particularly in the form of tight gas and shale gas. It is expected to play an increasing role in the energy mix of most nations in the coming decades

Unconventional Gas Resources and Energy Security

Natural gas is important for the Western Australian economy, with it contributing substantially to power generation and projects which rely on natural gas as an energy resource. Given the importance of natural gas to the state, shale and tight gas presents an opportunity to diversify the state's supply base.

While the initial cost of unconventional gas is likely to be high, as fields are better defined and companies are prepared to make longer-term commitments to suppliers, then there are both an economy of scale as well as experiential cost reductions that will occur.

The development of unconventional gas resources around the world will substantially change natural gas markets and sovereign energy security dynamics. For example, as a result of increased supply of gas from unconventional production in the United States, the Henry Hub Gulf Coast Natural Gas Hub Spot Price has gone from a trading range of between US$5.00/MMBTU and $15.00/MMBTU in the first decade of this century to a range of between US$2.00 and US$5.00 in the first part of the second decade of this century. Most importantly, shale gas production in the United States has seen the natural

[12] Lior, N. (2011), 'Sustainable energy development with some game changers' , *The Energy Journal,* p1-16
[13] U.S Energy Information Administration (2013), *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States, EIA Statistics*
[14] International Energy Agency (2011), 'CO2 Emissions from Fuel Combustion', *IEA Statistics*

gas price break its long-standing linkage to the crude oil price[15], providing more stable and predictable energy costs for United States industry.

It is important to note the United States has a highly liquid and mature market, with a substantial transmission network and a variety of buyers and sellers (see figure 5 in following section). This contrasts to the market in Western Australia, which does not have the degree of market maturity as that of the United States.

The 2012 Energy White Paper[16] suggests consumers will benefit from further developing the gas market by increasing market liquidity, improving transparency and trading mechanisms, increasing customer numbers, adding injection points and storage facilities, and removing impediments to the development of new, onshore gas reserves.

Both the State and Commonwealth Government are undertaking initiatives to foster greater transparency and liquidity in domestic gas markets and CME is broadly supportive of efforts to further develop the state's gas market.

There have been concerns domestic gas supply may not meet demand in the near term. In 2011, the Department of Mines and Petroleum (DMP) forecasts suggested domestic supply could be tight from 2014 in its worst case scenario 'low supply' case, whereas in its 'high supply' case, gas supply is sufficient to meet demand. [17] This 'high supply' forecast includes a limited shale and tight gas supply, whereas in the low supply option, shale and tight gas is not considered.

More recently, the Independent Market Operator's (IMO) first gas statement of opportunities forecasts the state's domestic gas supply will annually grow by 3.7 percent and demand by 1.1 percent to 2022, suggesting domestic gas supplies will be adequate to meet demand. The report also forecasts the state's proved gas reserves will be sufficient to meet total gas demand, including demand for LNG production, through to 2022 and into the foreseeable future beyond that time.[18] As with all forecasting, some caution should be exercised, with the IMO forecasts dependent on projected domestic gas prices to 2022. The future domestic gas supply from all projects will ultimately be dependent on commercial negotiations. In addition, the IMO's high supply forecast excludes shale and tight gas completely due to the uncertainty over the timing of its development.

Sustainable Economic Development of the Kimberley Region

It is estimated in 2010-11, the Kimberley Region produced Gross Regional Product (GRP) of A$3.1 billion[19], which represents approximately 1.4 percent of Western Australia's 2010-11 Gross State Product (GSP) of approximately A$216 billion[20].

In 2011-12 the Kimberley Region had an estimated residential population of 38,850 people with that population growing at an average annual growth rate between 2007 and 2012 of 3.1 percent[21]. The

[15] United States Energy Information Administration IN: Hyland, L., Ladislaw, S., Pumphrey, D., Verrastro, F. and Walton, M. (2013), *Realising the Potential of U.S. Unconventional Natural Gas,* Center for Strategic and International Studies

[16] Australian Government, 2012. Energy White Paper 2012: Australia's Energy Transformation, Canberra.

[17] DMP, 2011. 'Western Australia's potential domestic gas demand and supply outlook', Petroleum WA, April 2011. Perth.

[18] IMO & National Institute of Economic and Industry Research, 2013. Gas Statement of Opportunities, July 2013. Perth.

[19] Kimberley Development Commission, Department of Regional Development and Lands

[20] Australian Bureau of Statistics Cat. 5220.0 Australian National Accounts: National Income, Expenditure and Product, Department of Treasury

[21] Australian Bureau of Statistics, 2011 Census

Kimberley Region is home to almost 25 percent of Western Australia's Aboriginal population, with approximately 40 percent of the Kimberley's population comprised of Aboriginal peoples[22].

In the September quarter of 2012, the unemployment rate in the Kimberley Region was 6.6 percent, compared to an average unemployment rate in Western Australia of 3.8 percent[23].

The sustainable development of an unconventional gas industry in the Kimberley represents an opportunity for economic and employment growth in the Kimberley, particularly for the Kimberley's significant Aboriginal population, not only through the production of gas, but also through the expansion of existing industry and the development of new industry that will result from a local, secure and cost competitive supply of energy. A study into the economic impact of the United States shale gas industry found that the growth in onshore gas and oil in the United States in recent times has created 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[24].

Unconventional Gas and State Government Revenue

The Government of Western Australia currently receives royalties from petroleum production equivalent to approximately $900 million per annum. This revenue will plateau as offshore production in Western Australia continues to move further offshore into Commonwealth Waters where it is exempt from State production royalties.

Western Australia's shale gas resources are entirely within State boundaries, allowing the State to receive full production royalties, which in accordance with the legislation are equivalent to 10 percent of the well-head value. This represents a potentially significant new source of revenue for the State.

The Economics of Development of Shale Gas in Western Australia

Because there has been limited development of shale and tight gas in Western Australia there is an absence of historical data on which to estimate capital and operating costs associated with the development of these resources. Nevertheless, in the context of contemplating regulation, it is important to understand the impact of any changes to regulation that result in additional cost may have on the economic viability of the State's shale and tight gas resources.

A recent study investigating the cost associated with drilling wells for unconventional gas in the United States[25] indicates there is considerable variability in costs both across and within different shale gas regions.

In Western Australia the costs associatesd with developing a shale gas field are high. Western Australia is generally a higher cost environment than the United States, particularly with respect to acquiring oil

[22] Western Australian Department of Education
[23] Australian Bureau of Statistics, 2011 Census
[24] HIS (2012), *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy,* Volume 1
[25] MIT (20121a) IN Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

and gas engineering services. For example, oil and gas industry contractor rates in Australia are the highest in the World and at least 25 percent higher than they are in the United States[26].

In addition, these high costs are exacerbated by the remote location of resources particularly the Canning Basin resources in Western Australia and the comparative absence of installed gas distribution infrastructure.

In this context, in Western Australia the current regulatory framework is adequate and encourages best practise in the industry. As such, additional regulatory burden will be costly and unlikely to result in better environmental outcomes. Regulation pertaining to the development of Western Australia's unconventional gas industry should ensure it does not create unnecessary additional costs for the industry.

[26] Hays (2012), *The Oil and Gas Global Salary Guide 2012: Global Trends and Recruiting Trends*

How Hydraulic Fracturing may Impact on Current and Future Land Uses

For reasons discussed in previous sections of this submission, the process of hydraulic fracturing associated with the development of Western Australia's shale and tight gas resources itself will have limited impact on current and future land uses.

The purported risks, that might arise from the hydraulic fracturing process ,of contamination of multiuser freshwater aquifers that could arise from poor well design and/or construction and micro-seismic activity impacting on current land uses are negligible and are effectively managed through regulation and ongoing monitoring.

The main potential for land use conflict is expected to arise from the overall unconventional gas development process and footprint. However, industry applies best practise principles in its engagement with land users, through early, timely and transparent consultation with land users. Practises such as these can mitigate the potential for, and prevent, conflict situations.

Micro-seismic Activity

The purpose of hydraulic fracturing is to crack rocks beneath the surface. As such, by its very nature, it results in a very small seismic event typically several magnitudes too small to be felt at the surface. Indeed operators use data to avoid seismic faults where possible, and use specially developed micro-seismic monitoring equipment to determine the effectiveness of a fracturing process.

Larger seismic events have occurred where the well or fractures happen to intersect with an existing geological fault and as a result, reactivate that fault. Such an event occurred as the result of a hydraulic fracturing operation at Cuadrill near Blackpool in the United Kingdom, where a small discernible earthquake of approximately 2.0 on the Richter-scale was detected. This event did not result in any surface damage.

Given the relative tectonic stability of Western Australia's geology, larger seismic events are unlikely to be a concern. Similarly the remote location where most of Western Australia's unconventional gas development is likely to take place further mitigates the risk of damaging seismic events.

The Unconventional Gas Development Footprint

Since the formations that host unconventional gas resources are typically more diffuse than the reservoirs that contain conventional gas resources, a larger number of wells are typically required to recover the gas. This results in a scale of industrial activity (typically drill pads, drilling equipment, storage vessels, pipelines and roads) per volume of recovered gas that is typically larger than is the case for conventional gas production[27]. However the footprint for shale and tight gas activities is smaller than that for CSG. In addition, due to significant advances in horizontal drilling technology, a field's footprint can be substantially reduced by drilling multiple wells from a single drill pad. For example, it was estimated in 2011 approximately 30 percent of new shale and tight gas wells in the United States and Canada were multiple wells drilled from a single pad[28].

While the overall footprint associated with the development of an unconventional gas resource can comprise a network of wells that covers a relatively larger geographical area, these well pads can be

[27] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

[28] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

located kilometres apart. In addition, technological advancements such as horizontal drilling and the drilling of multiple wells from a single well pad reduce and minimise the required land footprint.

A drilling rig, plus associated equipment and pits or vessels to store drilling fluids and waste will typically occupy an area of approximately 150 X 150 metres. Establishing drilling capability at a new location may require a number of truck movements to deliver all of the equipment. Substantially fewer truck movements will be required to service the well site through its lifecycle.

Once the development of the field is complete, the footprint and activity around the well site is substantially reduced. The drill mast is replaced by a production "Christmas Tree" within a small cleared and fenced area, which connects to a distribution pipeline. The "Christmas Tree" is rarely more than two metres in height and can be camouflaged to blend into the environment. Pipe lines connecting the Christmas Tree to the distribution network are typically subterranean. Some access roads will remain in place, but all other cleared land can be rehabilitated, enabling opportunities for sequential and multiple land use.

Land Use in the Context of the Development of Western Australia's Shale Gas Resources

The focus of the anti-fraccing movement on the east coast of Australia has been on rural conservation[29]. This has focused primarily on:

- Land use conflict with agriculturalists, who, unlike their United States counterparts do not have subterranean mineral and petroleum rights and as such are not compensated to the same degree for the development of unconventional resources that exist beneath their properties; and
- Potential contamination of land, surface water and freshwater aquifers as the result of product water from CSG wells (which as discussed in a previous section is very different to the water produced from shale gas wells).

In the case of potential shale and tight gas developments in Western Australia, legislation and regulations are in place which govern land access. In addition, industry employ best practice in their relationship building, communication and transparency.

In Western Australia the main types of land use will likely be:

- Aboriginal land use and Native Title;
- Pastoral grazing;
- minerals prospectivity;
- Alternate industries; and
- The natural environment.

Aboriginal land use and Native Title issues will be negotiated between the project proponents and Traditional Owners as part of existing regulation and processes, as is the case with any development. The impact on the pastoral grazing industry will be limited because the gas production facilities can be fenced, allowing for multiple land use. Additionally the footprint is small in comparison to the vast pastoral stations.

Land access arrangements should be built on co-operation, trust and high standards of behaviour. Transparency in land use planning decision-making is an essential enabler for effective relationships.

It is important to note that resource projects do not preclude or prevent other land uses. This is especially relevant to the shale and tight gas activities, where well pads and supporting equipment and

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[29] Wood, J. (2012), The Global Anti-Fracking Movement: What it Wants, How it Operates and What Next, Control Risk Group

infrastructure have a minimal footprint. There is also some flexibility in determining the well pad's location, with its positioning being assisted by the use of seismic position data. As a result, a variety of land users can coexist, or exist sequentially to the resource extraction.

In regards to the shale and tight oil and gas industry, CME believes there are enhanced opportunities for integrated land use arrangements. In particular, CME considers the Multiple Land Use Framework (MLUF)[30] as one such mechanism which, if implemented at a state and federal level with appropriate industry consultation, may have the potential to assist in developing a further understanding of the range of ways which different land users can harmoniously coexist.

The objective of the MLUF is to facilitate multiple and sequential land use outcomes by articulating common principles between land users, increase transparency in land use decisions, provide certainty to industry and improve community confidence in government land use decisions. The MLUF was endorsed by the Standing Council on Energy and Resources in December 2012.

[30] http://www.scer.gov.au/workstreams/land-access/mluf/

Regulation of Chemicals used in the Hydraulic Fracturing Process

As discussed in a previous section of this submission the process of hydraulic fracturing involves pumping large volumes of hydraulic fracturing fluid down a well at high pressures, where it enters the target formation through perforations in the well casing, causing fractures in the formation so the contained gas can flow freely to the well.

Fracturing fluid serves the following key purposes in the hydraulic fracturing process:

- Creation and maintenance of the fractures in the formation; and
- The placement of a proppant, carried by the hydraulic fracturing fluid, which keeps the fractures open and enables the gas to flow into the well, following the fluids removal.

Hydraulic fracturing fluid is comprised of water, sand and a small amount of chemical additive. The precise composition of hydraulic fracturing fluid and the chemical additives used is determined by the nature of the formation and the fracturing requirements. However, in all cases, the hydraulic fracturing fluid is comprised of between 97 and over 99 percent water, between 1-2 percent proppant (sand or ceramic material designed to keep the fracture open), and up to only 1 percent of chemical additives.

The chemical additives which collectively comprise approximately up to one percent of the total volume of the hydraulic fracturing fluid are designed to achieve the following:

- Ensure the proppant remains suspended in the fluid by gelifying the fluid while it is being pumped into the well and ensuring the proppant ends up in the fractures being created;
- Enable the properties of the fluid to change over time (for example, a more viscous fluid is more effective for the fracturing process, but once *in situ* a less viscous fluid enables the gas to flow more easily along the fractures to the well);
- Reduce friction and therefore reduce the energy required to inject the fluid into the well; and
- Reduce the risk naturally occurring bacteria in the water will affect the performance of the fracturing fluid or proliferate in the reservoir, producing hydrogen sulphide.

The chemical additive component of the fracturing fluid typically contains between three and twelve of the more common chemical additives described in Table 2 below. Individually, these chemicals typically comprise between 0.1 and 0.5 percent (by volume) of the hydraulic fracturing water[31].

Additive Type	Main Compound(s)	Purpose in the Fracturing Fluid	Other Common Uses of Main Compound
Diluted Acid (15%)	Hydrochloric Acid or Muriatic Acid	Helps dissolve minerals and initiate cracks in the rock	Swimming pool chemical and cleaner
Biocide	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive byproducts	Disinfectant used to sterilise medical and dental equipment
Breaker	Ammonium Persulfate	Allows a delayed breakdown of the gel polymer chains	Bleaching agent in detergent and hair cosmetics; manufacture of household plastics
Corrosion Inhibitor	N,n-Dimethyl Formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, acrylic fibres, plastics
Crosslinker	Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergents, hand soaps and cosmetics
Friction Reducer	Polyacrylamide and/or Mineral Oil	Minimises friction between the fluid and the pipe	Polyacrylamide is used in water treatment and as a soil conditioner; mineral oil is used as a makeup remover, in laxatives and in candy
Gel	Guar Gum or Hydroxyethyl	Thickens water in order to suspend the sand	Cosmetics, toothpaste, sauces, baked goods and icecream
Iron Control	Citric Acid	Prevents precipitation of metal oxides	Food additives, flavouring in food and beverages, lemon juice (7% citric acid)
KCl	Potassium Chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Oxygen Scavenger	Ammonium Bisulfate	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
pH Adjusting Agent	Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water, softener, glass and ceramics
Proppant	Silica, quartz sand	Allows the fractures to remain open so gas can escape	Drinking water filtration, play sand, concrete, brick mortar
Scale Inhibitor	Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, household cleansers, and de-icing agent
Surfactant	Isopropanol	Used to create the viscosity of the fracture fluid	Glass cleaner, antiperspirant and hair colour

TABLE 2 – TYPICAL CHEMICAL ADDITIVES USED IN HYDRAULIC FRACTURING FLUIDS[32]

Much of the controversy surrounding chemicals used in fracturing has focused on the use of the chemicals Benzene, Toluene, Ethylbenzene and Xylenes (commonly referred to as BTEX chemicals). New South Wales and Queensland have in place bans on BTEX compounds.

In Western Australia, environmental petroleum regulations are robust, and have the strongest chemical disclosure requirements of any Australian jurisdiction. In addition, as stated previously, chemical additives comprise a small fraction of the fracturing fluids. This significantly lessens its potential impact.

Until recently, the chemical composition of fracturing fluids was considered a trade secret and not made public in the United States. Since 2010, voluntary disclosure of the chemical content of fracturing fluid has become more or less standard practice in the United States unconventional gas industry[33].

The industry is continually looking for ways to reduce chemicals used in the fracturing fluid. ‘Slickwater’ comprised of water, proppant, simple drag-reducing polymers and biocide has become increasingly popular in the United States, albeit with the limitations that it needs to be pumped at higher rates and can carry only very fine proppant.

[31] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

[32] USDOE (2009) IN Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

[33] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

The Use of Groundwater in the Hydraulic Fracturing Process and the Potential for Recycling of Groundwater

Water Usage in Hydraulic Fracturing of Unconventional Wells

While hydraulic fracturing is used on occasion to stimulate flow from conventional reservoirs, shale gas developments almost always require the use of hydraulic fracturing to generate adequate flows into the well.

The associated use and release of water has resulted in water usage and management being one of the main environmental concerns associated with hydraulic fracturing in the unconventional gas industry[34].

In Western Australia, industry abides by a strict set of regulations and develops water management plans as part of a broader environmental plan. In doing so, companies effectively manage any risk associated with resource extraction and environmental impact, and operations are conducted in a safe and responsible manner.

Hydraulic Fracturing Water Usage Cycle

Water used in hydraulic fracturing can be sourced from surface water resources such as rivers, lakes or the sea, or from local boreholes which may draw from shallow or deep aquifers. Because road transportation of the large volumes of water required for hydraulic fracturing to a well site typically represents a substantial cost, sourcing water from a supply in close proximity to the well site is an important consideration in the economic viability of the well.

Most shale gas resources in Australia are either located within the arid or semi-arid zone where ground water systems will often be the only local source of water.

Waste water produced from the hydraulic fracturing process known as 'flow-back' (see next subsection) can be managed in a number of ways, including the following:

- Optimally, hydrocarbons (from the target formation), fracturing chemicals and other mineral contaminants from the target formation are separated out and the water is stored for re-use in a subsequent fracturing process, although this is not always an economically viable option;
- If available, the waste water can be treated through technologies such as reverse osmosis to remove impurities and return the water to a quality that enables it to be released to the environment;
- Waste water can be treated in appropriately lined evaporation ponds, similar to those used in the mining industry, with the residue appropriately removed and disposed of; and/or
- Appropriately treated waste water can be re-injected into deep geological formations.

To date most management plans have included the use of evaporation ponds and containment pits that are either lined or unlined. Spillage incidents involving this type of management system have typically been the result of unusually high or unexpected rainfall, poor pit/pond design and/or poor pit/pond construction. The risk of spillage resulting from an unusual weather event can be substantially mitigated

[34] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

by designing adequate free-board into the containment pond or pit, as is done routinely in hardrock mining applications. In some instances the use of sealed vessels may be the appropriate solution.

As there is a diverse range of climates in Western Australia, the appropriateness of a specific management plan will be dependent on the climatic and hydrogeological conditions in the region. As a consequence of the use of evaporation ponds and containment pits in the mining sector, extensive expertise exists in the state in this regard.

Composition of Backflow Water from Hydraulic Fracturing

Once the hydraulic fracturing is completed, some of the injected fluid flows back to the well as part of the production stream, with some remaining trapped in the treated rock. The flow-back period can occur over a couple of days for single-stage fracturing, to several weeks for multi-stage fracturing operations.

The total amount of fluid returned as ‘flow-back” depends on the geology. For shale the “flow-back” can represent 20 to 50 percent of the total volume of water injected, with the rest remaining bound to clays in the shale rock. Flow-back fluids from a shale fracturing process needs to be distinguished from the highly saline product water removed from CSG deposits prior to production of gas.

Flow-back water contains some of the chemicals used in the hydraulic fracturing process, together with metals, minerals and hydrocarbons that can be leached into the fluid from the shale formation. The precise composition of the flow-back water is a function of the composition of the initial fracture fluid and the geology and mineralogy of the formation. In some circumstances the flow-back water may contain constituents drawn from the hydrocarbon pool and the surrounding geological structures.

The precise composition of the flow-back water is a function of the specific characteristics of the formation targeted by the well and therefore risk should be assessed on a case-by-case basis.

Volumes of Water Used in Hydraulic Fracturing

Due to its relative density, the volume of water required to fracture shale strata can be greater than that for CSG. Conversely, by virtue of the absence of a need to de-water the formation, the volume of waste water produced during shale production is orders of magnitude less than the amount produced over the life of a CSG project. As such, it is unlikely shale gas operations will face the same waste water disposal or water draw down issues as CSG[35].

[35] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

Hydraulic fracturing can use between a few thousand and 20,000 cubic metres of water per well and as such efficient use of water during hydraulic fracturing is essential. Table 3 below compares the amount of water used per unit of natural gas produced between conventional gas, conventional gas with fracture stimulation, tight gas and shale gas.

	Minimum Water Consumption (m^3/Tj)	**Maximum Water Consumption (m^3/Tj)**
Conventional gas	0.001	0.01
Conventional gas with fracturing	0.005	0.05
Tight Gas	0.1	1
Shale Gas	2	100

TABLE 3 - TYPICAL WATER USAGE PER UNIT OF ENERGY PRODUCED - CONVENTIONAL, TIGHT AND SHALE GAS PRODUCTION[36]

Because shale gas production in Australia is in its infancy, the average volume of water needed to hydraulically fracture Australian shales in not yet accurately known. As an indication, Table 4 below summarises the median volume of water used per shale gas well in the United States up to 2011.

Shale Gas Play	**Volume of Water used (m^3)**
Barnett, Texas	10,600
Haynesville, Texas	21,500
Eagleford, Texas	16,500
Marcellus, Texas	17,100

TABLE 4 - AVERAGE WATER USEAGE PER WELL IN THE UNITED STATES[37]

[36] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

[37] Nicot Scanlon (2012 and Beauduy (2011) in Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

While water consumption associated with hydraulic fracturing is not insignificant, it is useful to place the water consumption of hydraulic fracturing in the context of other water users. In particular, water consumption associated with hydraulic fracturing is modest when set against the consumption in irrigated agriculture.[38] Table 5 below summarises the main water consumers by sector in the shale gas basins in the United States.

Shale Gas Basin	Public Supply	Industrial and Mining	Power Generation	Irrigation	Livestock	Shale Gas	Total Water Usage (billions m^3/annum)
Barnett	82.70%	4.50%	3.70%	6.30%	2.30%	0.40%	1.77
Fayetteville	2.30%	1.10%	33.30%	62.90%	0.30%	0.10%	5.07
Haynesville	45.90%	27.20%	13.50%	8.50%	4.00%	0.80%	0.34
Marcellus	11.97%	16.13%	71.70%	0.12%	0.01%	0.06%	13.51

TABLE 5 - WATER USE BY SECTOR IN THE UNITED STATES SHALE GAS BASINS[39]

Reducing water consumption associated with the fracturing process has been a major focus of innovation in the shale and tight gas industry. For example:

- Total pumped volumes can be decreased through the use of more traditional, high viscosity, fracturing fluids (using polymers or surfactants) but these require a complex mix of chemicals to be added;
- Foamed fluids, in which water is foamed with nitrogen or carbon dioxide with the assistance of surfactants can assist as 90 percent of the fluid can be gas and this fluid has very good proppant carrying properties
- Water can be eliminated altogether by using hydrocarbon – based fracturing fluids such as propane or gelled hydrocarbons. The fluid's flammability makes it more difficult to handle safely at the well site, and is an unlikely alternative to the elimination of water.

To date, the main source of water savings has been through recycling. For example, the average use of water during fracturing in the Eagleford play in west Texas has reduced from 18.5 thousand cubic metres to 13.6 thousand cubic metres since mid-2010, primarily as a result of recycling of waste water from flow-back of fracturing fluid[40].

[38] Nicot Scanlon (2012 and Beauduy (2011) in Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies
[39] Pearson, I., Zeniewski, P., Gracceva, F., Zastera, P., McGlade, C., Sorrell, S., Spiers, J. and Thonhauser, G. (2012), *Unconventional Gas: Potential Energy Market Impacts in the European Union,* JRC Scientific and Policy Reports
[40] International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

The Potential Sources and Likelihood of Groundwater Contamination Risk

Much of the global controversy surrounding the development of unconventional gas has focused on concerns about the potential for contamination of surface or groundwater resources.

Industry's focus upon well design and construction are best practise, and mitigate potential risks associated with the development of unconventional gas resources. The potential risks listed below are not specific to the development of unconventional gas resources, and demonstrate the proactive approach by industry in Western Australia to address these potential risks:

- **Surface water contamination**
  Surface water contamination is linked to the management of flow-back water. If flow-back water is not sufficiently contained, there is a possibility that run-off from a pond in a storm event or higher than normal rainfall may result in overflow of evaporation ponds. This water then contaminates other water sources through runoff. Climatic and hydrological studies assess the risk of contamination from surface water runoff, with industry utilising best practise in the design and construction of water storage to mitigate any risks identified.

- **Groundwater Contamination**
  Where unlined evaporation ponds are used, there is a risk that contaminants may enter the groundwater system, contaminating groundwater sources. In New South Wales, evaporation ponds have been banned for this reason. However, this risk is substantially mitigated through appropriate design, construction and lining of evaporative ponds. It is important to note in Western Australia, industry employ best practise, and regularly line ponds.

- **Fracturing Effect on Aquifers**
  Perhaps the most controversial issue surrounding fracturing is the hazard of penetrating surrounding aquifers, thereby contaminating the aquifers. This occurred with fracturing activity associated with operations in the Marcellus Shale formations in the eastern United States, where some of the thin shale formations are in close proximity to aquifers that are a source of drinking water for communities in the State of New York. It is important to note however, in Western Australia shale formations are at great depth and are not in close proximity to water aquifers, mitigating this risk. In addition, industry conduct stringent ongoing monitoring throughout the life of the well.

In New South Wales and Queensland, there have been concerns CSG activities are leading to marked depletion of aquifers in prime agricultural regions, especially in the Gunnedah and Bowen/Surat Basins[41]. Produced water from CSG is significantly different to that produced from shale gas. Water produced from coal seams is generally briny as a result of the salts in the coal formations. Furthermore, when fracturing is undertaken on CSG formations it is used to assist in dewatering the coal seams[42], and Western Australia is not currently prospective for CSG.

Australian companies conducting hydraulic fracturing utilise best practise in the design and construction of wells. This proactively prevents acquifer penetration and any subsequent contamination. In addition, aquifer penetration in the Perth and Canning Basins in Western Australia is highly unlikely since the shale formations are at great depth (over 2,000 metres), are generally thick (over 100 metres) and are distant from aquifers.

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[41] Hunter, T. (2011), *Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia: An Analysis of the Capacity of the Petroleum and Geothermal Energy Act 1967 (WA) to Regulate Onshore Gas Activities in Western Australia,* Bond University
[42] Queensland Department of Environment and Resources Management (2010), *Coal Seam Gas Water Management Policy*

Indeed, research into the geomechanics of fracturing has demonstrated no contamination of drinking water aquifers from thermogenic gas as result of fracturing outside of target formations. Instead aquifer contamination has been confined to poor well design and cementing rather than overstimulation of a well leading to fracturing beyond the target formation into drinking water aquifers[43].

As noted above, an industry focus upon well design and construction best practise is important in risk reduction. The risk to groundwater from properly managed wells is negligible. For example, in 2011, the Massachusetts Institute of Technology (MIT) examined 43 widely-reported onshore gas well drilling incidents which occurred on the mainland United States between 2005 and 2009. They found no conclusive evidence that shallow water zones had been contaminated with hydraulic fracturing fluids during any of these incidents[44]. Another study in 2011 examined more than 33,000 wells drilled and completed in the State of Ohio between 1983 and 2007, identifying 185 (0.006 percent) groundwater contamination incidents (more than 80 percent of which occurred during the 1980s and 1990s before modern technology and regulations were in place) and found that none of the identified incidents were the result of hydraulic fracturing[45].

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[43] Osborn, S., Vengosh, A., Warner, N. and Jackson, R. (2011), 'Methane contamination of drinking water and accompanying gas well drilling and hydraulic fracturing', *Proceedings of the National Academy of Sciences 14 April*

[44] United States Department of Energy (2006), *Energy Demands on Water Resources*

[45] Kell, S. (2011), *State Oil and Gas Agency Groundwater Investigations and their Role in Advancing Regulatory Reforms: A Two State Review of Ohio and Texas,* Groundwater Protection Council, United States

As summarised in Table 6 below, water contamination risks can be substantially mitigated through standard industry operating practices. Indeed, separate studies undertaken by the Australian Council of Learned Academies[46] and The Royal Society of Engineers[47], both concluded the environmental health, safety and environmental risks, including groundwater contamination can be managed effectively if existing best practice is followed. The industry remains committed to following best practice to mitigate these risks.

Risk	Mitigation Practice
Backflow water surface spill	Rigorous fluid containment systems and practices that are appropriate for the climatic and hydrogeological environment in which the development is taking place.
Fracturing effect on aquifers	Mitigating the risk of leakage into shallow aquifers behind the well casing requires the use of best practice well design and well construction, particularly during the cementing process, to ensure a proper seal is in place, systematic verification of the quality of the seal and ensuring the seal does not deteriorate through the life of the well. This is a particular issue for wells in which multi-stage fracturing is performed as the repeat cycles of high pressure pumping can apply repeated stress to the casing and to the cement column, potentially weakening them.

TABLE 6 – WATER CONTAMINATION RISK MITIGATION

[46] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J. (2013), *Engineering Energy: Unconventional Gas Production: A Study of Shale Gas in Australia,* Australian Council of Learned Academies

[47] Royal Academy of Engineers (2012), *Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing,* The Royal Society, United Kingdom

The Reclamation (Rehabilitation) of Land that has been Hydraulically Fractured

The recovery profile from shale gas wells is typically very different to conventional wells. Where a conventional well will typically produce for 30 years or more, output from a shale gas well can be highly variable with recoverable gas extracted after just a few years in some cases[48] to wells that produce for up to 20 years in other cases.

Abandonment Decommissioning of wells involves cementing and capping to ensure they are not a threat to water systems or lead to gas emissions. A decommissioning plan needs to be considered in the original well design, and ongoing monitoring of abandoned wells is undertaken as standard practice. There are standard and regulated processes that have been used for many years for resealing an oil and gas well once production is finished. Modern practices include filling the well with cement and capping it at the surface in accordance with plans approved by the regulator. The natural pressure of surrounding rock also provides an effective mechanism to seal around the cement filled casing over long periods of time.

The key issue is the long term prevention of leaks from an abandoned well to the surface or aquifers. This risk is managed through the regulatory framework to ensure the companies concerned make the necessary financial and/or insurance provisions, and maintain technical capacity beyond the field's economic life to ensure decommissioning is completed satisfactorily and well integrity is maintained over the long-term.

[48] IEA 2009 in International Energy Agency (2012), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*

The Current Regulatory Regime is Robust

Regulation of Unconventional Gas Production in Western Australia

The Legislative Framework

The Western Australian Government agency principally responsible for the regulation of all petroleum activities, including hydraulic fracturing of unconventional gas resources, within State boundaries is the Department of Mines and Petroleum (DMP).

The DMP's main instrument of regulation of onshore petroleum activities is the *Petroleum and Geothermal Energy Resources Act* 1967 (WA) (the 'Act') and the regulations covering occupational health and safety, environment and resource management and administration of the Act. The legislative framework for the development of unconventional gas and associated hydraulic fracturing operations in Western Australia is illustrated in Figure 3 below.

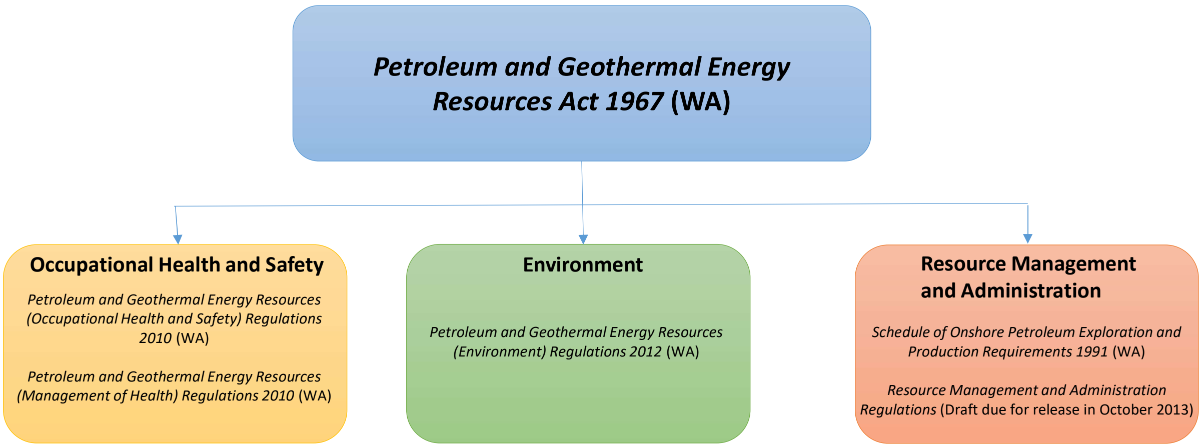

FIGURE 3 - WESTERN AUSTRALIAN LEGISLATIVE FRAMEWORK FOR UNCONVENTIONAL GAS DEVELOPMENT

The *Resource Management and Administration Regulations*, a draft of which is due in October 2013 will present an outcomes-based approach to regulating issues such as well integrity.

In certain prescribed circumstances (see next subsection) the *Environmental Protection Act 1986* (WA) and the Environmental Protection Authority (EPA) also perform a regulatory role and where the specific development involves the installation of gas transmission pipelines, the *Petroleum Pipelines Act 1969 (WA)* provides additional regulatory obligations.

Unlike CSG operations, the development of a shale or tight gas resource does not automatically trigger the provisions of the *Environmental Protection and Biodiversity Conservation Act* 1999 (Cth), unless the development potentially impacts on an environmental asset of national significance. This means Western Australian shale gas developments are not automatically subject to the separate and largely duplicated Commonwealth approvals processes that the Eastern States CSG industry faces through the 'Water Trigger' amendments passed earlier this year.

The Legislative Framework in Practice

Unconventional gas project proponents intending to undertake drilling and/or flow stimulation activities, including hydraulic fracturing, must acquire the same regulatory approvals as conventional gas project proponents intending to undertake the same activities.

To be eligible for regulatory approval, the project proponent must submit the following documents to the DMP for review and approval:

- Drilling Application;
- Reservoir Management Plan;
- Environmental Plan; and
- Safety Management Plan

With respect to a proposed hydraulic fracturing activity, the proponent must provide the DMP with detailed information on:

- The physical location, size and scale of the hydraulic fracturing program;
- The hydrogeological systems within the project area, including distances to the nearest aquifers;
- The volume of water that will be used, how water usage will be managed and how waste streams will be disposed of;
- Containment structures for flow-back water;
- All chemical additives used in fracture fluid including concentrations and toxicity
- Well integrity including casing and cementing design;
- Fracture modelling and process for the monitoring of the fracturing operation;
- Baseline monitoring; and
- Long-term monitoring for determining potential chemical contamination.

With respect to chemicals used in the hydraulic fracturing fluid, the following detailed information must be provided for each chemical additive:

- Product or additive trade name;
- Name of supplier;
- The additive's purpose;
- The additive's ingredients;
- The additive's Chemical Abstract Service (CAS) registry number;
- Maximum ingredient concentration in the additive;
- Maximum ingredient concentration in total fluid used;
- Material Safety Data Sheets; and
- Information pertaining to eco-toxicity.

Once the required documents are lodged with the DMP, the DMP undertakes a detailed assessment of the information provided. The DMP will then make an informed case-specific decision as to whether the activity is approved, and apply case-specific conditions to ensure that occupational health and safety standards are adhered to, any environmental impact or risk is minimised and managed, and natural resources, including water resources are adequately managed.

If the activity is proposed in or within 500 metres of an environmentally sensitive or Priority 1 water area, the proposal will be referred to the EPA. The DMP will also liaise with the EPA if the proposed activity is within two kilometres of a town site or the coastline, or is likely to impact a water resource area including a water reserve, water catchment area, groundwater protection area and declared or proposed water supply catchment area.

In circumstances where a proposal is referred to the EPA, the EPA will subsequently determine the level of assessment required under the *Environmental Protection Act 1986* (WA).

Based on this process, a decision will be made as to whether the activity may proceed, as well as any conditions that the proponent may be required to adhere to with respect to the activity. The activity and adherence to conditions is then monitored and enforced by the DMP.

Recent Review of Legislation and Regulations Pertaining to the Development of Unconventional Gas Resources in Western Australia

In 2011, an independent review was undertaken of the existing regulatory framework for the extraction of onshore shale gas resources in Western Australia[49]. The review was commissioned by the DMP and specifically examined the capacity of the *Petroleum and Geothermal Energy Resources Act 1967* (WA) to regulate shale gas exploration and production activities in Western Australia.

This report concluded the current DMP processes are adequate to ensure the management of risk across the environment, workforce safety and resource management results in minimisation of potential unwanted or adverse impacts. The report also recommended improvement in the legal enforceability of the DMP's current practices, including the requirement for the Environmental Plan to be made public, which includes details of the water management plan and chemicals used in the hydraulic fracturing process. These recommendations in part resulted in the expedited proclamation of the *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012* (WA) and the expedited drafting of the *Resource Management and Administration Recommendations.*

Industry Code of Practice

In addition to being governed by regulation, the unconventional gas industry in Australia subscribes to an industry-developed code of practice with respect to hydraulic fracturing.

The Australian oil and gas industry's peak national body, the Australian Petroleum Production and Exploration Association (APPEA) has developed, in conjunction with an industry working group, a code of practice for hydraulic fracturing based on established operating principles and leading practices in other jurisdictions that are relevant to local conditions:

1. **Community, landholder and stakeholder interaction**
   To ensure operators communicate openly and as early as practicable with landholders, local communities and other stakeholders, including explaining how risks are being managed to minimise an potential unwanted or adverse impacts

2. **Protection of Aquifers**
   To ensure well design and implementation practices include protection of aquifers or groundwater that may be accessed for commercial or residential water supply.

3. **Sourcing and use of Water**
   To protect and, where required, effectively and responsibly use groundwater resources.

4. **Use of Chemicals in Hydraulic Fracturing**
   To minimise the use of chemicals in hydraulic fracturing operations, to provide clear and accurate information on any chemicals that may be used, and promote the safe and responsible use of chemicals.

5. **Fluid flow-back and produced fluids containment**
   To ensure post-fracture stimulation clean-up, flow-back or produced fluids cannot come into contact with aquifers that may be accessed for commercial or residential water supply.

[49] Hunter, T. (2011), *Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia: An Analysis of the Capacity of the Petroleum and Geothermal Energy Act 1967 (WA) to Regulate Onshore Gas Activities in Western Australia,* Bond University

6. **Fugitive Emissions**
   To ensure the fugitive emissions from stimulated wells during flow-back and testing activities are minimised.

7. **Continuous Improvement**
   To ensure continuous performance improvement and the sharing of information with regulators and other stakeholders to reduce potential risks of hydraulic fracturing.

No Case for a Moratorium in Western Australia

Some jurisdictions around the world such as France, Luxembourg, Netherlands, Bulgaria, the Czech Republic and parts of Germany have placed moratoriums on the development of unconventional gas resources.

While in some cases these moratoriums may be politically motivated, in many cases the main concern of government is not that shale gas production presents inherent risk to the environment, but rather that the jurisdiction's existing environmental legislation is deficient with respect to regulating aspects of shale and tight gas production and evaluating the impact of its effect on the environment.

This is not the case in Western Australia, where hydraulic fracturing activities have been conducted since 1958 without incident. Western Australia's existing regulation provides for robust case specific assessment, condition imposition and monitoring. In addition, across environment, land access and resource extraction, industry employs best practice to minimise and manage risk, so as to ensure it operates in a responsible, safe and transparent manner.

A Robust Legislative Framework

The robust, case specific objectives and outcomes based approach to regulating hydraulic fracturing associated with the development of Western Australian unconventional gas resources is world-class and provides strong mitigation of the minimal risks associated with the development of Western Australia's shale gas resources.

Large scale development of unconventional gas resources in Western Australia is unlikely to occur for at least another five years. Importantly, the existing regulatory environment provides flexibility that is necessary to allow the regulatory framework to evolve with the Western Australian shale gas industry and as more knowledge about the nature of Western Australian shale gas resources is generated and new technologies are developed.

Recommendations

R1: ensure the regulatory environment is conducive to the sustainable development of Western Australia's unconventional gas resources

The Western Australian Government should ensure the regulatory environment pertaining to the development of Western Australia's shale and tight gas resources is transparent, efficient and does not create any unnecessary obstacles to the environmentally and socially responsible development of Western Australia's shale and tight gas resources.

Western Australia hosts significant undeveloped resources of tight and particularly, shale and tight gas. The formations that host these resources are deep and distant from aquifers, presenting minimal environmental risk that can be effectively managed and mitigated.

The future development of these resources presents Western Australia with an opportunity to diversify the domestic market and achieve energy security, ensuring Western Australian industry and households have a long-term supply of relatively clean, cost competitive energy. Given many countries around the world will develop their domestic unconventional gas resources, the dynamics of the global natural gas market will change, likely rendering the development of Western Australia's unconventional gas resources a competitive imperative for the State.

The development of Western Australia's unconventional resources will also deliver a new industry to Western Australia and stimulate the establishment and growth of other new industries, leading to economic growth and employment, particularly in the Kimberley Region. A Western Australian unconventional gas industry will also likely become a significant source of revenue for the State Government.

However, capital and operating costs associated with the development of an unconventional gas industry in Western Australia will be substantially higher than they are in other regions around the world. As such, the Western Australian Government must ensure regulation does not impose any unnecessary additional cost on the industry, including resisting any pressure from the Commonwealth for the development of tight and shale gas resources in Western Australia to trigger the provisions of the *Environmental Protection and Biodiversity Conservation Act 1999* (Cth) and thereby enforcing a separate and substantially duplicated Commonwealth approvals process on the industry.

R2: recognise current Western Australian regulatory philosophy remains best practice

The existing processes used by the Department of Mines and Petroleum for assessing and managing the occupational health and safety, environmental and resource management risks associated with the development of Western Australia's unconventional gas resources are best practice, providing industry with a robust and practical approvals and project management framework.

The case-specific, objectives and outcomes-based approach to assessing, approving and monitoring activity relating to the development of Western Australia's unconventional resources currently undertaken by the Department of Mines and Petroleum provides industry with a robust framework while

ensuring the interests of the State and community are protected. Conditioning for risks specific to individual projects is critical for efficient project development and optimal occupation health and safety, environmental and resource impact management.

Importantly, this framework allows the regulations to evolve in the form of case-specific conditions as the industry develops and more knowledge pertaining to the development of Western Australia's unconventional resources is generated.

R3: recognise regulation and industry best practice minimise the impact on current and future uses of land, and implement the Multiple Land Use Framework

The source of impacts on current and future land uses is the overall unconventional gas development process, rather than the hydraulic fracturing process itself. Current regulation, conventional negotiation processes and industry standards ensure a consultative approach is undertaken with relevant stakeholders and that land use impacts from unconventional gas developments are optimally minimised.

The most significant impact on alternative land use that results from the development of unconventional resources is the overall footprint of the drilling pad operations, access roads and supporting activities that occur during the development phase. This footprint is substantially reduced and isolated from other land uses once a field is in production.

The assessment process currently used by the Department of Mines and Petroleum ensures that all land use conflicts are identified and appropriately managed. Industry guidelines requiring extensive stakeholder consultation are adequate for the management of land use conflicts that might arise from the development of unconventional gas resources in Western Australia.

In addition, the Multiple Land Use Framework (MLUF) presents an opportunity to provide additional certainty, transparency and confidence with all stakeholders, if appropriately implemented at a state and federal level with appropriate industry consultation. If it is fully realised, the MLUF has the potential to facilitate further multiple and sequential land use outcomes for land users.

R4: recognise current regulations and industry best practice standards for chemicals used in hydraulic fracturing are adequate

Western Australian regulations mandate full disclosure of the chemical composition of hydraulic fracturing fluids. This represents best practice. In addition industry standards relating to the minimisation of chemicals used in hydraulic fracturing fluids are also considered best practise.

Through its approvals process, the Department of Mines and Petroleum undertakes a detailed assessment of the occupational health and safety and environmental implications of the specific hydraulic fracturing fluid that will be used in a specific well, and sets appropriate conditions. Full public disclosure of the composition and volume of the hydraulic fracturing fluid that will be used for a well occurs through the summary Environment Plan which is published on the Department of Mines and Petroleum website.

Industry standards prescribe a continuous improvement philosophy with respect to minimising the chemicals used in hydraulic fracturing.

R5: recognise the interaction between groundwater resources and hydraulic fracturing is adequately managed by current regulations and industry best practice standards

Risk of depletion or contamination of groundwater resources from hydraulic fracturing activities is substantially mitigated by competent well design and construction and best practice fracturing fluid and flow-back water management and handling systems. The case for recycling groundwater used in the hydraulic fracturing process should continue to be assessed on a case-by-case basis, based on the content of the flow-back water, local climatic and hydrogeological settings and project economics.

While hydraulic fracturing is not an insignificant user of water, compared to other industrial applications it uses a relatively small amount of water. The fact that Western Australia's tight and shale gas resources are located in deep formations separated from aquifers by thousands of metres of rock means that in the context of competent well design and construction, contamination of aquifers from the hydraulic fracturing operation is highly unlikely.

Options for managing flow-back water including evaporation, containment and processing, and treatment and re-injection should continue to be assessed on a case-by-case basis by the Department of Mines and Petroleum in the context of project-specific flow-back water composition and local climatic and hydrogeological conditions all of which impact on risk of contamination to the surrounding environment, surface and groundwater resources and technical and economic viability of any project under consideration.

The protection of aquifers is an objective of best practice industry standards.

R6: recognise full and safe land reclamation and rehabilitation is standard practice and a regulated activity

The safe and secure decommissioning of petroleum wells and the restoration of land to its natural state or a form suitable for other productive purposes (such as agriculture) has been standard industry practice for many years and is a condition of production licenses.

The practice of safely decommissioning a well, dismantling facilities and rehabilitating land to its natural state or some other form desired by society has been common practice in the petroleum industry for many decades and the industry has developed state-of-the-art skills in performing this function.

Current methods for well decommissioning and land rehabilitation will affect total rehabilitation of land that has been the subject of an unconventional gas development in Western Australia.

Competent well decommissioning and land restoration is a condition of a production license and consistent with best practice industry standards.