Drilling down.

Coal Seam Gas:

A background paper.

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DISCLAIMER

EXECUTIVE SUMMARY

BACKGROUND

The debate around coal seam gas has become very contentious in New South Wales, with strongly held views on all sides. Building consensus and community confidence in such an environment is very challenging. The City of Sydney commissioned this report to gather objective information and inform the debate about the current situation and drivers for coal seam gas in Eastern Australia.

It should be noted that the City of Sydney does not support the extraction of coal seam gas in built up areas, and considers hydraulic fracturing (fraccing) may pose risks to aquifers[1]. The City of Sydney welcomed the NSW Government's July 2011 announcement[2] of new environmental and community consultation conditions for coal and coal seam gas mining, and believes there should be an independent investigation into the full environmental and social impacts of coal seam gas exploration and extraction.

WHAT IS COAL SEAM GAS

There is no functional difference between coal seam gas (CSG) and conventional natural gas. Both are naturally occurring methane formed from the decay of organic matter in oxygen poor environments over geological time, and both are formed by the same processes that produce coal and oil[3]. The differences are mainly in where they are found and how they are extracted. Conventional gas is methane which has migrated from where it formed into an underground reservoir, for example beneath an impermeable rock layer, and is found in sandstone and limestone. Once you drill into the reservoir, gas is released under its own pressure. CSG is methane which remains where it formed, held within the coal seam by adsorption and pressure from water in the seam. Coal is a highly adsorptive substance and is relatively impermeable, which means that gas cannot move easily through it. Extracting the gas requires depressurising the coal seam by removing the water and may include the use of techniques to increase the permeability of the coal seam.

Much of the controversy over unconventional gas has centred on shale gas; that is, methane held within shale layers, rather than within a coal seam, and there is a great deal of confusion between shale gas and CSG. There are some key differences however: shale is much harder than coal, is much more impermeable, and is usually found deeper underground. Shale always requires fracturing in order to allow the gas to flow, simply because it is so impermeable. There is currently no shale gas production in Australia, although there are large shale gas reserves in South Australia, the Northern Territory, and Western Australia. There are no proven shale gas reserves in NSW or Queensland. In the US, by contrast, shale gas supplies about 15% of gas consumption.

EXTRACTION TECHNIQUES

Extracting CSG involves drilling a well into a coal seam and 'dewatering', or pumping out the water held in the coal seam. This extracted water is called 'produced water'. Dewatering reduces the

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[1] Resolution of Council, City of Sydney, December 6th 2010

[2] The Hon Chris Hartcher Minister for Resources and Energy, Media Release, *NSW Govt Has Listened And Acted: Tough New Conditions For Coal & Coal Seam Gas*. 21 July 2011. Available from http://www.resources.nsw.gov.au/__data/assets/pdf_file/0003/400728/Minister-Hartcher-med-rel-end-of-moratorium.pdf

[3] CSG usually has higher concentration of methane (>95%), and lower concentration of other hydrocarbons relative to conventional natural gas.

pressure in the coal seam and allows the adsorbed gas to be released. The drill hole should be sealed sufficiently along its length to prevent the flow of water, gas and other materials between the coal seam and any overlying or underlying aquifers. Horizontal or angled wells may be drilled into and along the coal seam from a vertical well.

If the flow of gas is insufficient, the coal seam may be fractured to increase the permeability of the coal and allow the gas to flow more freely. Hydraulic fraccing involves pumping large volumes of a fluid (usually water based) at high pressure down the well causing the coal seam to fracture for distances of up to 400 metres. The fraccing fluid most often contains a 'proppant', usually sand, to hold the fractures open, and a mixture of added chemicals to help the drilling process. There has been considerable public concern regarding the environmental and health impacts of these added chemicals.

Fraccing has been used in about 8% of the 4500 CSG wells in Queensland to date, and this could increase to 10–40% over time (DERM 2011c). Some estimates are that CSG extraction in NSW could see fraccing used at perhaps 25% of sites[4]. Proponents usually seek permission for fraccing in their licences, as they are often unsure whether it will be needed until drilling has taken place. Fraccing is expensive, so is not undertaken unless gas flows are low.

In conventional gas extraction, gas will usually come out under its own pressure from a vertical well drilled into a gas reservoir. Wells are often deeper than for CSG, and may be as deep as five kilometres compared to one kilometre or less for CSG. Conventional extraction can also involve fraccing. Shale gas always requires fracturing to extract the gas because shale does not have natural fractures, and generally does not require dewatering as shale is too impermeable to hold water.

CSG, CONVENTIONAL GAS AND THE EASTERN GAS MARKET

In 2009–10, coal seam gas (CSG) accounted for 20% of gas production in the Eastern Gas Market, and 10% of total Australian gas production[5]. The Eastern Gas Market includes Queensland, NSW, Victoria and South Australia, and is not connected to Western Australia, which has huge reserves of conventional gas. The Camden Gas Project 60 kilometres south-west of Sydney supplies 6% of NSW gas consumption, and is currently the only NSW CSG project feeding into the natural gas distribution network in eastern Australia.

Looking at the Eastern Gas Market alone, currently proven and probable reserves are about 8,000 PJ of conventional gas and about 28,000 PJ of CSG. Assuming gas use keeps increasing at the current rate of 4% per year until 2025, conventional gas is sufficient for about nine years of consumption, currently 679 PJ/year, and CSG for about 27 years (AER 2010, p. 72). Projected exports from the Queensland Curtis Liquefied Natural Gas (LNG) Project at Gladstone are approximately 1440 PJ by 2020 (GEIDB, 2009), which would reduce the lifetime of conventional gas reserves to seven years, and that of CSG reserves to 16 years.

Most projections for Australia's electricity supply in a low carbon future, including those produced by ABARES and Greenpeace, assume the proportion of Australia's electricity produced through gas-fired

[4] Dr Peter Stone (CSIRO). In the national interest, Radio National, 14/7/ 2011.

[5] Data from Australian Energy Regulator, 2010, State of the Energy Market 2010 p.72.

generation will increase very significantly from now until 2030[6]. Australian gas-fired electricity generation is currently projected to grow nearly fourfold and to account for more than half of domestic electricity consumption by 2030 (ESAA 2011).

The City of Sydney is undertaking a trigeneration project as part of its strategy to reduce the council's greenhouse emissions by 70%. The trigeneration is projected to use between 17 PJ and 27 PJ of gas per year (City of Sydney 2010), accounting for between 3% and 4% of projected demand for gas in the Eastern Gas Market, and up to 4% of the projected Australian demand for gas for electricity generation in 2020. By contrast, exports of CSG from Queensland as LNG at 2020 may be 1440 PJ, 50% more than the total projected demand in the Eastern Gas market.

The City of Sydney's trigeneration project will reduce overall electricity consumption, as it uses the waste heat produced in the generation of electricity to provide energy for heating and cooling. The project could therefore be expected to result in the consumption of less gas than a centralised gas electricity generation plant meeting the same proportion of Sydney's demand for electricity.

Western Australia has large conventional gas reserves of approximately 68,376 PJ, compared to current Australian gas consumption of 1,037 PJ per annum. Most of the gas production in Western Australia is destined for export as LNG. If Australia wished to preserve this resource for domestic use, it would last approximately 60 years, assuming current annual growth in gas demand remains constant to 2025[7]. The gas would need to be converted to LNG, shipped to the Eastern Gas Market, and re-gasified or decompressed. Apart from the economic cost, the emissions benefits compared to coal generation would be reduced because of the additional processing and transport. There are also significant environmental concerns about some conventional gas developments proposed in Western Australia. For example, there is an international campaign to protect the Dampier Peninsula from the effects of the proposed LNG processing plant and associated infrastructure at James Price Point near Broome[8].

EMISSIONS FROM CONVENTIONAL GAS, CSG AND COAL

One of the main drivers for the increase in natural gas use is the need to reduce greenhouse gas emissions, as gas-fired electricity generation is generally considered to offer significant greenhouse benefits compared to coal generation. This has been questioned recently, with some authors suggesting that emissions from gas are similar or worse than those from coal (Howarth et al. 2011). If gas does not offer a significant greenhouse emissions advantage, there is little environmental benefit achieved by a transition to gas.

One of the key issues raised is whether estimates of the impact of methane emissions should use the 20-year or the 100-year global warming potential (GWP) of methane. Methane has a lifetime of about 12 years in the atmosphere compared to carbon dioxide, which may last for thousands of years (IPCC 2007). Methane has a GWP of 72 at the 20-year horizon and 25 at the 100-year horizon (IPCC 2007).

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[6] ABARE is projecting domestic gas use in Australia to supply 37% of electricity generation in 2030 (Syed et al, 2010). Some low carbon energy projections for Australia see gas generation making an even greater contribution by 2030, for example 43% (Greenpeace International, European Renewable Energy Council. 2008. Energy [r]evolution. A Sustainable Australia energy outlook) or 50% (AGL, Frontier Economics, and the World Wide Fund for Nature, 2006. Options for moving to a lower emission future).

[7] Assuming that gas use continues to grow at 4% per year until 2025 and then remains stable.

[8] For example, http://handsoffcountry.blogspot.com/2009/07/camping-on-dampier-peninsula.html, www.savethekimberley.com/wp/dinosaur-prints-our-kimberley-national-heritage/, www.environskimberley.org.au/

National and international accounting currently uses the 100-year horizon, but this has been questioned, as the next few decades are crucial for climate change (Howarth et al. 2011).

Using the 100-year GWP for methane, an analysis of six recent studies showed unconventional gas (CSG and shale gas) used in a combined cycle gas turbine has an emissions benefit of between 39% and 59% compared to coal. Trigeneration has a benefit of 69%, and open cycle gas turbines a benefit of 30%. Using the 20-year GWP for methane, the difference between coal and gas-fired electricity generation is smaller, as fugitive methane emissions make up a relatively larger proportion of total emissions for gas-fired electricity generation. The benefit for conventional gas ranged from 35% to 54%, and for shale gas from 21% to 44%. Trigeneration still showed a benefit of about 54%.

However, direct measurement of life cycle GHG emissions from CSG will be required in Australia to reach firm conclusions on the scale of the GHG emission benefits from CSG compared with coal. Unfortunately there is a dearth of studies looking specifically at the emissions of CSG, and four of the six studies reviewed only compared conventional gas, shale gas, and coal emissions. Emissions from CSG are likely to be lower than for shale gas, as the most emissions-intensive stage of shale gas extraction is the flowback period after hydraulic fracturing (Howarth 2011; Prior 2011). In CSG extraction, fugitive emissions are very unlikely to be produced at this stage, as dewatering has to occur for days or even months before there are gas flows to the surface. In addition, all of the reviewed studies stress that methane emissions from gas production can be reduced significantly by industry best practice, with reductions of 40%–90% possible (Howarth 2011).

WILL USING GAS AS A TRANSITION FUEL REDUCE EMISSIONS OVERALL?

The use of gas as a transition fuel has been assumed in most low-carbon projections. This is firstly because at present, gas is in many cases the next cheapest electricity generation source after coal, and has a significant greenhouse emission benefit. Secondly, gas-fired electricity generation (like hydroelectricity) can start up very quickly. This quick responsiveness is very valuable in an electricity system, particularly in systems with a high proportion of intermittent renewable sources such as wind and solar. However, the practical validity of this approach has been questioned by some who express concern that a new, large, relatively cheap source of fossil fuels such as CSG could be just as likely to displace renewable energy development as it is to displace coal fired generation (Wood et al. 2011).

Although gas, including CSG, has an emissions benefit relative to coal fired generation, it is certainly not sufficient to reach the emissions targets necessary to keep global warming within 2°C, or to outweigh the worldwide growth in energy consumption. Without an effective cap on emissions there is little price incentive to go to fuels with lower emission profiles than gas, and the intensive development of unconventional gas resources may simply provide a further cheap source of fossil fuels and divert investment from lower emission options such as renewable energy and increasing energy efficiency. This is an issue for national and international climate policy, but certainly the development of unconventional gas resources in the absence of effective emissions reduction targets is unlikely to reduce global emissions.

ENVIRONMENTAL AND COMMUNITY ISSUES

CSG extraction will have very different impacts depending on the characteristics of the targeted coal seam itself, the geology of the surrounding rock strata, the proximity and hydraulic connectivity to aquifers, and the specific extraction techniques and safeguards used to extract the gas. The interaction of extraction techniques and geological formations is complex, and it is not possible to make accurate generalisations about the circumstances in which there would be adverse impacts.

However, the main issues are likely to revolve around water impacts. These may be:

- effects at the aquifer level, either through potential contamination and or depletion
- surface water effects, from disposal or treatment of the produced water or drilling muds
- water consumption effects. Hydraulic fracturing typically uses 0.22–0.75 ML per well (Roy, 2011), so cumulative water use may be significant. Where depletion is an issue there may be significant resource conflicts between agriculture and CSG.

Other potential issues are subsidence from depressurisation in the coal seam, the surface footprint of the mining operation (including noise, odour, dust, traffic, etc.), direct greenhouse gas emissions (known as fugitive emissions) of methane and CO_2, and land use conflicts between resource extraction and either agriculture or urban development. Air pollution from drilling operations or from some water treatment options may also be an issue.

There are significant health concerns regarding potential water and air pollution (e.g. Doctors for the Environment 2011). Potential contaminants include the chemicals used in drilling and fraccing, and chemicals which occur naturally in coal seams and may be taken up and carried by produced water.

PRODUCED WATER

The need to 'dewater' coal seams to depressurise the gas results in large volumes of produced water. This gives rise to potential subsurface issues from depressurisation, and to surface issues in the handling, disposal and use of the produced water.

Normally, water production falls rapidly and gas production increases rapidly after the extraction commences. The quantity and time profile of produced water in Queensland CSG extraction sites varies enormously. The ratio of water to gas varies from 22:1 to only 0.1:1 (Helmuth 2008). In situations where water production stabilises at higher levels, it is very likely the water is being recharged; that is, the produced water is not just coming from the coal seam. However, gas production in this scenario is unlikely to be economic, and the well would probably be capped and production terminated.

The quality of produced water also varies considerably. Salinity is usually measured by the level of dissolved solids, with drinking water having up to 500 mg per litre and sea water about 37,000 mg per litre. The salinity of produced water in Queensland CSG extraction sites varies from less than 200 mg per litre to over 10,000 mg per litre (DERM 2010). Produced water may also contain a range of chemicals from drilling or fraccing activities, or from the coal seam itself.

It is part of the environmental approval process to stipulate water treatment and management options. These currently include treatment and then reinjection, or treatment and so-called 'beneficial use', for example for use in irrigation. Water treatment is likely to produce waste in the form of brine or solids, which require safe disposal. In some cases produced water management includes disposal to surface waters after treatment, and has included disposal via evaporation dams. Evaporation dams were disallowed in NSW in June 2011 and in Queensland in October 2010, although with some exceptions.

GAPS IN REGULATION, POLICY AND INFORMATION

Given the potential scale of CSG production in NSW and Queensland, and the corresponding scale of potential impacts, the regulatory framework should ensure that industry development proceeds in a way that does not compromise community or environmental values. The pace of development of a new type of extractive industry with widespread infrastructure poses new challenges for the protection of water resources. The growth of CSG production highlights the lack of sufficient baseline information on geology and aquifer interactions, and a lack of modelling to assess such cumulative sub-surface impacts. These gaps should be addressed urgently in order to inform strategic planning, regulation and monitoring regimes.

At present the legislation governing CSG development is framed with a presumption of consent for mining; for example, if arbitration occurs, the determination often relates to what conditions should be attached rather than whether the consent should be given (EDO 2011, p. 47). The Environmental Defenders Office has undertaken a detailed review of NSW regulation of mining and CSG activities, and makes 21 detailed recommendations (EDO, 2011). It is beyond the scope of this report to make detailed recommendations regarding legislative reform. However, there are some key areas of policy and regulation that should be addressed:

1) Strategic planning, regulation, and compliance monitoring of CSG should be informed by coordinated regional research on hydrogeological interactions, overseen by an appropriate body, such as the National Water Commission.

2) Federal environmental legislation should be amended to include oversight of regional water resources.

3) CSG development needs to occur within a framework of strategic planning which assesses the demands of competing land uses, including agriculture, conservation, residential development, renewable energy development, and resource extraction.

4) The information base and regulation regarding CSG and potential impacts on aquifers should be strengthened. This should include baseline and ongoing hydrological monitoring, and an investigation of the potential for cumulative impacts.

5) Community involvement in decisions and approvals needs to be strengthened.

6) Regulation of access arrangements should be reformed to redress the imbalance between landholders and project proponents. These regulations should include standard requirements for information provision.

7) Monitoring and reporting of fugitive emissions should be required for exploration and production wells, with a view to developing minimum standards under consent conditions.

8) A centralised, coordinated, and transparent procedure for compliance monitoring and reporting should be adopted for all exploration and production activities.

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ABBREVIATIONS

APPEA	Australian Petroleum Production and Exploration Association
BTEX	Benzene, toluene, ethylbenzene and xylene
CBM	Coal Bed Methane
CMM	Coal Mine Methane
CO_2	Carbon Dioxide
CRS	Congressional Research Service (USA)
CSG	Coal Seam Gas
CSM	Coal Seam Methane
CWA	Clean Water Act (USA)
DCCEE	Commonwealth Department of Climate Change and Energy Efficiency
DERM	Department of Environment and Resource Management (Qld)
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services (NSW)
DP&I	Department of Planning and Infrastructure (NSW)
DPI	Department of Primary Industries (NSW)
EA	Environmental Assessment
EDR	Economic Demonstrated Resources
EIS	Environmental Impact Statement
EMP	Environmental Management Plan (Qld)
EPA	Environmental Protection Act (NSW)
FEA	Federal Environment Agency
GGAS	Greenhouse Gas Abatement Scheme (NSW)
GHG	Greenhouse Gas
GIPA	Government Information Public Access
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
MT	Million tonnes
NWC	National Water Commission
OEH	Office of Environment and Heritage (NSW)
PoEO	Protection of the Environment Operations (NSW)
ppm	parts per million
QLD	Queensland
QWC	Queensland Water Commission
SDWA	Safe Drinking Water Act (USA)
SEPP	State Environmental Planning Policy
US EPA	USA Environmental Protection Agency
VAM	Ventilation Air Methane

1 INTRODUCTION

The current commercial production of coal seam gas (CSG) in Australia commenced in 1996 (AER, 2010 p.71), although coal mine methane was produced from the abandoned Sydney Harbour colliery from 1943 to 1949, with the gas compressed and sold for use as industrial and motor fuel (Miyazaki, 2005).

CSG accounted for 10% of total Australian natural gas production in 2009-10 (AER, 2010 p.69), and this is projected to be 29 per cent by 2029 (GA & ABARE, 2010). It is a very large resource, which has only become accessible relatively recently as extraction techniques have developed. Production is growing extremely quickly, increasing more than 30% per year in the five years to 2009 (GA & ABARE, 2010). CSG made up 27% of proved and probable Australian gas reserves in August 2010, and 78% of the reserves in the Eastern Gas Market.

A significant expansion of gas fired electricity generation is often regarded as a key element of the transition to a low carbon energy sector. Gas fired generation generally provides an emission reduction of 40 to 60 per cent compared to coal fired generation, with a greater emissions benefits possible for trigeneration. It also provides more flexible and responsive generation capacity that complements power provision with a large proportion of variable output renewable generation such as wind or solar PV. ABARE is projecting domestic gas use in Australia will increase by 250% by 2030 and supply 30% of electricity generation (GA & ABARE 2010, AER 2010). Some low carbon energy projections for Australia see gas generation making an even greater contribution by 2030, for example 43% (Greenpeace and EREC 2008) or 50% (AGL, Frontier Economics, and World Wide Fund for Nature, 2006). Coal seam gas is likely to contribute a substantial part of the switch away from coal to gas.

CSG accounts for 27% of current Australian gas reserves, even including the Carnarvon field in Western Australia which is largely supplying an export market. If the proportion of gas supply follows the currently proven reserves, it is likely that CSG will supply at least 30% of the Australian domestic market by 2030, and more than 50% of the gas demand in the Eastern Gas Market.[9]

However, significant environmental issues have been raised about coal seam gas, and there is considerable community concern about the rapid expansion and exploitation of this resource (for example, the Lock the Gate Alliance, Get Up, No Gas Mining in Sydney, or the Basin Sustainability Alliance[10]). There are potential conflicts over land use, for example between gas extraction and agriculture or residential development, and significant concerns about potential impacts on water resources (for example, NWC 2010). It is important that these concerns are addressed if this resource is to be developed with the support of the community.

The City of Sydney commissioned this report to gather objective information and inform the debate about the current situation and drivers for coal seam gas in Eastern Australia. It should be noted that the City of Sydney does not support the extraction of coal seam gas in built up areas, and considers hydraulic fracturing (fraccing) may pose risks to aquifers[11]. The City of Sydney welcomed the NSW Government's announcement of new environmental and community consultation conditions for coal and coal seam gas mining and its six month moratorium on the use of 'fraccing'. The City believes

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[9] CSG accounts for 78% of the proved and probable reserves in the Eastern Gas market, but a significant proportion is likely to be exported as LNG.

[10] http://lockthegate.org.au/, www.nogasmininginsydney.com, www.getup.org.au/campaigns, www.basinsustainabilityalliance.org/role.html

[11] Resolution of Council, City of Sydney, December 6th 2010

there should be an independent investigation into the full environmental and social impacts of coal seam gas exploration and extraction.

Coal seam gas extraction will have very different impacts depending on the characteristics of the coal seam itself, the characteristics of the surrounding rock strata, the proximity and connectivity to aquifers, the specific extraction techniques used to produce the gas, and the regulatory safeguards in place. It is beyond the scope of this report to determine what environmental best practice means for CSG production. Considerable research would be required to categorise risks according to the characteristics of the coal seam or the extraction techniques, or to determine whether there are situations in which development should be ruled out. Given the environmental and economic importance of this resource, and the extent of community concern, it is important that such research is undertaken.

1.1 WHAT IS DRIVING DEMAND FOR CSG?

Looking at the Eastern Gas Market alone, currently proven and probable reserves are about 8,000 PJ of conventional gas, and about 28,000 PJ of CSG. Assuming domestic gas use keeps increasing at the current rate of 4% per year until 2025, conventional gas reserves in the Eastern Gas Market are sufficient for about 9 years domestic consumption, and CSG for about 27 years[12]. If planned liquefied natural gas (LNG) exports from Queensland of 1440 PJ by 2020 are included, conventional reserves would last about 7 years, and CSG reserves 16 years. Of course, reserve estimates are frequently revised upwards.

Nearly all projections for Australia's electricity supply aimed at achieving low carbon outcomes, whether from ABARES or Greenpeace, assume gas is a transition fuel and that the proportion of gas generation increases very significantly from now until 2030[13]. This is firstly because gas generation is currently the next cheapest source of electricity generation after coal, and has a greenhouse emission reduction of between 40% and 60% compared to coal. Secondly, gas generation (like hydro-electricity) can start up very quickly. This responsiveness is very valuable in an electricity system with a high proportion of intermittent renewable sources such as wind and solar, so more gas generation would be useful in a transition to renewable energy, at least in the short term.

Export of LNG is a significant driver for the expansion of CSG production. Exports from Gladstone (Qld) from four planned projects are expected to reach 1440 PJ by 2020 (GEIDB, 2009), compared to projected domestic demand of 975 PJ if domestic demand continues to grow at 4% per year.

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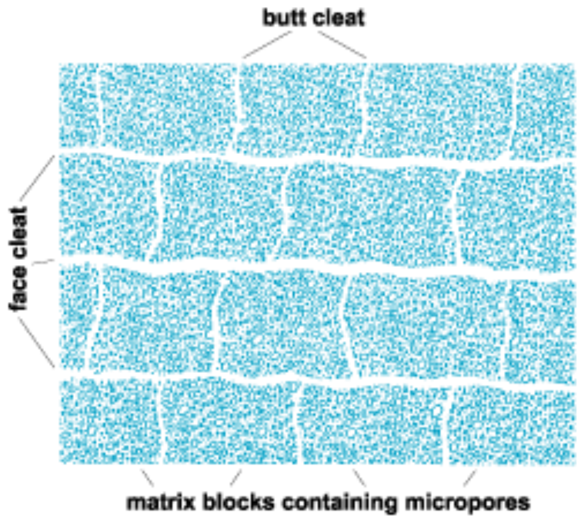
[12] Data from Australian Energy Regulator, 2010, State of the Energy Market 2010 p.72.

[13] ABARE is projecting domestic gas use in Australia to supply 30% of electricity generation in 2030 (for example Geoscience Australia and ABARE, 2010, *Australian Energy Resource Assessment*, Canberra). Some low carbon energy projections for Australia see gas generation making an even greater contribution by 2030, for example 43% (Greenpeace International, European Renewable Energy Council. 2008. Energy [r]evolution. A Sustainable Australia energy outlook) or 50% (AGL, Frontier Economics, and the World Wide Fund for Nature, 2006. Options for moving to a lower emission future).

1.2 WHAT IS COAL SEAM GAS?

Coal seam gas (CSG) is a naturally occurring methane-rich gas held in underground coal seams. It is produced during the formation of coal and is found in varying amounts in all coal types. Pressure from overlaying rock, and water in the coal seam, holds it in place. Approximately 90 per cent of CSG is adsorbed[14] onto internal surfaces of the coal with the remainder[15] occupying the natural fractures (cleats) in the coal seam, as shown in see Figure 1 (Miyazaki, 2005 p.132, ABARE, 2002 p.15). Due to its large internal surface area, coal is able to store an enormous amount of gas[16]. Coal is extremely porous (a measure of the number of openings), but has low permeability (a measure of connected openings), which can make CSG extraction difficult (Dallegge et al, 2000 p.4). However, recent technological advances in CSG extraction has made accessing this vast gas reservoir possible and economic (CSUG, 2010 p.5).

Figure 1: Cleat and micropore structure of Coal
Source: ASE, 2011



CSG typically contains greater than 95 per cent methane with small quantities of other gases such as carbon dioxide, longer chain hydrocarbons[17], nitrogen and inert gases (ABARE, 2002 p.15). The highest concentrations of CSG are contained on black coals. Accordingly, the vast bulk of Australia's CSG resources are located in Queensland and New South Wales with Victoria's brown coal deposits having very limited resources (ABARE, 2002).

Coal seam gas has several names. It is also referred to as Coal Seam Methane (CSM) and Coal Bed Methane (CBM). Within New South Wales, South Australia and Western Australia it is often called CSM and in Queensland it is called CSG (GA, 2011). This report uses coal seam gas (CSG).

Coal seam gas associated with coal mining operations, often extracted in an effort to avoid explosions, is called Coal Mine Methane (CMM); it is of course exactly the same gas. Coal seam methane emissions through mine ventilation are known as Ventilation Air Methane (VAM) (ABARE, 2010 p.87; GA, 2011). VAM is also known as Waste Coal Mine Gas (WCMG).

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[14] Gas molecules are packed tightly as a monolayer on the large internal surface area of coal (U.S. EPA, 2009 p.5).

[15] A very small amount of CSG also exists dissolved in water present in the coal seam.

[16] One gram of coal can contain as much surface area as several football fields (Dallegge et al, 2000 p.4), and coal seams can store almost six times more gas than conventional gas reservoirs on an equivalent volume basis (CSUG, 2010 p.5).

[17] Methane is the simplest hydrocarbon, with one atom of carbon attached to four atoms of hydrogen. More complex hydrocarbons, for example benzene, are the main constituents of crude oil.

CSG extraction which is specifically from unworked coal seams is sometimes known as Virgin Coal Bed Methane (VCBM) and methane emissions from abandoned mines as Abandoned Mine Methane (AMM) (Creedy & Tilley, 2003).

CSG is used in this paper, and unless otherwise specified refers to CSG where it is produced as the primary activity, for use either directly in a gas fired electricity generator or via transport in a natural gas pipeline.

Much of the controversy over unconventional gas has centered on shale gas, i.e. methane held within shale layers, rather than coal seam gas (for example, the US documentary Gaslands is about shale gas extraction). Shale gas supplied 19% of US gas consumption in 2010.[18] Shale is much more impermeable than coal, is usually deeper, and always requires extensive fracturing in order to allow the gas to flow. There is almost no water present within shale, so extraction does not require depressurization by pumping out water. The use of hydraulic fracturing has been integral to extracting shale gas because the difficulties in extraction result from the lack of pathways (fractures) within the formation. There is currently no shale gas production in Australia, but there are large shale gas reserves in South Australia, the Northern Territory, and Western Australia. There are no shale gas reserves proven in NSW or Queensland.

1.3 CSG AND CONVENTIONAL NATURAL GAS

CSG is referred to as 'unconventional' natural gas, although this refers as much to the type of reservoir as the gas itself. Natural gas accumulated in a subsurface reservoir (structural trap) that can be readily extracted using simpler technology is called conventional natural gas. Natural gas in deposits, such as coal seams, that requires the use of more complex extraction technology is called unconventional natural gas. More sophisticated technology is required to extract CSG as the gas is held within the coal seam matrix (mostly adsorbed onto the surface of the coal), and is not free to migrate to a collection point (well bore) as is the case in a conventional natural gas reservoir (ABARE, 2010 p.87; Maracic et al, 2005 p.1). Figure 2 shows this schematically.

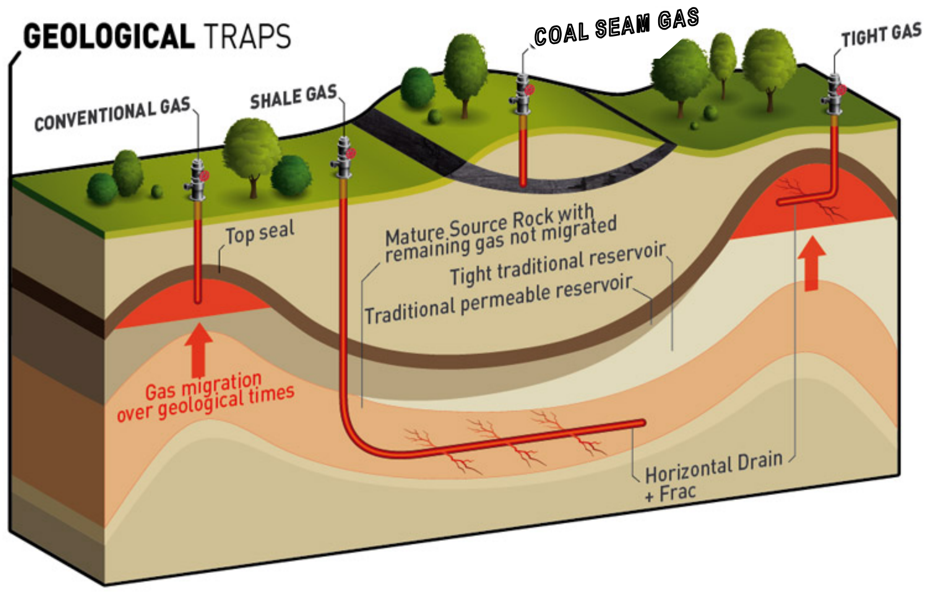
Conventional natural gas may be almost pure methane (referred to as "dry"), or may contain varying levels of longer hydrocarbons such as ethane, propane, butane (referred to as "wet") as well as other gases (including nitrogen and carbon dioxide) (ABARE, 2010 p.86). Typically conventional natural gas contains about 90 per cent methane (Kimber & Moran, 2004 p.3). CSG is often of higher quality and typically comprises greater than 95 per cent methane with small amounts of carbon dioxide and nitrogen (Rahman - personal communication, 2011; BCMEM, 2011).

Before being used for industrial or commercial purposes, both CSG and conventional natural gas are processed to remove impurities. Most often CSG requires only removal of water vapour and any coal dust before it is compressed and injected into the pipeline for end-use. Conventional natural gas typically requires more comprehensive processing, during which carbon dioxide and heavier hydrocarbons are removed (Kimber & Moran, 2004 p.4). The end-use product of CSG is almost identical to conventional natural gas, and is added to natural gas pipelines without special treatment and utilized in all natural gas applications (ABARE, 2010 p.87; Kimber & Moran, 2004 p.4).

CSG and conventional natural gas are compared in Table 1. Very small differences exist in levels of carbon dioxide, water content, and total sulphur, but these should not be apparent to the user of the gas. Appendix 1 gives a more detailed comparison of the composition of CSG and conventional gas.

[18] Shale gas 4.5 TCF (US DOE and NETL, 2011), total US gas consumption 3.8 TCF (Skone, 2011)

Figure 2: Stylised depiction of unconventional and conventional natural gas wells.



Source: Total, 2011a

Table 1: Comparison of CSG and Conventional Natural Gas

Characteristic	Coal seam gas	Conventional Natural Gas[1]
Composition in the ground	Higher methane content > 95% [2] Less impurities [3]	Lower methane content ~ 90% [3]
Composition In the pipe	Methane content 97% [4]	Methane content 90% [4]
Typical reservoir - geology, depth, size	Lower pressure (300 – 500 kPa), closer to surface - between 200m to 1,000m below ground. Gas is adsorbed onto coal surface [3,5]	Higher pressure (7,000 – 15,000 kPa) in the pores of sandstones and other porous rocks at depths up to 5,000 m[3]
Typical extraction techniques	Vertical, horizontal and multi-lateral wells including in-seam drilling [6] An estimated 10% - 40% of Queensland wells will require fraccing[7].	Vertical wells, fraccing[8]
Total life production cost	Similar between CSG and conventional natural gas [3]	Similar between CSG and conventional natural gas [3]
Typical well - economic production lifespan	0.5 TJ/day for 5 to 7 years [3] 5-15 years [6]	10 to 20 TJ/day becoming uneconomical within 5 years [3]
Produced water	Water:gas volumes vary from 10% - 2000% (Qld data)[9]; <1% (Camden Project)[10], and 0.02% - 1.5% (US data)[11]. Water quality varies considerably.	Average volume of water: gas is 0.5% [12] Water quality varies considerably, but generally poorer than CSG.[13]

Notes

1. Conventional gas reserves include LNG & ethane.
2. ABARE, 2010.
3. Kimber & Moran, 2004 (pages 1, 3, 5)
4. APIA fact sheet No. 2
5. Origin Energy, 2011a
6. All Consulting, 2004 p.17
7. DERM 2010.
8. Congressional Research Service (CRS) 2009 (pg 1)
9. Helmuth 2008, Table 4, p20
10. See Section 4.3.1
11. USGS 2000b, Table 1
12. Veil and Clark, 2011. Table 4 p237
12. Hayes and Arthur, 2004

1.4 RELATIONSHIP BETWEEN CSG, COAL MINING AND CMM

Large amounts of coal mine methane (CMM) are released when coal mining is carried out. CCM poses considerable safety problems, primarily because of explosion risk, and is a limitation to high levels of productivity in underground coal mines. Vented to atmosphere it is also a potent greenhouse gas. To put the scale of the issue in perspective, coal mine methane emissions in 2003 were estimated at 48 PJ, equivalent to 5% of Australian gas consumption (Miyazaki, 2005). CMM CO_{2-e} emissions in 2004 were 21.3 million tonnes of carbon dioxide equivalent, nearly 4% of Australia's total emissions, and expected to increase by more than 50% by 2020 (Australian Greenhouse Office, 2006).

Coal seam gas (CSG) and coal mine methane (CMM) are essentially the same thing, that is, the naturally occurring gas trapped in coal seams. The definition of the two as distinct gases relates to the core activity associated with extraction or liberation of the gas:

- CMM is defined as the combustible gases in, above, or under recoverable coal reserves or coal seams within permitted, active, or abandoned mine areas (Kennedy, 2010 p.6).
- CSG is defined as the combustible gases produced from naturally occurring deposits extracted **outside** mine permit boundaries, or not influenced by pre-mining or mining operations (Kennedy, 2010 p.6). CSG wells are drilled solely for commercial gas production.

There are thirteen operational CMM projects in Australia, three in development, and two closed. These include 10 power generation projects, 1 pipeline injection, 1 boiler fuel, 3 ventilation and 3 flaring projects (Karacan et al, 2011 p. 153-4). Thirteen are located at operational underground coal mines, and five at abandoned mines.

CMM capture using boreholes during pre- and post- mining phases uses fundamentally the same techniques used in CSG operations (Karacan et al, 2011 p.153).

To maintain in-mine methane concentration in air within acceptable limits, many coal mines develop a degasification system to supplement the mine ventilation system. Drainage boreholes are drilled from the surface, or from within the mine, to extract as much methane as possible from coal seams and surrounding strata, before, during, and after mining (U.S. EPA, 2009 p.1).

Capturing and using CMM is important for energy production and greenhouse gas reduction. Over a 100-year horizon, methane has a global warming potential 25 times that of carbon dioxide (IPCC, 2007) [19]. Using CMM that would otherwise be vented into the atmosphere, for example for safety reasons in mining operations, has unambiguous environmental benefits (ABARE, 2002 p.18). CMM may be of high quality and concentration, such as methane produced in advance of mining, or low, such as Ventilation Air Methane (VAM). Depending on the quality CMM can be directly injected into a gas pipeline, or it can be improved by removing contaminants, such as oxygen and nitrogen (Karacan et al, 2011 p.153).

In the case of VAM, it is costly and impractical to upgrade it to pipeline-quality gas. In the past VAM was flared (if sufficiently concentrated) or emitted directly to the atmosphere. More recently VAM has been used in specialised engines and reactors to generate electricity (see Figure 3). A good example is the specialised furnace used at Appin Colliery of BHP Billiton. Fully operational in 2007, it generates 56MW of electricity from VAM of 0.9% methane, supplemented with 25% methane drainage gas when VAM methane concentrations fall below 0.9%. Reported power plant availability for July 2007 to June 2008 was 96%. By 2009, the installation generated over 500,000 carbon credits (traded within New South Wales GGAS) and over 80,000 MWh of electricity sold into the State electricity grid (UN, 2010 p.59; NSW DPI, 2011).

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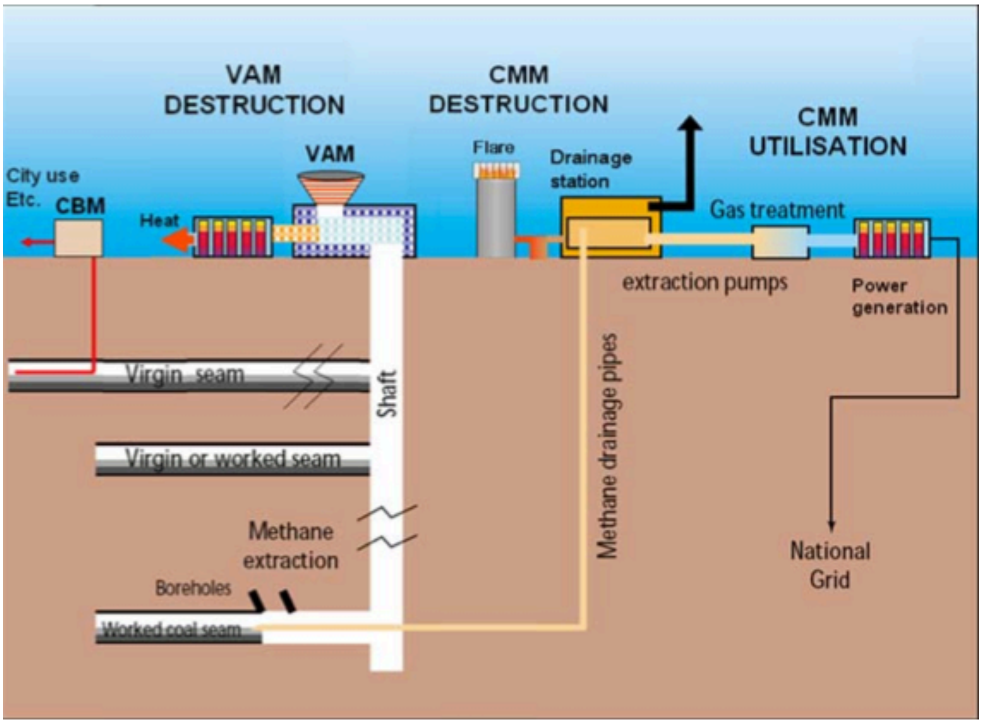
[19] The GWP of 25 has been revised upwards since the IPCC Second Assessment Report (1995), which gave a GWP of 21 (100 year horizon). The Australian NGA (DCCEE 2011) still uses the GWP of 21, but 25 is used in this report

Figure 3: CMM and VAM recovery and utilization for energy production (NB: CBM = CSG)



Source: UN, 2010 p.31

2 CSG EXTRACTION

Exploration for CSG involves the search for a particular set of geological conditions likely to contain natural gas reserves that can be economically extracted (ABARE, 2010 p.88). The permeability, porosity (typically 2-3%) and gas content of the coal seam are the most important properties for CSG exploration and development (Miyazaki, 2005 p.134; Rahman - personal communication, 2011). If a coal seam is of low porosity (fewer cleats) and permeability, gas production from the seam may be very difficult, as gas will not be able to move from the coal seam matrix into the cleats and ultimately into the bore well (Maracic et al, 2005 p.1) High quality, productive, CSG deposits have cleats permeable enough to allow gas and water to flow freely through them (Origin Energy, 2011a; All Consulting, 2004 p.8).

Many production techniques are available and the appropriate technique must be matched to the characteristics of the coal seam and its geology (Kimber & Moran, 2004 p.5). CSG drilling technique is crucial to the success of gas production and has a far greater effect on final production than in traditional gas reservoirs (Henderson, 2010 p.64).

The main extraction techniques are summarised in Figure 4 below with a graphical representation provided in Figure 5. These techniques may be combined in almost any permutation, although the majority of CSG production techniques begin by drilling a vertical well from the surface.

Figure 4 Summary of common CSG techniques

Vertical drilling

- Cheapest drilling option, well usually 'cased' with steel pipe and cemented to provide strength and isolate well from surrounding formations
- A project may have only one vertical well to the surface, or many

Horizontal drilling

- Horizontal or directional drilling, includes Surface to in-Seam (SIS) drilling
- May include elaborate subsurface 'web' of drill holes to provide drainage to the gathering well
- Better access to target area, smaller surface footprint relative to vertical drilling.

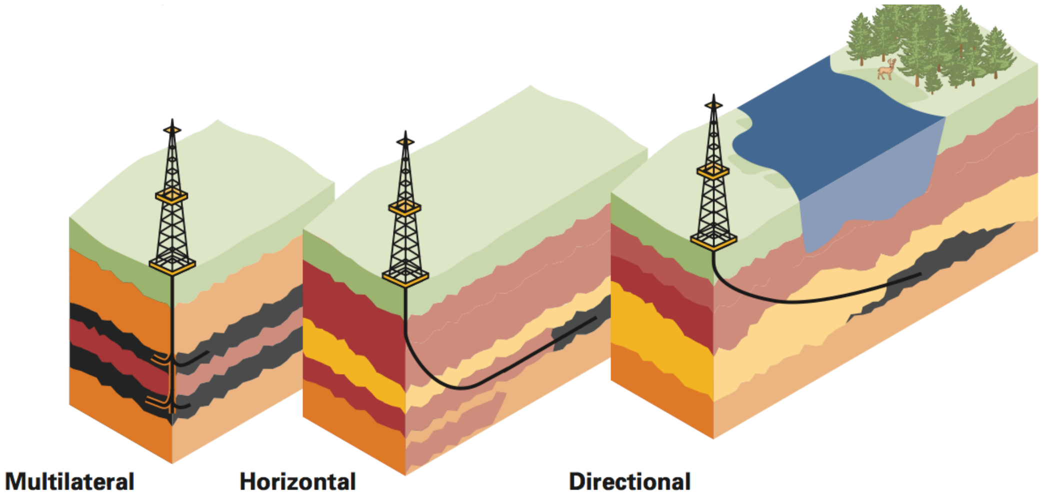
Dewatering

- Continuous dewatering is usually required to depressurise the seam and allow gas to move through the natural fissures in the coal
- The ratio of water to gas produced from a well may vary from more than 20 times to less than one tenth

Fracturing

- Fracturing or "stimulation" of coal seam to allow gas to move through the seam aiding extraction
- Required in about 10% - 40% of Vertical wells (Qld)
- Most common is hydraulic fracturing which uses large volumes of water often combined with sand, a viscoscity controler and other chemicals. Fraccing can also use gases such as air or carbon dioxide.

Figure 5 Stylised representation of various CSG drilling techniques



Source: US DOE Office of Fossil Energy, 1999

2.1 VERTICAL, LATERAL AND DIRECTIONAL DRILLING

Most often a CSG well is drilled to the top of the target coal seam and a production casing is set and cemented to the surface. The casing and cement provide structural integrity for the well and should isolate formations (e.g. aquifers) in the earth from each other and from the surface (Origin, 2011b p.1). The well is "completed" when connected to gas and water in the target formation.

Historically, drilling techniques similar to those used for conventional oil and gas exploration were adopted for CSG extraction, often with limited success (Kimber & Moran, 2004). More recently, directional and horizontal drilling has been used in order to gain access to large portions of a reservoir from a single drilling pad. Horizontal drilling greatly increases contact with the gas reservoir through increased wellbore contact; bore lengths of 1000m+ within a coal seam are achievable (Thomson et al, 2003 p.4; Rahman, 2011). A typical single vertical well (Figure 6) may drain gas from an area with a radius of between 200-400 m, whereas a single vertical well with six radiating horizontal wells can drain gas from an area with a radius of 1500 m (NSW DITRIS spokesperson, 2011).

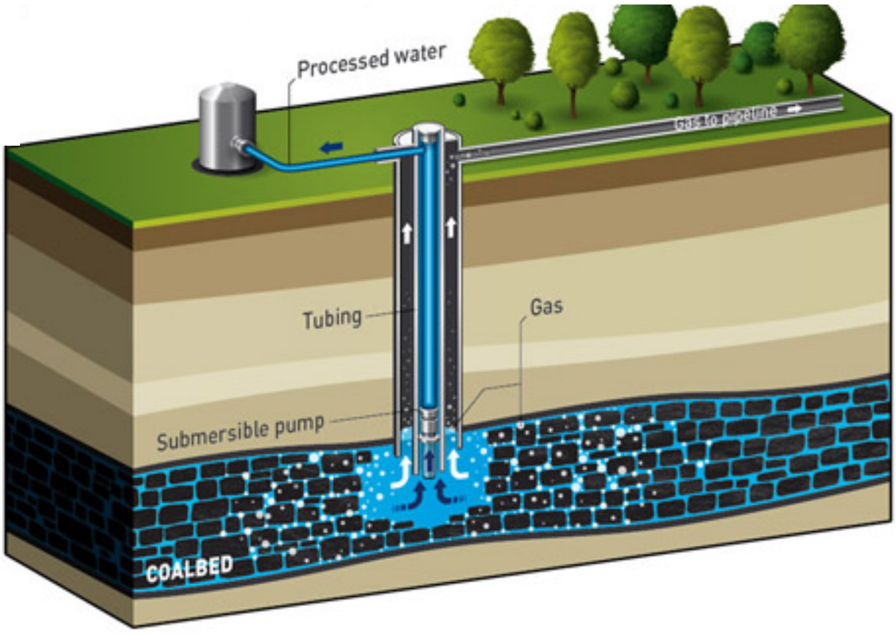
In the U.S. horizontal wells in one seam (generally single-lateral, but occasionally dual-lateral) commonly produce gas rates 3 to 10 times greater than those of vertical wells which have been hydraulically fractured in all the main seams. However, the cost for these wells range from 1 to 4 times that of vertical wells (Palmer, 2010 p.194; Keim et al, 2011 p.307). Horizontal wells are generally capital intensive, but they also tend to result in long-term, sustained production of methane (Keim et al, 2011 p.307), reduce the number of wells required, lessen surface disturbances and often improving overall project economics (US EPA, 2008. p.A4).

CSG exploration well spacing is relatively sparse with approximately one well per 30 km^2. Production wells however are generally spaced at some 600m–1200m with each well occupying a cleared area of around 6000 m^2 (Arrow, 2008. p.20; APPEA, 2011). Finished well pads can have a much smaller footprint, well pads containing 6 wells at the Camden AGL project occupying 120 m^2, after occupying 8000 – 12,000 m^2 during drilling operations (Roy, 2011).

Vertical wells within the NSW Camden Gas Projects take approximately one week to drill and horizontal wells take 25 – 28 days. Horizontal wells must be drilled 24 hours a day to ensure the drill bit does not become stuck in the coal seam (Roy, 2011).

Gathering wells are drilled into the deposit to collect the gas and typically a large number of wells are required (over 100 in most cases) to ensure a sustained and continuous gas flow (ABARE, 2002 p.17).

Figure 6: Stylised representation of CSG vertical well



Source: Total, 2011b

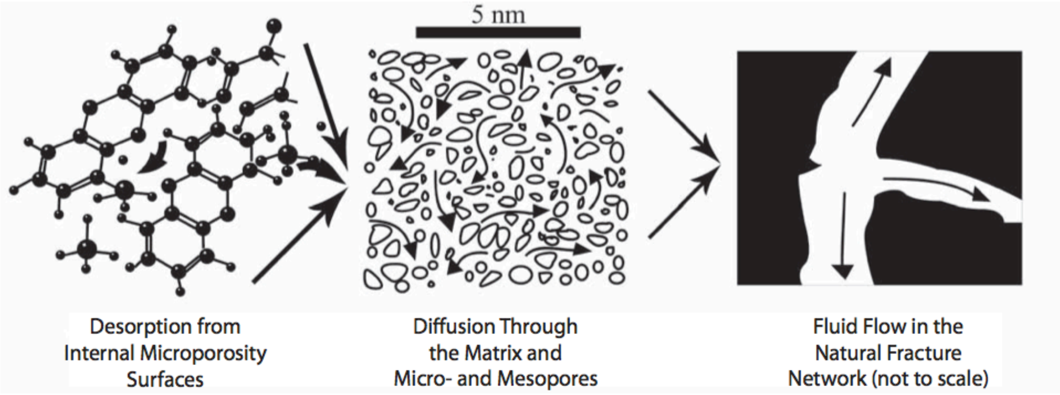
2.2 DEWATERING

Continuous dewatering is usually required to reduce the coal seam reservoir pressure and release the gas (ABARE, 2002 p.17). Prior to drilling into the coal seam, the system is in equilibrium i.e. the pressure from overlying rock and water kept the gas in place. Once the pressure in the coal seam is lowered the gas begins to desorb from the coal matrix and diffuse to the cleats (see Figure 7). Some wells may not be economical if too much water must be removed, as pumping and subsequent treatment and disposal of the produced water requires energy. Other wells cannot be dewatered sufficiently to release the gas, as they are constantly recharged from adjacent strata (All Consulting, 2004 p.10) – such wells are not economic and are generally sealed. If a CSG well is associated with a conventional gas trap, gas may flow freely from the well without the need for dewatering (Dallegge, 2000 p.6). The dewatering process can take anywhere from a few days to several months depending on the CSG well configuration (Maricic, 2005 p.1) and can take a number of years to reach peak production (All Consulting, 2004 p.16). Generally, the water production declines until the gas rate reaches the peak value (see Figure 8). Usually, the gas production curve of vertical and horizontal wells will differ significantly, horizontal wells dewatering the system more quickly (Maricic, 2005 p.2).

The amount of produced water from coal seam gas can vary greatly, in the US Powder River region values ranges from approximately 4,000 L/day to 63,500 L/day (All Consulting, 2004 p.19 Table 2). The ratio of water to gas produced from Queensland wells varies from more than 20 times to less than one tenth the amount of gas produced (Helmuth 2008) , and wells typically produce 5,000 – 20,000 L/day (Stone, 2011). The amount and the quality of the produced water can play a significant role in determining if a particular well is economic for gas production.

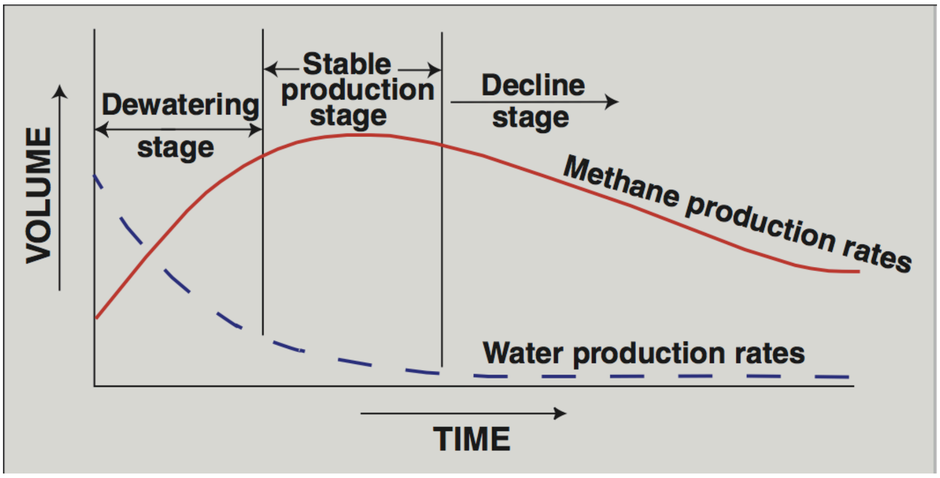
Dewatering, and the resulting produced water, is a key difference between extraction of shale gas and CSG. Shale is generally too impermeable to contain water, so does not have to be dewatered to produce the gas.

Figure 7 Desorption of CSG from coal



Source: CSUG, 2010

Figure 8 Typical changes in water and gas production over time



Source: USGS, 2000

2.3 HYDRAULIC FRACTURING

If the flow of gas from a well is insufficient the coal seam may be fractured to allow the gas to flow more freely. Hydraulic fracturing (fraccing) the coal seam produces cleats or fissures that increase its permeability, thus allowing gas to be released at a faster rate. It involves pumping large volumes of a fluid at high pressure down the well into the coal seam causing it to fracture for distances of up to 400m. The fluid, often but not always water, contains a "proppant" (to hold the fractures open) often sand, and a chemical solution that is varied based on drill site geology (All Consulting, 2008 p.9; US

Committee On Energy And Commerce, 2011 p.2) See Appendix 2 for details of typical chemicals used in fraccing.

Water is not the most effective carrier for the proppant and one of the roles of the additional chemicals is to make the mixture more “gel like” aiding proppant transport (DERM 2011c). Other additives include bactericides, pH control and chemicals to breakdown (reduce viscosity) of fraccing fluid following completion of the fracturing. The concentration of these chemicals is low (typically less than 1%) however large amounts of fraccing fluids are used (CSUG, 2011 p.19). For example, the Camden Gas Project uses around 225,000 L per well when fraccing using water and additives (Roy, 2011).

Some of the chemicals used in fraccing could damage the environment or pose a risk to human health if not disposed of safely or allowed to leach into the drinking water supply. Well failures, such as the use of insufficient well casing, could lead to the release of fraccing fluid at shallower depths, closer to drinking water supplies (US Committee on Energy and Commerce, 2011 p.3). There has been particular concern over the use of BTEX chemicals (benzene, toluene, ethyl-benzene and xylene) in fraccing fluids, however the use of these chemicals has been banned in both Queensland and NSW (see Section 5).

The sand carried in the water is deposited in the fractures and prevents them closing when pumping pressure ceases. The produced water and gas then moves through the sand-filled fractures to the well (AMA, 2011). The fraccing fluid is pumped back to the surface, but a substantial amount remains underground (US Committee on Energy and Commerce, 2011 p.3). The potential effect of sand remaining and keeping the coal cleats open over time are unknown.

The typical time to complete fraccing a well is one to three days (DERM 2011c).

Figure 9 CSG well being fracced at Gloucester gas project (NSW)

Photo courtesy of AGL

Since 2000 about 8% of CSG wells in Qld have been fracced, and the industry estimates between 10% and 40% of the vertical wells to be drilled to support the liquefied natural gas industry may be fracced (DERM 2011c).

A key element of successful hydraulic fracturing is proper well construction. During the drilling and completion process proper techniques must be used to ensure groundwater is isolated from the wellbore and protected from completion and production operations (CSUG, 2011 p.10). Fractures will extend in the vertical direction until they hit less brittle rock that acts as a containment layer and can extend horizontally for several hundred meters (CSUG, 2011 p.14). It has been suggested fraccing can result in vertical fracture growth into adjacent formations potentially resulting in excess water production and inefficient depressurization of the coal seam (Colmenares and Zoback, 2007). It should be noted it is counterproductive to extend fractures past the coal seam as this may allow entry of additional water that must be removed before gas can be produced. For this reason the type of hydraulic fracturing used depends on many variables including the well (vertical, horizontal), rock characteristics, well construction and cost of fraccing materials (CSUG, 2011 p.3). Fraccing can increase the gas extraction rates, often more than 10 times (CSIRO research fact sheet, 2010), but adds substantially to the cost of production (Kimber & Moran, 2004 p.5). Fraccing may be used in both lateral and vertical drilled wells, although in the Camden project is only used in vertical wells (Roy, 2011).

Fraccing has attracted a great deal of criticism (for example, Lloyd-Smith & Senjen, 2011). Fraccing techniques are extremely complex, including a considerable range of practices, and it is beyond the scope of this paper to examine how fraccing can be carried out to minimise environmental harm.

Hydraulic fracturing is not always undertaken to extract CSG, and current estimates in Queensland are that fraccing may eventually be undertaken in 10 – 40% of wells. By contrast, extensive fraccing of shale wells is always required, as there are very few natural fractures or cleats within the rock. Shale is also a much harder rock, so that fraccing in shale typically requires 25,000 – 35,000 horsepower, compared to 4000 – 5000 horsepower in CSG wells (Roy 2011).

Much of the concern about fraccing has arisen from shale gas extraction, rather than CSG extraction, even though the CSG industry has been operating for longer (for example, Riverkeeper 2010a and 2010b), and most of the international action to restrict the practice has specifically concerned shale gas (see Appendix 10).

3 ENVIRONMENTAL IMPACTS

The major potential environmental effects of CSG can be summarised as:

- Groundwater effects, which may include depletion or contamination of surrounding aquifers,
- Subsidence as a result of large scale extraction of produced water and depressurization of the coal seam,
- Changes in water availability from depressurization in adjacent aquifers,
- Surface water effects, generally arising from disposal of produced water,
- Hazardous waste, resulting from either treatment of produced water or drilling muds,
- The surface footprint of the mining process, including noise, night time lighting, traffic, access routes, and dust.
- Direct greenhouse gas emissions (known as 'fugitive' emissions) of methane or CO_2,
- Air pollutant emissions from the drilling operations, and
- Land use conflicts between resource extraction and agriculture, urban amenity, or high conservation value areas.
- Water consumption for hydraulic fracturing.

Most of the concern regarding human health has been because of potential or proven groundwater contamination, in particular contamination of drinking water wells. Much of this concern centres on shale gas extraction, rather than CSG extraction (for example, Riverkeeper 2010a and 2010b). However, there been some documented water pollution events arising from coal seam gas extraction in the US (US EPA 2004).

Actual environmental effects, particularly those on groundwater, will vary according to the geology of the coal seam itself, the geology of the surrounding rock strata and the connectivity or otherwise with the coal seam, the techniques used for extraction, and the application or otherwise of remediation and control techniques.

The need to 'dewater' coal seams to depressurise the gas results in large volumes of produced water. This gives rise to potential subsurface issues from depressurization, and to surface issues in the handling, disposal and use of produced water, which is often saline. The quantity of produced water in Queensland CSG extraction sites varies enormously, from a ratio of 22:1 water to gas to only 0.1:1 (Helmuth, 2008). The quality of water also varies considerably (DERM 2011b).

It is beyond the scope of this paper to identify the characteristics of low and high risk sites or techniques, to identify best practice, or to determine whether sufficient mitigation is possible for the identified issues. However, these are crucial issues that need to be better understood as a matter of priority.

The lifecycle greenhouse emissions of CSG have also raised concerns, particularly because the need to reduce carbon emissions is one of the main drivers for the expected expansion of gas consumption, and therefore the CSG industry. Recent studies of the life cycle emissions of conventional and unconventional gas are discussed below in Section 3.3.

3.1 WATER EFFECTS

Groundwater effects may arise if there is connectivity between the coal seam and under- or over-lying aquifers, which may potentially be increased if coal seams are hydraulically fractured. The scale of the potential for contamination will be significantly determined by the geological formation. For example, whether the coal seam is above or below the aquifer and the characteristics of the intervening strata will have a material effect on the risk. The Centre for Water in the Minerals Industry has done a scoping study in Queensland to characterise different coal measures and locations as higher or lower risk, but this has not been undertaken for NSW (Helmuth, 2008). The two main concerns regarding groundwater are depletion and contamination. The major issues are:

- **Depletion**: over time the removal of large amounts of water to depressurise the coal seam to extract the gas may result in inflow from the surrounding strata. As CSG production may become a very large industry, this could have a considerable cumulative effect on aquifers. In some cases this can be mitigated by re-injection of produced water, and in some instances the time horizon for recharge from adjacent aquifers will be sufficiently long because of the impermeability of the coal or the surrounding strata that this will not be a significant issue.

- **Contamination** can result from increasing the flow between the coal seam and the aquifer. This could happen as a result of poor containment of the drilling, as 80% of wells involve drilling through aquifers (SMH, June 18th 2011). Contamination could occur if fraccing is carried out, through fractures propagating outside of the coal beds and allowing communication between the coal and the overlying formation. Contamination from fraccing is of concern because of the mixture of chemicals used in the fraccing fluid (see Appendix 2), but also because of the chemicals in the coal seam and the methane itself. Extraction techniques and fluids vary considerably, and this may be an area where appropriate regulation could mitigate the potential impact.

- **Produced water:** The production of large volumes of treated waste water, if released to surface water systems, could alter natural flow patterns and have significant impacts on water quality, and river and wetland health. There is an associated risk that, if the water has all contaminates removed from it, 'clean water' pollution of naturally turbid systems may occur (National Water commission, 2010). This is covered in more detail below.

- **Water consumption:** hydraulic fracturing consumes significant volumes of water, in the order of 0.2 – 0.6 ML of water per well (Roy, 2011). Produced water from wells may meet some of this demand, but there are likely to be situations where additional water is required.

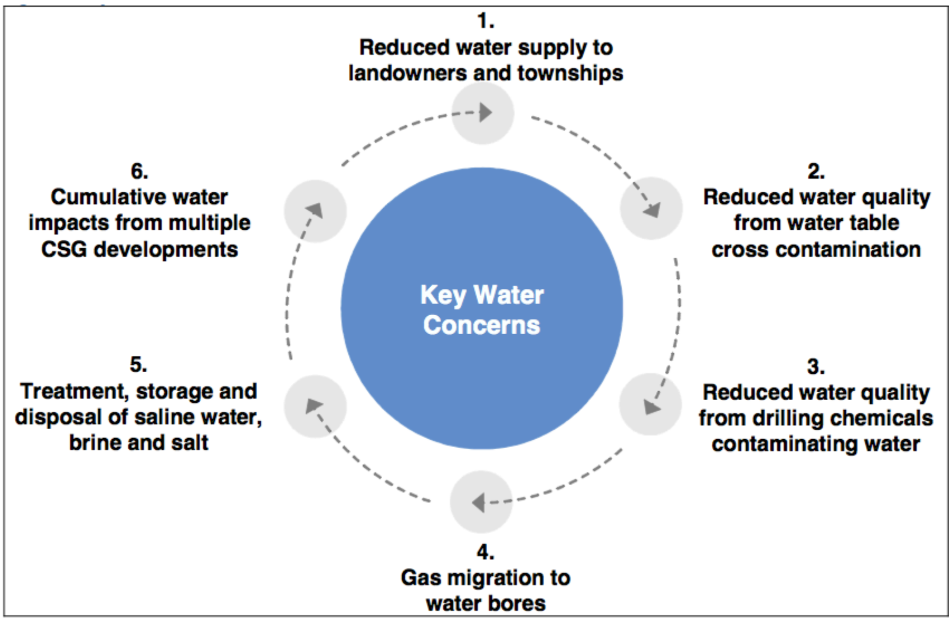
JP Morgan (2010, p.10) identifies six key concerns regarding CSG and water, presented in Figure 10. Three of these issues relate to produced water. Extensions of the above concerns include soil and agricultural salinity issues and alteration of local ecological systems, especially with surface release of water and ground subsidence following dewatering (US Committee on Produced Water, 2010 p.5).

The Queensland Department of Environmental and Resource Management started comprehensive reporting on CSG monitoring and enforcement this year, with more than 4000 CSG wells in their jurisdiction. During the first six months of 2011 there have been 36 incidents of possible water contamination: 23 spills of produced water, 6 sewage overflows from temporary work camps, and 4 uncontrolled releases of produced water or permeate (treated produced water), and 3 breaches of produced water storage during floods (DERM, 2011d).

Two incidents of concern relating to water contamination from BTEX chemicals have been reported widely, although in both cases the companies involved maintain that they do not use BTEX chemicals in their fraccing fluids:

- Origin Energy / Australia Pacific LNG (APLNG) announced in October 2010 the discovery of BTEX traces in fluid samples in eight CSG exploration wells west of Miles (in Queensland). The samples were taken from exploration wells that had been stimulated by hydraulic fracturing. The concentration of BTEX identified was very low and restricted to eight wells.
- Arrow Energy announced in November 2010 that traces of benzene were detected in two wells in Moranbah tenure (Queensland), and one in an adjoining exploration tenement. Independent testing is being undertaken to determine if the traces of benzene are naturally occurring or entered the water via other means. The company is also testing water bores closest to the affected wells.

Figure 10 Six key CSG water concerns (JP Morgan, 2010 p.10)



Information on incidents from coal seam gas operations is not comprehensively available. The US EPA invited the public to comment on water contamination from CSG hydraulic fracturing activities, and published a report in 2004 on the complaints and the outcomes of State agency investigations (US EPA 2004). The report confirmed actual and suspected water contamination in two of the Basins. The complaints and investigation outcomes are summarised below:

- San Juan Basin (Colorado and New Mexico), the EPA reports CSG activities to be likely cause of elevated methane levels in local drinking water wells, soil methane seeps, and for explosive methane levels in some residences. It found evidence of connectivity between the coal seams and the aquifer such that there could be movement of hydraulic fracturing fluid, although it could not confirm whether this had actually taken place. Poorly sealed abandoned wells and poor sealing between the casing and the walls of some wells was found to be responsible for at least some of the incidents.

- Powder River Basin (Wyoming and Montana): there are reports of aquifer depletion resulting from extraction of produced water from approximately 2000 wells in the Basin, resulting in aquifer levels falling approximately 70 metres, as well as subsidence and clinker beds forming from surface coal beds catching fire and continuing to burn because of the lack of groundwater.

- Black Warrior Basin, Alabama: while there are a number of reported contamination incidents from hydraulic fracturing fluid surface discharge and methane contamination, the State Agency investigations concluded contamination did not result from CSG activities.
- Central Appalachian Basin (Virginia and West Virginia): more than 70 complaints were received regarding both water loss from wells and contamination. The State agency follow up concluded that CSG activities were not responsible.

3.2 PRODUCED WATER

The need to dewater coal seams to desorb and extract the natural gas results in large volumes of produced water. The quality and quantity of produced water is determined largely by the geologic and hydrologic characteristics of the target coal seam.

Potential depletion effects on aquifers are largely determined by the degree of hydraulic connectivity between water-bearing coal seams targeted for CSG production, overlying and underlying aquifers and surface water. Hydraulic connectivity relates to the amount of produced water but also the time taken to replenish or recharge a depleted aquifer from its surroundings (US Committee on Produced Water, 2010 p.3).

A large proportion of Queensland's CSG resources are in the Surat and Galilee basins, which form part of the Great Artesian Basin (GAB). The GAB currently provides the water which allows a major part of arid Australia to form productive grazing land (Parsons Brickenhoff, 2004)

The *Coal Seam Gas Water Management Study* undertaken for the Qld Department of Natural Resources, Mines & Energy in 2004 by Parson Brickenhoff highlighted the lack of baseline monitoring data available to for CSG groundwater impact studies. This study suggested the Walloon Coal Measures, the CSG target within the Surat basin, was not hydraulically connected to the GAB aquifers, but that this could not be confirmed without site specific hydrological data (Parsons Brickenhoff, 2004).

A more recent study, on the impacts of the proposed CSG operations on surface and groundwater systems in the Murray-Darling Basin, provides evidence of hydraulic connectivity between the Walloon Coal Measure and some GAB aquifers based on bore water levels and water quality data (Moran & Vink, 2010 p.3). The modeled draw down effects were small relative to draw down due to water extraction for agricultural purposes in recent decades, but significant given the projected growth and potential cumulative impact of CSG operations. Significant gaps in our knowledge of the system and modeling currently used to assess the impacts of CSG extraction are highlighted and a call for further research made (Moran & Vink, 2010 p.3).

Helmuth (2008 p.11) asserts it is highly likely that the CSG companies hold information that can be used to fill some of the key knowledge gaps and uncertainties in current hydraulic connectivity modeling. The Queensland Water Commission now requires CSG companies to supply it with this information, so that a more complete assessment can be made.

The Australian National Water Commission considers that the potential impacts of CSG developments, particularly the cumulative effects of multiple projects, is not well understood (NWC, 2010 p.1).

A similar experience is shared in the US CSG industry (called Coal Bed Methane, or CBM, in the US) where a lack of knowledge of aquifer recharge characteristics and the hydraulic conductivity of target formations has contributed to uncertainty in understanding the consequences of long-term produced water withdrawals (US Committee on Produced Water, 2010 p.4). The US Committee on Produced water (2010 p.4) recommends the "age" of produced water be determined and used as a measure of how renewable a particular water resource is. They recommend the "renewability" of the water in potentially affected aquifers should be included in the development and implementation of CSG produced water management regulations (US Committee on Produced Water, 2010 p.4). (Kinnon et al, 2009 p. 219).

The quality of produced water varies considerably. Salinity is usually measured as dissolved solids, with drinking water having up to 500 mg per litre and sea water 36,000 – 38,000 mg per litre (DERM, 2011a). Produced water in Queensland varies from less than 200 mg per litre to over 10,000 mg per litre (DERM, 2011a), and has historically averaged 5,000 mg per litre (Stone, 2011) . Water may also contain a range of chemicals, either from drilling or fraccing activities, or from the coal seam itself.

Approximately 450 gigalitres of groundwater is extracted from the entire GAB per year for domestic, agricultural and industrial purposes. Projected CSG activities in Queensland's Surat and Bowen Basins are estimated to extract between 125 - 350 gigalitres of water per year or an additional ~30% - 80% of current water extracted (JP Morgan, 2010 p.6; NWC, 2010). This is a significant cumulative impact from CSG extraction.

Water production generally falls and gas production increases rapidly after extraction commences. The quantity of produced water in Queensland CSG extraction sites varies enormously, from a ratio of 22:1 water to gas to only 0.1:1 (Helmuth, 2008). In situations where water production stabilizes at higher levels, it is very likely the water is being recharged from adjacent aquifers, i.e. it is not just coming from the coal seam. It may be that consent conditions need to refer to the water production profile of the coal seam, with trigger levels set for review of the approval, as the production profile will often not be known prior to extraction commencing. This may be addressed by amendments to the Water Act (Qld) 2000 which sets trigger values for impacts on bore water and aquifers.

US CSG water to gas ratios range from 213 L/m^3 to 9,375 L/m^3 (0.038 barrels/MCF to 1.67 barrels/MCF) Attempts at methane extraction in one-sixth of the Powder River Basin fail because water-to-gas ratios are excessively high, compared to other parts of the basin (US Committee on Produced Water, 2010 p.34).

Options for CSG produced water disposal and storage include deep-well reinjection, storage in lined surface impoundments, direct discharge to surface waters, and surface irrigation. Potential beneficial use applications include livestock and wildlife watering, subsurface drip irrigation, in-stream flow augmentation, wetlands augmentation, and industrial and municipal uses (US Committee on Produced Water, 2010).

The Queensland Government provides guidelines on the use of produced water, as follows (DERM 2011a):

- **Category 1 – preferred management options:**
  - injection where detrimental impact is unlikely
  - untreated use where detrimental impact is unlikely
  - treatment to an agreed standard for agricultural, industrial and potable uses (listed uses are aquaculture, coal washing, dust suppression, industrial use, and irrigation).

- **Category 2 – non-preferred management options:**
  - disposal via evaporation dams
  - disposal via injection where detrimental impact is likely
  - disposal to surface waters
  - disposal to land.

The US CSG experience with produced water shows the cost of treatment and beneficial use of produced water almost universally results in a net cost for the CSG producer compared to disposal, which contributes to the small proportion of the produced water being put to beneficial use under current US regulation (US Committee on Produced Water, 2010 p.5). The technology exists to treat produced water to any desired water quality but the majority is being disposed of using the least cost option rather than employing it for beneficial use (US Committee on Produced Water, 2010 p.7).

Parson Brinkerhoff provide a good overview of impacts, management and treatment options (Parsons Brickenhoff, Coal Seam Gas Water Management Study, 2004 p.xii and xix), and JP Morgan gives a good summary of the advantages and disadvantages of different uses (JP Morgan, Water Concerns: QLD Coal Seam Gas Developments Report Summary, 2010 p.22)

3.3 CSG, CONVENTIONAL NATURAL GAS AND COAL – GREENHOUSE EMISSIONS

One of the main drivers for the increase in natural gas use is the need to reduce greenhouse gas emissions, as gas has generally been considered to offer considerable greenhouse reductions compared to coal, in the order of 40 – 80%. Gas has commonly been seen as a transition fuel as the electricity sector decarbonizes, both because of its lower emissions profile and because gas offers more flexible operation as gas generation can start and stop much more quickly than coal.

The emissions reduction relative to coal has been questioned recently, with some authors suggesting that emissions from gas are similar or worse than from coal (Howarth 2010, Howarth et al 2011). If gas does not offer a significant greenhouse gas emissions advantage compared to coal there is little environmental benefit achieved by the transition to gas.

There are two distinct questions raised regarding the emissions effect of gas:

1) Does gas, and coal seam gas in particular, have a significant emission benefit compared to coal fired electricity?
2) Is the strategy of using gas as a ‘transition fuel’ justified, and will it reduce emissions overall?

Recent controversy over the emissions comparison between gas and coal revolves around three issues, the correct Global Warming Potential (GWP) to use for methane, the correct time horizon to use for the GWP, and whether fugitive emissions have been correctly estimated. These questions are explored below.

3.3.1 THE GLOBAL WARMING POTENTIAL OF METHANE

Greenhouse gasses are assigned a global warming potential (GWP), which is the warming effect of that gas compared to carbon dioxide (CO_2); CO_2 has a GWP of 1. The IPCC gives GWPs for gases at time horizons of 20, 100 and 500 years. Methane has a lifetime of about 12 years in the atmosphere, much shorter than CO_2, which may last for 1000s of years (IPCC 2007). Methane has a GWP of 72 at the 20 year horizon, 25 at the 100 year horizon, and 7.6 at the 500 year horizon (IPCC 2007)[20].

Which time horizon is appropriate to use? National and international accounting currently uses the 100 year horizon, which gives methane a GWP of 25. However, as the next couple of decades are critical for warming, Howarth (2011) argues that the 20 year time horizon may be more appropriate.

[20] The GWP of 25 has been revised upwards since the IPCC Second Assessment Report (1995), which gave a GWP of 21 (100 year horizon). The Australian NGA (DCCEE 2011) still uses the GWP of 21, but 25 is used in this report

The CO_2 will persist in the atmosphere for several hundred years more than methane. However, looking at the next half century, substitution of methane emissions for CO_2 emissions on a like for like basis using the 100 year horizon would seem to exacerbate warming considerably.[21] The issue of which time horizon is appropriate can best be determined by climate modelers, but in the interim some comparative studies have started presenting both calculations (e.g., Howarth 2011, Fulton et al 2011b), although most use the 100 year horizon to present their main findings.

One study suggests that the actual GWPs of methane at both time horizons is higher, mainly due to sulfate and other aerosol interactions, and puts forward GWPs of 33 at the 20 year horizon, and 102 at the 100 year horizon (Shindell et al, 2009). The IPCC values of 25 and 72 are used here, other than in the reported data from Howarth (2011), which uses the higher values from Shindell et al.

3.3.2 FUGITIVE AND UPSTREAM EMISSIONS FROM CSG

Life cycle emissions from gas and coal include emissions from combustion, so called 'fugitive' emissions (escapes or flared or vented gases), and upstream emissions from consumption of fossil fuels during extraction, processing, and transport.

Combustion emissions are relatively easy to calculate for both coal and gas, and generally dominate the emissions profile. Combustion GHG emissions are nearly all CO_2, the main product from burning both methane and coal.

Fugitive emissions may be either methane from leaks or escapes, or from venting gas rather than flaring (also called "cold venting"). If gas is flared, the methane is burnt and emissions are CO_2, with a resulting reduction in GWP. There may also be direct venting of CO_2 (generally more of an issue for conventional gas), and some nitrous oxides. Fugitive emissions associated with coal are dominated by the methane which escapes when the coal is mined.

Fugitive emissions from the Australian gas sector are projected to average 10.7 MT (million tonnes) from 2008–2012, with 8 MT a result of venting and flaring. This is about 2% of total Australian emissions (this is the whole gas sector, not just CSG) (DCCEE 2010). These emissions are projected to double by 2020. Fugitives from coal are currently 31 MT, and are expected to reach 48 MT by 2020.

The most recent Australian National Greenhouse Accounts (DCCEE 2011) gives values for Scope 3 (fugitive) emissions for natural gas of between 4 and 15 kg CO_{2e} /GJ for natural gas, which includes coal seam gas. The figure for NSW is 14.2 (metro areas) and 15 (non-metro areas). No separate figure is given for coal seam gas, but Queensland has lower values than NSW, at 7.8 – 8.6 kg CO_{2e}/GJ. As Queensland has 80% CSG in their gas supply compared to 6% in NSW, this would indicate that the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) calculates CSG emissions as lower than conventional gas when long transport distances are taken into account. However, the detailed methodology for the calculations is not available.

The USA EPA revised their methodology for estimating fugitive emissions from natural gas operations in 2011, with an increase of 120%, primarily because of emissions associated with unconventional gas (US EPA 2011, reported in Fulton et al, 2011a).

Direct measurement of life cycle GHG emissions from CSG in Australia is required to reach firm conclusions on the scale of the GHG benefits from CSG compared with coal. There are certainly

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[21] If methane with GWP equivalent to a unit of CO_2 using the 100 year horizon is emitted each year, the actual warming effect of the methane is double the warming effect of the CO_2 after 20 years. It reaches parity after 40 years, after which the CO_2 has a greater effect.

differences in the life cycle emissions of conventional gas and CSG, simply because the production is different. For example, large amounts of produced water require treatment and disposal, which will consume energy; the drilling practices are different; and the expected output from a well is different so that upstream emissions may be relatively higher compared to output. Unfortunately there is a dearth of studies looking specifically at the emissions of CSG.

3.3.3 EMISSIONS FROM CONVENTIONAL GAS, CSG, AND COAL

There are a number of recent studies comparing emissions from natural gas and coal, although unfortunately none of them have focused on Australian coal seam gas for domestic consumption. However, a Citi Group report looked at emissions of CSG exported as LNG (Prior, 2011). Four of the studies examined conventional gas, shale gas, and coal, while one looked at the US gas mix, which includes approximately 80% conventional gas, 15% shale gas and 5% CSG. There is a need to calculate the life cycle emissions from Australian CSG projects.

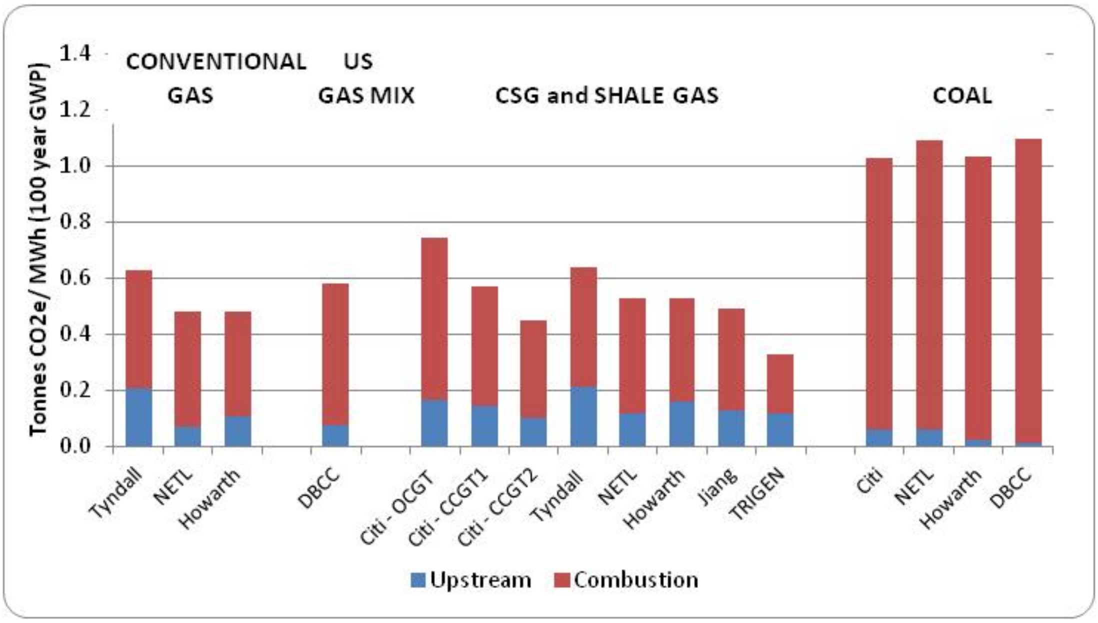
The results summarised here use data sourced from six studies:

- **CITI:** published Citi Group (Prior 2011). The study examined emissions from coal seam gas production for LNG, and included processing to LNG, shipping internationally, and reprocessing in the import country. The data reproduced here is for gas used in an open cycle turbine (CITI OCGT), with conversion efficiency of 39%, and the highest and lowest calculations for gas used in combined cycle turbines, with efficiency of 53% (the calculations are for different CNG projects, and are graphed as CITI CCGT 1 and CITI CCGT2). The emissions associated with regasification and shipping have been excluded from the results. Production emissions may still be higher in this data than CSG for domestic use, as processing to LNG requires more energy input than processing to inject in a pipeline. The Citi emissions calculation for current coal generation assumes 33% conversion efficiency.
- **DBCC**: study published by Deustsche Bank Climate Change Advisors and Worldwatch institute (Fulton et al, 2011b). The study reviewed current best evidence on natural gas emissions, and did a top down calculation for the current emissions from the US gas supply (approximately 80% conventional gas, 15% shale gas, and 5% CSG). They presented results for both 20 year and 100 year GWP time horizons.
- **HOWARTH**: presents a study of the emissions from conventional gas, shale gas, and coal, and presents high and low estimates (Howarth et al, 2011). Howarth uses higher GWPs than the other studies, of 33 and 105 at the 100 year and 25 year horizon respectively. The averages of the low and high results are presented for shale and conventional gas, and the low result from coal (the low result is for surface mining, which is more common is Australia). The results in Howarth did not include figures for gas and coal generation, so the data has been adjusted to account for conversion efficiencies, using 53% for gas and 33% for coal (from Prior, 2011).
- **NETL**: published by US National Energy Technology Laboratory (Skone 2011), the presentation gives detailed results of a life cycle analysis of gas extraction and delivery in the US, and separates results into conventional and shale gas. The study gives results using both 20 and 100 year GWPs.
- **JIANG:** detailed study of the life cycle emissions from Marcellus shale gas, including a comparison with coal combustion (Jiang et al, 2011). The study did not include figures for gas and coal generation, so the data has been adjusted for conversion efficiency, using the Citi group efficiencies (53% for gas generation, 33% for coal generation).
- **TYNDALL:** a provisional assessment of the environmental impacts of shale gas in the UK (Wood et al, 2011), published by the Tyndall Centre for Climate Change at the University of Manchester.

The study did not include emissions from generation, so the Citi group estimates have been used (Prior 2011)

- **TRIGEN:** the data from NETL has been replicated using a conversion efficiency of 80% for use of gas in a trigeneration engine, instead of the 47% assigned to gas generation in the NETL study.

Figure 11. Emissions from conventional gas, CSG, shale gas, and coal used for domestic electricity production (GWP time horizon of 100 years)



Note: only the three CITI studies are for coal seam gas. CITI –OCGT has significantly higher emissions because it is for CSG used in an open cycle turbine, rather than a combined cycle turbine.

Figure 12. Emissions from conventional gas, shale gas, and coal used for domestic electricity production (GWP time horizon of 20 years)

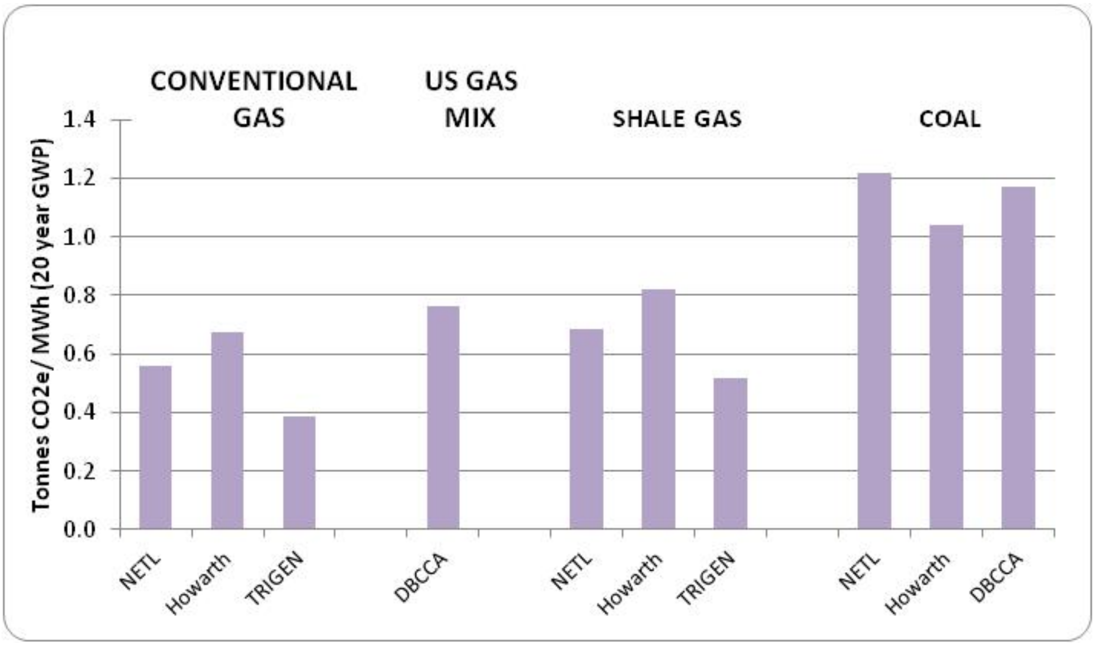


Figure 11 and Figure 12 show the comparative emissions of conventional gas, shale gas, and coal. Data is taken from six recent studies, adjusted to common units and to include the conversion to generate electricity where this was missing in the original data. Figure 11 uses the 100 year and Figure 12 the 20 year GWP for methane.

Using the 100 year GWP, shale gas used in a combined cycle gas turbine is shown to have a benefit of between 39% and 59% compared to coal. Trigeneration has an average benefit of 69%, and open cycle gas turbines of 30%[22].

Using the 20 year GWP for methane, the difference between coal and gas generation is smaller, as a much greater proportion of the emissions associated with gas are methane. The benefit for conventional gas ranges from 35% to 54% in the different studies, and for shale gas from 21% to 44%. Trigeneration has a benefit of about 54%. Only four studies undertook the analysis using the 20 year GWP for methane.

The estimates for shale gas are likely to be higher than for coal seam gas, as the most emissions intensive stage of unconventional gas extraction from shale is the flowback period after hydraulic fracturing (Howarth 2011, Prior, 2011). The process is very different for CSG. Firstly, only a proportion of wells are fractured, unlike shale gas where hydraulic fracturing is used in all wells. Secondly, there is very unlikely to be any gas production with flowback water, as produced water is generally extracted for weeks or months to depressurise the coal seam before gas production commences. Howarth (2011) puts the emissions during well completion as equal to 1.9% of the lifetime gas production of a well, with these dominated by flowback emissions. As explained, these emissions would generally not occur with coal seam gas.

Three studies that allow comparison show unconventional gas (including both CSG and shale gas) has life cycle emissions between 1% and 11% higher than conventional gas. However, the greatest proportion of upstream emissions in shale gas is from flow back after fracturing. As noted, these are unlikely to occur with CSG.

Most studies also stress that methane emissions from gas production can be reduced significantly by industry best practice, for example Howarth (2011) notes that reduction from gas production emissions of 40% - 90% are possible, and the Deutsche Bank study (Fulton et al, 2011b) notes the US EPA is proposing regulation to mitigate emissions from well closure. Certainly a carbon price and regulation requiring monitoring and reporting will put downward pressure on fugitive emissions.

3.3.4 WILL USING GAS AS A TRANSITION FUEL REDUCE EMISSIONS OVERALL?

The use of gas as a transition fuel has been assumed in most low carbon projections. However, the validity of this approach has been questioned recently, with concern that a new, large, relatively cheap source of fossil fuels such as coal seam gas is as likely to displace renewable energy development as to displace coal fired generation. While gas, including CSG, has an emissions benefit relative to coal fired generation, it is certainly not sufficient to reach the emissions targets necessary to keep climate change within 2^{o}C, or to outweigh the worldwide growth in energy consumption. The OECD/IEA World Energy Outlook 2010 presents a ‘450 ppm’ scenario, which shows gas demand peaking before 2030, and does not emphasise the role of fuel switching.

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[22] The average is given for open cycle and trigeneration as data from only one study is used, and the difference is only due to different calculations for coal emissions.

A UK Tyndall Centre report (Wood et al. 2011) included an estimate of the effects of unconventional gas exploitation on world emissions to 2050. It found that exploitation of 20% of the world's estimated recoverable resource of unconventional gas by 2050 would add an estimated 11ppm CO_{2e} to the atmosphere by 2050 (Wood et al, 2011). Without an effective international cap on emissions there is little price incentive to go to lower carbon fuels, and the intensive development of unconventional gas resources may simply provide a further cheap source of fossil fuels, and divert investment from lower emission energy sources. This is an issue for national and international climate policy, but certainly development of large unconventional gas resources in the absence of effective targets is unlikely to reduce emissions.

3.4 POTENTIAL SOCIAL AND HEALTH IMPACTS

The potential social and health effects may be summarised as:

- Adverse effects from fraccing and/ or drilling chemicals, with the most likely pathway to human consumption via water contamination. Potential effects on the endocrine (hormone regulation) system have been highlighted as these may occur at very low concentrations (Colburn et al, 2010).
- Adverse effects from the so called 'BTEX' chemicals (benzene, toluene, ethyl-benzene and xylene). These have been banned from use in fraccing fluids in both Queensland and NSW, but could potentially be present in the coal seam gas in very low concentrations, and become mobilized by the gas extraction (note that these chemicals are also present in conventional gas, generally at higher concentrations).
- Air pollution from treatment of produced water.
- Land use conflicts with housing agriculture, and potential effects on water availability,
- Conflict over proposed development in urban environments, particularly near housing,
- Effects of surface infrastructure, including noise, traffic, and dust.
- The potential for a drop in property values from proposed or actual development CSG.

A more extensive discussion of potential health impacts may be found in Doctors for the Environment Australia (2011), Lloyd Smith and Senjen (2011), and Colburn et al, 2010. A discussion of chemicals sometimes used in natural gas operations may be found in TEDX 2011.

3.5 EXPERIENCE IN AUSTRALIA TO DATE

There has been a coal seam gas industry in Australia for over a decade. Commercial production started in 1996, although exploration commenced in 1976 (Baker and Slater, 2008). Queensland has far more activity, with numbers of wells perhaps ten times greater than NSW. An overview of the experience with these projects is given below. We have used information from four sources:

- Queensland government information and fact sheets,
- A brief review of CSG issues highlighted in the media, as an indicator of community concerns. We have tried to include individual incidents once only, and to record CSG related *incidents*, rather than concerns. Tabulated results of this review are provided in Appendix 3
- Records of complaints and actions from NSW and Queensland regulatory agencies, and

- Environmental performance reports and independent environmental audits from the most advanced NSW project.

3.5.1 EXPERIENCE IN QUEENSLAND

The Queensland coal seam gas industry has experienced remarkable growth over the last 15 years. The number of coal seam gas wells drilled annually has increased from 10 in the early 1990s to over 600 in 2009–10. (DEEDI, 2011a p.1). As of September 2011 the total number of CSG wells drilled in Queensland is approximately 4489 (DEEDI 2011b). CSG production is concentrated in the Bowen and Surat basins.

A large driver for the expansion of CSG in Queensland is the proposed liquefied natural gas (LNG) export industry to be based in Gladstone (DEEDI, 2011a p.1). As at February 2011, three of the proposed LNG projects, the Gladstone Liquefied Natural Gas Project, the Queensland Curtis LNG Project, and the Australia Pacific LNG Project, had received state and federal government environmental approval.

To develop a picture of the community concern with CSG in NSW, ISF approached the Qld State Government agencies (Table 2) responsible for the regulation of the CSG industry, as shown in Table 2.

Table 2 Qld Government Agencies involved with CSG regulation

Government Agency	Role
Department of Employment, Economic Development and Innovation (DEEDI)	Manages licensing and land access *
Department of Environment and Resource Management (DERM)	Environmental and groundwater issues *

* Following the formation of the LNG Enforcement unit this year, the roles and responsibilities of each agency are no longer as defined (http://www.derm.qld.gov.au/link/2011issue05/csg_unit.html)

DERM was able to supply the majority of the CSG complaints data requested in a timely manner without the need for a formal request (Right To Information). In addition, as of this year DERM report much of the complaints information sought for this report in their biannual CSG/LNG Compliance update. The update details compliance activities carried out by DERM under the CSG/LNG Compliance Plan released in May 2011, and includes audits, inspections and complaints management reporting. The major results for January 2011 to June 2011 are summarised below:

Inspections: DERM conducted 11 inspections of level 1 activities and 20 inspections of level 2 activities. DERM officers found companies were meeting environmental compliance at the time of audits. There were no warning letters or Penalty Infringement Notices (PINs) issued across the level 1 activities audited. To put the number of inspections in context, indicative numbers of level 1 activities (taken as wells in development) and level 2 activities (taken as exploration wells) are 2148 and 1064 respectively in 2011.

Audit follow-up and enforcement: DERM has issued three warning notices as a result of detecting low level non-compliance during proactive compliance activities. The warning letters related to matters such as inadequate refueling areas, insufficient soil erosion and sediment control measures and lack of faunal ladders in water ponds.

Unscheduled audits and inspections of CSG operators: Between 1 January 2011 and 30 June 2011 there have been 45 compliance related incidents. (This does not incorporate enquiries and complaints, which are reported separately). Of the 45 compliance related matters, 21 matters had been finalised as of 30 June 2011 and 24 matters were current.

Incidents, broken down by type, are shown in Table 3.

Table 3 Incidents by type Jan - June 2011

Type of Incident	Number of Incidents	Percentage of Total
Spills Releases of CSG water during operations account for the largest incident type. These spills typically occurred during drilling activities or resulted from opened/faulty valves within pipework.	23	51%
Sewage Gas field operating staff reside at base camps across the gas fields, and these temporary camps have had several incidents from sewage overflows from associated latrines.	6	13%
Discharge These incidents involved the controlled or uncontrolled release of coal seam gas water or permeate to the environment.	4	9%
Overflow (flooding) During the January 2011 floods, several CSG water storage dams breached the dam banks.	3	7%
Exceedance release limits Discharge limits are set on environmental authorities and these limits were exceeded on several occasions.	3	7%
Noise Complaints were received by adjacent landholders of CSG activities. Conducted noise monitoring showed acceptable levels. (These complaints were received by the Pollution Hotline or through DERM Environmental Services)	2	4%
Other (vegetation clearing, BTEX etc.) There was one incident relating to BTEX contamination and one incident of excessive vegetation clearing.	4	9%
Total	45	100%

Table 4 Complaints and enquiries Jan - June 2011

Category	Resolved cases	Current cases	Total cases
Bores	18	7	25
CSG operations	38	15	53
Environment	13	8	21
General enquiries	21	2	23
Land access	19	7	26
Water (Other than bores)	41	13	54
Total	150	52	202

The vast majority of complaints and enquires were finalised by providing information to landholders in addition to facilitating their contact with CSG proponents. Only 47 per cent of all complaints and enquiries received to date relate to a CSG company, with only 15 matters directly attributed to CSG activities. At the end of June 2011, no landholder bores had been found to have been impacted as a result of CSG water extraction and seven are currently under investigation.

Further information supplied by DERM showed complaints and enquiries by 15 September 2011 at 341; of which 284 (84%) have been resolved and 57 (16%) remain current. The department was able to provide an estimate only (owing to short time frame of our enquiry) that around 10% of the 341 cases, or 34 instances, were complaints.

Further information on CSG in Queensland:
Maps and well information - http://mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm
Compliance reporting - http://www.derm.qld.gov.au/environmental_management/coal-seam-gas/enforcement-compliance.html

3.5.2 EXPERIENCE IN NSW

CSG production in NSW is relatively small in scale compared with current operations in Queensland. As of September 2011 a total of 493 CSG exploration and production wells have been drilled in NSW (NSW DTIRIS, 2011 – personal communication). There are currently three productions sites, two in the Gunnedah basin and the largest, the Camden Gas Project, in the Sydney Basin. The Camden Gas Project is operated by AGL and began selling gas in 2001 (for detailed information on the Camden project see Section 4.3.1). However, operations in NSW are projected to grow rapidly.

To develop a picture of the community concern with CSG in NSW, ISF approached the NSW State Government agencies (Table 5) responsible for the regulation of the CSG industry, and used information from the environmental reporting at the Camden Gas project.

Table 5 NSW Government Agencies involved in CSG regulation

Government Agency	Role
NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS)	Lead organization, manages tenements, licensing, complaints and reporting
NSW Office of Environment and Heritage (OEH)	Environmental regulatory responsibility for operational sites with production over 5 PJ/yr
NSW Department of Planning and Infrastructure	Planning and Approvals

The process of obtaining information through the NSW Government departments was involved and time consuming. Generally information on the size of operations and number of wells was easy to access, but information on community complaints was more difficult. NSW OEH and Department of Planning and Infrastructure agreed to supply a subset of the complaints information informally, whereas a Government Information Public Access (GIPA) application was required to access CSG complaints information held by DTIRIS. ISF submitted a GIPA application to DTIRIS on September 15 2011 requesting details on the number and nature of any NSW CSG complaints received to date. A response was received from DTIRIS on October 17 2011, stating DTIRIS has "refused to deal with (the) application" as "the information you seek is not compiled is a way that is easy accessible… (it) is stored on a combination of electronic and hard files…. Located across all Mineral Resources functional units… and to retrieve the information would take weeks of dedicated resources." The department concluded, "it would be an unreasonable and substantial diversion of resources to deal with your application further."

The response highlights the lack of co-ordination of information relating to CSG and other oil and gas exploration and development activities in NSW, and the difficulty for the public in gaining access to comprehensive information about these activities in NSW.

NSW OEH did however highlight the NSW regulatory complaints reporting requirement for producing CSG companies, although this does not assist in accessing complaints about exploration activities.

Complaints information was sourced for the Camden Gas Project, which is reported annually and publically accessible. Five complaints were received in 2010/2011 the majority relating to noise, lighting or drilling activity.

There were 16 complaints between 2004 and 2011, including 5 in 2010/11. Nearly all relate to noise or lighting disturbance. One complaint was received about a suspected creek discharge (not substantiated), and 3 about traffic disturbance (AGL, 2007 - 2010, Roy, 2011). Complaints are reported in AGLs Annual Environmental Performance Reports, and in the biannual independent environmental audits. Both are available on the website for the project http://agl.com.au/camden/.

The Independent Environmental Audit reported 12 instances of non-compliance with regulatory requirements between 2006 and 2008 (URS, 2009).

Further information: on CSG in NSW
Maps and licence information - http://www.dpi.nsw.gov.au/minerals/titles/online-services/tasmap
Well and site information - http://www.dpi.nsw.gov.au/minerals/geological/online-services/digs

4 CSG IN AUSTRALIA'S EASTERN GAS MARKET

4.1 RESOURCES, CONSUMPTION AND DRIVERS

The Australian domestic gas market consists of three distinct regional markets: the Eastern Gas Market (QLD, NSW, ACT, VIC, SA and TAS); the Western market (WA) and the Northern market (NT). These markets are geographically isolated from one another, as shown in Figure 14, making transmission and distribution of gas between markets uneconomic at present. Production is either consumed within each market or exported as Liquefied Natural Gas (LNG).

In August 2010 Australia's proved and probable[23] natural gas reserves - those with reasonable prospects for commercialization - were calculated at 106,000 petajoules (PJ)). This includes 28,000 PJ of CSG and 78,000 PJ of conventional natural gas (AER, 2010 p.69). Around 46 per cent of Australia's gas production—all sourced from offshore basins in Western Australia and the Northern Territory—is exported as LNG (AER, 2010 p.72).

Table 6 CSG and conventional gas production 2009-10 and proven and probable reserves

Petajoules	NSW	Qld	Rest of Eastern Gas Market	WA/ NT	Total Australian
Production 2009-10					
CSG	5.8	189	-	-	**195**
Conventional gas		16	448	1,251	**1,716**
Proven and probable reserves					
CSG	2,466	26,008	-	-	**28,474**
Conventional gas		196	7,910	69,730	**77,836**

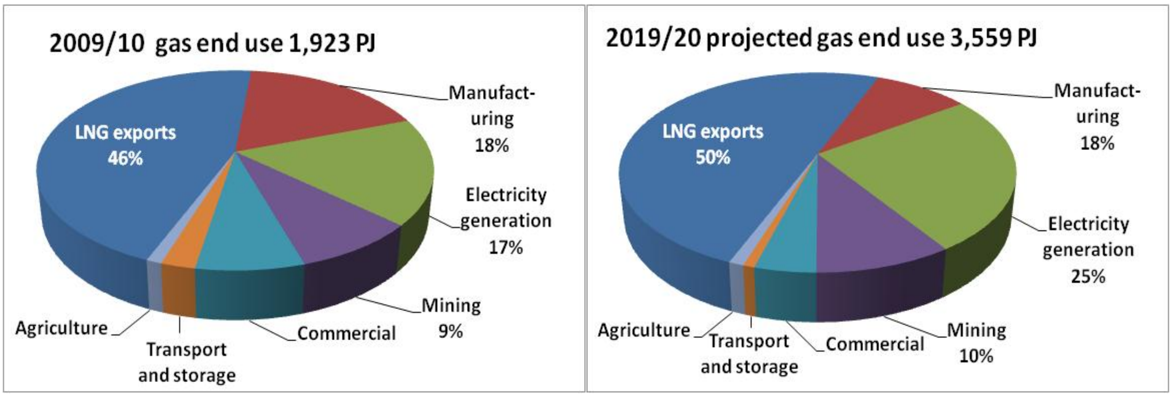
Data from AER, 2010 p.71. Conventional gas production for 2009-10 includes 874 PJ of LNG exports.

Table 6 lists the production of CSG and conventional gas in 2009-10, and the proven and probable reserves. CSG reserves are shown in Figure 14. All of the CSG reserves are in NSW and Queensland, and these make up 78% if the eastern gas market reserves. Note these do not include gas production from existing coal mines, called Coal Mine Methane (CMM); which is not counted in CSG production statistics (GA, 2010 p.23).

The Eastern Gas Market accounts for around 35 per cent of Australia's gas production, and 63% of domestic consumption. It is the only region where coal seam gas supplements conventional gas supplies (mainly in Queensland), accounting for nearly one fifth of current total gas supply in the region (ABARE, 2010 p.105). Consumption in 2009/10 was 659 PJ. The Cooper Basin in central Australia (which is connected to the Eastern gas market) meets about 10 per cent of demand but its reserves are declining (AER, 2010 p.71), with about 10 years supply left at current extraction rates unless the reserve estimates are revised.

[23] Proved reserves are those for which geological and engineering analysis suggests at least a 90 per cent probability of commercial recovery. Probable reserves are those for which geological and engineering analysis suggests at least a 50 per cent probability of commercial recovery.

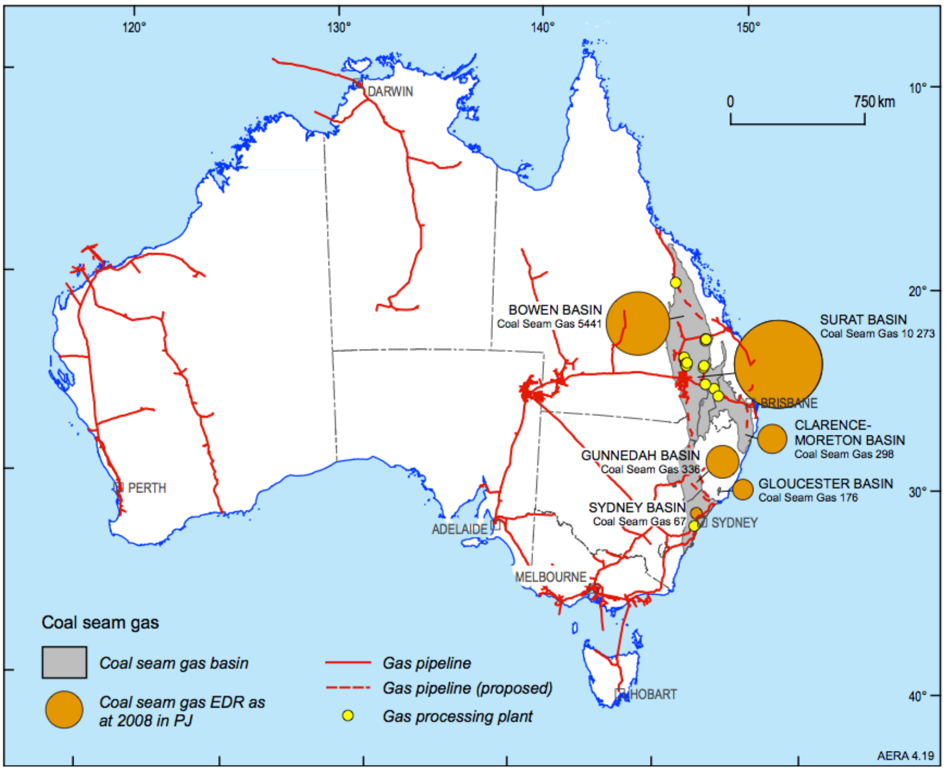
Figure 13 Current and projected Australian gas consumption by end use



Source: ESAA 2011 Table 5.3, GEIDB 2009, AER 2010

Gas fired electricity generation is projected to grow nearly fourfold and to account for 1,280 PJ, more than half of domestic consumption, by 2030 (ESAA, 2011). The City of Sydney's trigeneration is projected to need between 17 PJ and 27PJ of gas per year (City of Sydney, 2010), accounting for between 3% and 4% of projected demand for gas in the Eastern gas market, and up to 4% of the projected Australian demand for gas for electricity generation in 2020. However, the trigeneration project will reduce electricity consumption overall as it uses waste heat to provide heating and cooling, so could reduce gas demand relative to meeting the same proportion of electricity consumption from centralized gas generation. Figure 13 shows current and projected gas consumption by end use in Australia. Additional gas pipelines will be required, particularly in eastern Australia, to provide sufficient supply for new gas-fired electricity generation (ABARE, 2010 p.24).

Figure 14: Location of Australia's CSG reserves and gas infrastructure



Source: ABARE, 2010 p.98

Western Australia has large conventional gas reserves of approximately 68,376 PJ, compared to current Australian gas consumption of 1,037 PJ. Most of the gas production is destined for export as

LNG. If Australia wished to preserve this resource for domestic use, it would last approximately 60 years assuming current annual growth in gas demand remains constant to 2025[24]. However, in order to supply the Eastern Gas Market the gas would need to be converted to LNG, shipped around Australia, and re-gasified. Apart from the economic cost, the emissions benefit compared to coal generation would be reduced because of the additional processing and transport. There are also significant environmental concerns about some conventional gas developments proposed in Western Australia. For example, there is an international campaign to protect the Dampier peninsula from the effects of the proposed LNG processing plant and associated infrastructure at James Price Point near Broome[25].

4.2 COMPANIES INVOLVED IN CSG ACTIVITIES IN AUSTRALIA

There are 38 companies active in CSG exploration and production in Australia (these are listed in Appendix 7, along with their areas of interest). The growth of the CSG industry has led to considerable new entry in Queensland's Surat–Bowen Basin over the past decade. The largest producers are Origin Energy (19 per cent), BG Group (18 per cent), ConocoPhillips (17 per cent)[26], Santos (16 per cent), Arrow Energy (now owned by Shell and PetroChina, 10 per cent), Petronas (6 per cent), and Shell and AGL Energy (4 per cent each) (AER, 2010 p.73).

4.3 NSW ACTIVE AND PROPOSED PROJECTS

Table 7 NSW active and proposed CSG projects

Company	Status	Project Name and Basin	Location/ description
AGL Upstream Investments Pty Ltd	Active (production)	Camden Gas Project, Sydney Basin	Camden Area Started selling gas to the grid in 2001.Stages 1 and 2 include 134 wells, 30 horizontal and 104 vertical. 117 wells have been hydraulically fractured.
Eastern Star Gas Ltd (ESG)	Active (pilot production)	Bohena, Bibblewindi Gunnedah basin	Narrabri Area Production licence held, nine wells drilled as part of pilot production.
Eastern Star Gas Ltd (ESG)	Active (production)	Narrabri Coal Seam Gas Project Gunnedah basin	Narrabri Area Gas in production, supplied to the 7 MW Wilga Park power station.
AGL Upstream Investments Pty Ltd	Proposed	North Camden Expansion Sydney Basin	Camden Area Extension of Camden Gas project. Currently applying for production approval, with a further 72 wells planned (12 vertical, 60 horizontal).
Metgasco Limited	Proposed	Richmond Valley Power Station	East Casino 30 MW gas fired power station in Richmond Valley supplying

[24] Assuming that gas use continues to grow at 4% per year until 2025 and then remains stable.

[25] For example, http://handsoffcountry.blogspot.com/2009/07/camping-on-dampier-peninsula.html, www.savethekimberley.com/wp/dinosaur-prints-our-kimberley-national-heritage/, www.environskimberley.org.au/

[26] Origin and Conoco Philips are in partnership in the APLNG project

Company	Status	Project Name and Basin	Location/ description
		Clarence-Moreton basin	power to Casino. Up to 40 CSG wells.
AGL Upstream Investments Pty Ltd	Proposed	Gloucester Gas Project Gloucester basin	Stratford Area Up to 110 wells, central processing facility (gas compression, water treatment, small scale power generation), high-pressure gas pipeline from Stratford to Hexham. Transfer point for CSG from Sydney Newcastle trunk pipeline.
Dart Energy	Proposed	St Peters Sydney Basin	St Peters, Sydney Single exploratory well. For testing purposes
Eastern Star Gas Ltd (ESG)	Proposed	LNG Newcastle Project Gunnedah Basin	LNG production and export facility on Kooragang Island, Newcastle. Plans to export up to 4 million tonnes LNG/yr

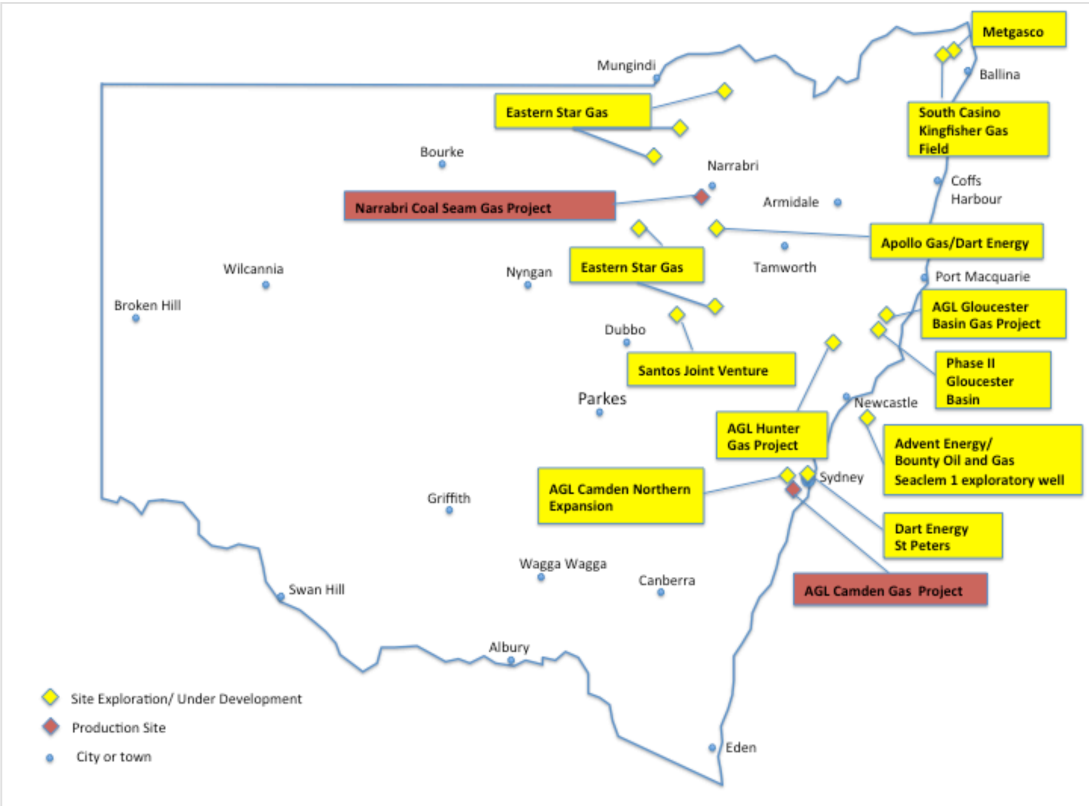


Figure 15 Active and proposed CSG projects in NSW

Source: NSW DPI, 2011

Table 7 lists the active and proposed CSG projects in NSW. These projects and the most advanced exploration projects are shown in Figure 15.

There are three active coal seam gas (CSG) projects in NSW, one in Camden and two near Narrabri. Only Camden is currently selling into the gas pipeline. One (Narrabri) supplies the 16 MW gas generator at Wilga. There are also two coal seam gas (CMM) projects, at Appin and Tower collieries.

Five further CSG projects are currently proposed for NSW. AGL has proposed a $100 million plus expansion of its Camden Gas Project including 12 surface well locations containing up to 6 wellheads each, associated gas gathering and water lines and access roads. Metgasco has proposed a 145 km high-pressure gas transmission pipeline from Casino to Ipswich, and construction of a 30 MW gas fired power station 4 kms east of Casino in the Richmond Valley Local Government Area.

There are 56 onshore petroleum exploration licences held in NSW (plus one offshore). These include 27 that are for CSG alone, 15 for CSG and conventional gas, 12 for conventional gas, and 2 for CMM. For full details and a list see Appendix 3. The first conventional offshore gas well in NSW, named Seaclem-1, was drilled in 2010 under PEP 11 in a joint venture between Advent Energy and Bounty Oil and Gas. Advent has demonstrated with geochemical studies that there is considerable gas generation and migration potential within PEP11, however no hydrocarbons were encountered in the Seaclem-1 well (MEC Resources, 2011).

4.3.1 CAMDEN GAS PROJECT

The Camden Gas Project, operated by AGL, is the only CSG production in NSW that is going into the gas market (rather than direct to a power station). The Rosalind Park Gas Plant at the Camden project is currently supplying 6% of NSW gas.

Production started in 2001, and AGL have drilled 134 wells in the first two stages of the project, which is located between Camden and Menangle Park and occupies an area of 70 km^2. Of the 134 wells, 104 are vertical and 20 horizontal. There are 124 well heads, with 10 wells finished, plugged and abandoned.

The gas processing plant has 37 permanent employees, with another 2 casual staff (Clifton, 2011), with approximately 43 contractors employed in the area (AGL, 2011).

AGL is currently applying for production approval for Camden North, which has an area of 38 km2, and is expected to have 72 wells (12 vertical and 60 horizontal), with well heads in 12 locations (wells are generally located on well pads, with 6 wells per pad). There are 83 wells currently producing, and gas is processed at the Rosalind Park gas plant. Methane concentration is very high, generally 96% and gas from the wells requires only filtering to remove particulates (mostly coal dust), dehydrating, odourising, and pressurizing prior to putting into the pipeline.

Drilling takes approximately 7 days per vertical well, and 25 – 28 days per horizontal well, so Camden North would take approximately two years of continuous drilling if wells were drilled consecutively. Of course, the development of the field is likely to be spread over a longer time period. After drilling the well, a smaller maintenance rig is used to install the remaining infrastructure to complete the well (pumps, rods, and tubing) and to perform general maintenance on the wells.

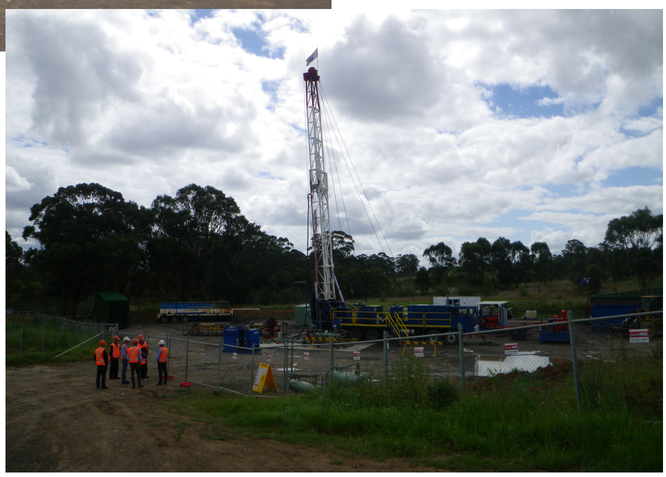
At Camden, AGL uses hydraulic fracturing in all of their vertical wells, but does not fracture horizontal wells. To date, 117 wells have been hydraulically fractured. About 15% of those are fractured twice, targeting two separate coal seams on consecutive days, before production commences.

Figure 16 CSG wells – Camden Gas Project

CSG WELL WITH TANKS FOR PRODUCED WATER

SINGLE ENCLOSED WELL WITH UNDERGROUND TANK FOR PRODUCED WATER

WELL PAD WITH THREE HORIZONTAL WELLS
Photo courtesy of AGL



MAINTENANCE RIG AT WELL PAD WITH FIVE HORIZONTAL CSG WELLS; ENCLOSURE WILL BE SMALLER ONCE WELLS ARE COMPLETE

In approximately 60% of cases AGL uses only water for fracturing, and in the remainder uses water mixed with a viscosifier and additives. When using water only, it takes approximately 0.6 ML of water, and most of that water will be reuse of produced water. When using a viscosifier, about 0.15 ML of town water plus 0.07 ML of produced water is used. AGL does not use BTEX chemicals in their fracture fluids, and is expected to publish a complete list of chemicals in the next two weeks.

Over the last four years AGL has used 8.2 GL of town water on average each year (Clifton, 2011).

Camden gas wells produce relatively little water compared to many wells in Queensland. Produced water peaked in 2008/9 at 8.3 ML, up from 2.7 ML in 2006/7, and is down to 3.3 ML in 2010/11[27] (AGL 2007, 2008, 2009, 2010, 2011). The ratio of water: gas production is approximately 1%[28], compared to 10% - 2000% in Queensland (Helmuth 2008, Table 4, p20).

The bulk of the produced water is taken to Campbelltown City Council disposal facilities. All water produced or used at wells is held in mobile tanks, which are trucked between locations and to the disposal facility. Produced water is saline, with conductance of 6,000 – 12,000 µS/cm. For comparison, seawater has conductance of approximately 58,000 µS/cm and drinking water no more than 830 µS/cm.

There were 16 complaints between 2004 and 2011, nearly all relating to noise or lighting disturbance. One complaint was received about a suspected creek discharge (not substantiated), and three about traffic disturbance (AGL 2007-2010, Roy 2011). Complaints are reported in AGL's Annual Environmental Performance Reports, and in the biannual independent environmental audits. The Independent Environmental Audit reported twelve instances of non-compliance with regulatory requirements between 2006 and 2008.

Sources
Technical information relating to Camden AGL operations was provided by Mike Roy, the Head of Gas Operations at AGL (Roy 2011), or where stated, from the AGL Annual Environmental Reports or the independent environmental audits undertaken by URS) http://agk.com.au/camden/.

[27] Only the 2009/10 and 20010/11 reports gives volumes for disposed and recycled or re-used water, so figures for other years may underestimate the produced water somewhat.

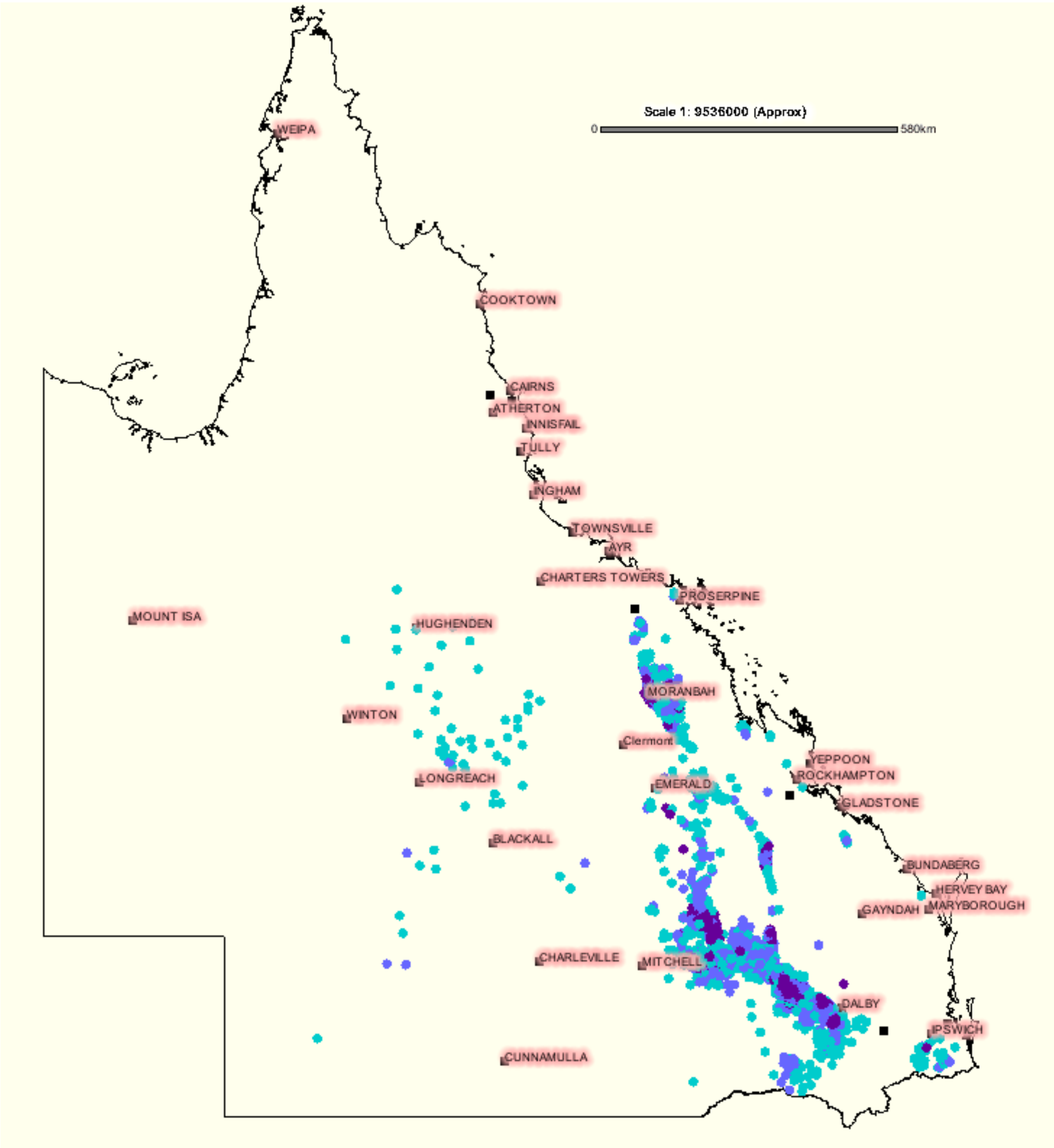
[28] The ratio of 1% is conservatively calculated from an estimate of 69 GL total produced water to date from AGL environmental reports (AGL 2007, 2008, 2009, and 2010), and cumulative gas production of 25 PJ (Roy 2010). Produced water volumes for 2001/02 to 2005/06 are not reported, so the peak production since has been assumed for those six years. If only the last 5 years are included, the ratio is less than 0.5%.

4.4 QUEENSAND CSG ACTIVITY

There are 20 active coal seam gas projects in Queensland, and 29 proposed projects. To date there have been 4,489 coal seam gas wells drilled in Queensland (DEEDI 2011b), shown in Figure 17. There is considerable overlap with the area of exploration for conventional gas and oil.

Appendix 6 lists active and proposed CSG projects in Queensland, with the company involved.

Figure 17 CSG wells in Queensland



Based on data provided by the State of Queensland (Department of Employment, Economic Development and Innovation) [2011], which gives no warranty in relation to the data (including accuracy, reliability, completeness or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data

Available http://mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm

4.5 PROPOSED GAS PIPELINES AND INFRASTRUCTURE LOCATIONS

Natural gas in Eastern Australia is transported by an interconnected transmission pipeline network which enables gas producers in the Surat–Bowen, Cooper, Gippsland, Otway, Bass and Sydney basins to sell gas to customers across Queensland, New South Wales, Victoria, South Australia, Tasmania and the ACT (AER, 2010 p.78).

Maps showing current Australian gas infrastructure are provided in Appendix 2. Proposed gas pipelines and pipelines currently under construction in NSW are listed in Table 8. With the exception of the Moomba to Sydney pipeline, all the proposed pipelines are likely to carry a mixture of both CSG and conventional gas, with CSG expected to contribute the larger share.

Table 8 Proposed gas pipelines and pipelines under construction in NSW

Proposed Infra-structure	Expected Completion	Location / Details
Queensland to Hunter Pipeline (Wallumbilla to Newcastle)	Construction commencing in 2012	Owner, Hunter Gas Pipeline, to place 833 km of new line linking Qld and NSW. Cost $750 – 850 million. Initially to flow 85PJ (Qld to NSW) for Hunter power stations and other NSW consumers.
South West Qld Pipeline Expansion – QSN Link stage 3	January 2012	Owner, Epic Energy, to place new line with diameter of 457 mm and capacity of approximately 380 TJ/d (expansion by additional 212 TJ/d) linking Queensland CSG fields with SA, NSW with link to Moomba to Adelaide, Moomba to Sydney and Carpentaria pipelines. Cost $760 million.
Lions Way Pipeline (Casino to Ipswich)	Construction commencing in 2012	Owner, Metgasco, to place 145 km link between Casino (NSW) and Ipswich (QLD). Cost $120 million.
South West Qld Pipeline Expansion – QSN Link stage 2	2013	Undertaken by Epic Energy, expansion of current line by additional 52 TJ/d. Links Qld, SA and NSW. Cost $64 million.
Moomba to Sydney Pipeline Expansion	From 2008	Project to take 5 years and increase capacity by 20%. Cost $100 million.
Gladstone LNG Pipeline (Fairview to Gladstone)	2014	Owner, Santos, to lay 432 km of new line between Fairview and Gladstone.
Surat Basin to Gladstone		Owner, Arrow, to lay 450 km of new line between Surat basin and Gladstone. Cost $500 million.
QCLNG Pipeline (Wandoan to Gladstone)	Construction commencing in 2010	Owner, BG Group, to lay 340 km of new line between Wandoan and Gladstone.

Sources: AER, 2010 p.80,
http://pipeliner.com.au/news/new_south_wales_the_new_frontier/008207/
http://www.qhgp.com.au/qhgp-project.asp
http://pipeliner.com.au/news/csg/041803/

5 CSG REGULATION

There has been rapid growth in CSG activity in Australia since production first commenced in Queensland in 1996. The development of a regulatory framework has been slow, and some have argued inadequate, considering the potential scope of environmental and social impacts. For example, the NSW Environmental Defenders Office considers many aspects of the regulatory framework for both mining and CSG extraction to be outdated and insufficient to produce sound environmental outcomes (EDO 2011). Without more clarity in regulation of CSG extraction challenges to the legitimacy of the process are likely to continue.

The legal framework regulating resource ownership and licensing in Australia is complex. CSG production is regulated mainly by the States with no national legislative framework. Increased public concern coupled with recent scientific reports related to the impacts of CSG production on groundwater resources, for example by the National Water Commission (National Water Commission 2009) has prompted both NSW and Queensland State governments to enact significant regulatory reforms. An overview of the NSW regulatory process for CSG is given in Figure 18. The main policies and legislation are:

- ***Strategic Regional Land Use Policy (Department of Planning and Infrastructure, DP&I).***
  In May 2011, the NSW Government announced a strategic planning process which will include the development of a NSW Coal and Gas Strategy and a Coal and Gas Policy. It introduced:
  - A 60 day moratorium on new coal, CSG, and petroleum exploration licences, and on hydraulic fracturing. The moratorium on hydraulic fracturing has been extended until the end of 2011.
  - A requirement that all applications for exploration licences be exhibited for public comment;
  - Guidelines to inform assessment of development impacts on strategic agricultural land;
  - A requirement for new extraction applications to include an Agricultural Impact Statement;
  - The exhibition of an Aquifer Interference Regulation for public comment; and
  - A stakeholder reference group to advise on the policy's development and implementation.

- ***NSW Coal and gas strategy and policy***
  In July 2010, the NSW Government formed a Ministerial Sub-Committee to lead the development of a Coal & Gas Strategy for NSW, which released a scoping paper in February 2011. In May 2011 the NSW Government announced it will replace the Strategy with an overarching Coal and Gas Policy, which will provide an overview of the current state of the industries and the likely growth over the next 25 years. This will form an input to the regional land use plans.

- ***Petroleum (Onshore) Act 1991* (responsibility Department of Primary Industries, DPI)**
  CSG is regulated in the same way as other onshore petroleum activities, and the Petroleum Onshore Act is the framework legislation covering licensing for exploration, assessment, and production. The Act may require assessment under other legislation, such as the EP&A Act, and imposes some statutory conditions on access.

- ***Environmental Planning and Assessment Act (EP&A) 1979* (responsibility of the Department of Planning and Infrastructure, DP&I)**
  Development consent under this Act is required prior to granting exploration and production leases to CSG projects. Both production and exploration projects require assessment under the Act. Production projects will generally require Environmental Impact Statements (EIS), while exploration projects may only require an Environmental Assessment (EA). Most CSG activities fall under Part 3 of this Act which is currently being amended.

- ***Mining Act 1992* (responsibility Department of Primary Industries, DPI)**
  The main effects of this Act are in relation to access issues.

- ***Protection of the Environment Operations (PoEO) Act 1997*** **(Responsibility of the Office of Environment and Heritage, OEH)**
  This covers actual operations, and a licence is required for CSG production. Specific conditions will apply to noise, waste, and discharges to air and water. The licence is reviewed every 5 years and may be varied or suspended.

- ***Water Management Act (2000),*** including the ***Aquifer Interference Regulation (interim)*** and the ***Water Management (General) Regulation 2011*** **(responsibility of NSW Office of Water)**
  This covers management of impacts of water extraction from CSG on bores, aquifers and springs. A draft aquifer interference policy is being developed by the NSW Office of Water as a component of the Strategic Regional Land Use Policy. The interim regulation took effect on 30 June 2011, and requires new mining and petroleum activities that take more than three megalitres per year from groundwater sources to hold a water access licence, banned the use of evaporation ponds, and banned the use of BTEX chemicals as additives during CSG drilling.

- ***National Parks and Wildlife Act 1974***
  A mineral claim must not be granted over any lands within a state conservation area, and it is unlawful to prospect or mine for minerals in a national park or historic site, except when expressly authorised by an Act of Parliament. The Mining Act 1992 , the Offshore Minerals Act 1999 , the Petroleum (Onshore) Act 1991 and the Petroleum (Offshore) Act 1982 do not apply to or in respect of lands within a national park or historic site.

There is currently a five-year royalty holiday on production from petroleum discoveries, including CSG, in NSW (NSW DPI, 2011).Depending on the type of coal seam gas activity proposed, licences or approvals may also be required under other State legislation, including the ***Heritage Act 1977,*** the ***Pipelines Act 1967,*** and the ***Native Vegetation Act 2003.***

The regulatory frameworks for CSG are similar in NSW and Queensland, although as most CSG activity to date is in Queensland, the regulatory regime there has developed somewhat further. Key differences with Queensland regulation are:

- Access negotiations for exploration or production will be covered by a Land Access Code and Strategic Cropping Land Policy, introduced to Parliament in October 2011.
- Applicants for a Production Licence must prepare an Environmental Management Plan and associated CSG water management plan under the Environmental Protection Act (QLD) 1994.
- Under the Water and Other Legislation Amendment Bill 2010, project proponents are required to undertake make good agreements with landholders, and undertake a baseline assessment plan and underground water impact report.
- The Environmental Protection Act 1994 CSG (2010 amendments) banned the use of BTEX chemicals in CSG operations, and set out requirements for the use and disposal of produced water.
- In 2010, DERM developed a *CSG Compliance Plan 2011* (DERM 2010) which sets out its strategy to address monitoring of key areas of potential environmental impact from the CSG industry. The LNG Enforcement Unit within DERM is responsible for the delivery of compliance activities and to ensure there is an integrated whole-of-government approach to managing complaints. The plan outlines how DERM will undertake compliance activities, in particular monitoring programs, audits, and annual reporting of complaints and the outcomes of complaints.
- In August 2011 Exploration Restricted Areas were established around built up areas in Queensland (defined as town with more than 1000 residents). The changes will include existing tenure holders, and are intended to prevent any exploration activities in and around urban areas

The coverage and requirements of the major NSW and Queensland legislation is explained in Appendix 8 and Appendix 9.

Figure 18 CSG project – legislation summary for NSW

PROJECT STAGE	LEGISLATION AND PROCESS - NSW
APPLY FOR AN EXPLORATION LICENCE	• NSW Minister for Primary Industries responsible for issuing exploration licence for CSG [1] under the ***Petroleum (Onshore) Act 1991*** • Requires an environmental assessment and approval under part 3A for significant development or part 5 of ***Environmental Planning and Assessment Act (EP&A) 1979*** • Conditions attached to approval under both acts covering, noise, setbacks, water, access etc • Apply for Water Access Licence (if taking more than 3ML of water/year) under the Aquifer Interference Regulation – from the NSW Office of Water
NEGOTIATE ACCESS	• Access conditions specified under the ***Mining Act 1992*** (Section 141) and the ***Petroleum (Onshore) Act 1991*** Land Access Policy (Section 69D (1)) • Written permission from landholder required for access, if withheld proponent can go to Land and Environment Court
PILOT WELLS	• Must comply with conditions attached to exploration licence. • Monitoring and reporting requirements imposed as conditions of approval under the EP& A act or the ***Aquifer Interference Regulation.*** • Requirements for water bore testing over a period in excess of a week under Section 18, Schedule 5, ***Water Management (General) Regulation 2011*** (commenced 1 September)
APPLY FOR PRODUCTION LICENCE (granted for up to 21 years)	• Minister for Primary Industries responsible for issuing licence • Development consent required under **EP&A 1979** (Part 3A or Part 4). • Generally requires Environmental Impact Statement under EPA 1979 Part 4, which includes public exhibition and comment • Monitoring and reporting requirements are imposed as conditions of approval under the ***EP&A 1979***, ***Water Management Act 2000*** and ***Aquifer Interference Regulation*** • Requires approval under Federal Environment Protection and Biodiversity Conservation Act 1999 **only** if the activity is likely to have a significant impact on a matter of national environmental significance (note this currently only applies to threatened species) • Required to obtain and hold an Environmental Protection Licence waste, water, air and noise control under the **PoEO Act** 1997[3]
PRODUCTION	• Must comply with consent conditions attached under ***EP&A 1979*** and ***Petroleum (Onshore) Act 1991***. • Monitoring and reporting requirements are imposed as conditions of approval under the ***EP&A 1979***, ***PoEO Act 1997*** and the ***Water Management Act 2000*** and ***associated Aquifer Interference Regulation (draft)***

NOTES

1) Called **petroleum titles**, which cover *Exploration, Assessment, or Production licences* for CSG
2) EP&A 1979 is the ***Environmental Planning and Assessment Act 1979***
3) ***PoEO Act*** 1997 is the *Protection of the Environment Operations (PoEO) Act 1997*

5.1 HOW ARE WATER IMPACTS REGULATED?

The management of water impacts is key to mitigating potential environmental effects of CSG. Concerns for potential water impacts from CSG activities include

- Potential contamination of aquifers from poorly controlled hydraulic fracturing,
- Potential depletion of aquifers from extraction of water for hydraulic fracturing,
- Potential depletion of aquifers via recharge of the coal seam as produced water is extracted, which may occur if there is connectivity between the coal seam and the aquifer.
- Contamination of surface water by poor management or disposal of produced water,
- Regional scale subsidence as a result of depressurizing coal seams changing drainage and erosion patterns in surface water flows.

5.1.1 WATER REGULATION IN QUEENSLAND

In Queensland water is primarily regulated under the *Water Act 2000* which is administered by the Queensland Water Commission (QWC). The Queensland Government amended legislation[29] in 2010 to improve management of water in the petroleum and gas industry. The changes create a new role for the QWC in managing the impacts of CSG water. The *Water and Other Legislation Amendment Bill 2010* was introduced in December 2010 and introduced a range of changes including:

- Petroleum tenure holders must provide baseline assessment plans and conduct baseline and borehole and groundwater assessments,
- Petroleum tenure holders must enter into 'make good' agreements with bore owners before extraction occurs
- A dispute resolution process is established for negotiation of these agreements, and
- The Queensland Water Commission (QWC) is tasked to manage cumulative impacts on underground water, for example via the declaration of cumulative management areas.

Produced water regulation

CSG water is defined as a waste under the Environment Protection Act (Qld) 1994. It must be disposed of under the conditions of the project's environmental authority, or beneficially used under a beneficial use approval. The disposal of brine or salt from CSG water treatment is also regulated under the Act. There are two general approvals related to CSG produced water:

- ***Beneficial use approval - associated water*** outlines the requirements for use for aquaculture, coal washing, dust suppression, industrial and manufacturing operations, irrigation and livestock watering.
- ***Beneficial use approval - reverse osmosis permeate***: outlines requirements for the use of treated produced water for flood cleanup, for example the removal of debris and sediment from flood affected buildings etc.

The Queensland government published a *Coal Seam Gas Water Management Policy* in 2010 which comes under the EP Act 1994. The main requirements include:

- CSG producers are responsible for treating and disposing of CSG water, which must be treated to a standard defined by DERM before disposal or supply to other water users.
- Discontinue the use of evaporation dams as a primary means to dispose of CSG water and remediation of existing evaporation dams within three years. However, it also defined possible

[29] The Water Act 2000 and the Water Supply (Safety and Reliability) Act 2008

exceptions: exploration and appraisal wells, or where access to the well site is limited, or remote from the rest of the project.

- Dams necessary for water aggregation and the storage of brine from treatment facilities are to be fully lined to a standard determined by DERM.
- A CSG water management plan (CWMP) is to be incorporated into the environmental management plan (EMP) required for a large scale CSG environmental authority application.
- As part of the Environmental Management Plan, CSG operators are required to include information about CSG water, including:
  - expected flow rate, quantity and quality expected to be generated
  - proposed management, including use, treatment, storage or disposal
  - criteria against which the CSG operator will monitor and assess management,
  - proposed actions taken by operator should any management criteria not be satisfied.

CSG operators are required to submit to DERM an annual evaluation of how effective and appropriate management of CSG water has been. If it is determined that CSG water has not been appropriately managed, the CSG operator will need to outline actions to ensure appropriate management in the future.

Groundwater regulation

Under the Water Act 2000, there are no restrictions on the quantity of groundwater that can be withdrawn for CSG projects and no licence is required for the extraction of groundwater for CSG activities. Changes introduced in the *Water and Other Legislation Amendment Bill 2010* apply to current and future projects and require evaluation and management of impacts of water extraction from the CSG process on bores, aquifers and springs. Trigger thresholds are set for investigation of an operators' impact that may reduce the ability of a water bore to supply water to the bore owner for its intended use. Trigger thresholds are:

- 5-metre drop for consolidated aquifers, such as sandstone
- 2-metre drop for shallow alluvial aquifers
- 0.2-metre drop for springs, including watercourses connected to springs

If a petroleum activity is likely to cause a decline in bore water levels in excess of the trigger value, the petroleum tenure holder is obliged to negotiate a 'make good agreement' with the bore owner. The agreement will identify measures to be undertaken by the tenure holder. For example, deepening the bore, or letting the owner use a pump, or 'establishing an alternative source of supply'. If several companies are involved, the QWC will oversee groundwater impacts in the area by declaring a 'Cumulative Management Area' i.e. will monitor, model and prepare cumulative impact reports on, the groundwater, and facilitate the group 'making-good'.

The QWC now has a role in monitoring and assessing the impacts of groundwater extraction in Cumulative Management Areas through the preparation of underground water impact reports. These are areas where there are overlapping impacts from more than one CSG operation, primarily in the Surat Basin and the Southern Bowen Basin. The reports aim to identify likely future impacts on underground water from the water extraction associated with the petroleum tenures, and provide appropriate strategies for managing these impacts.

5.1.2 WATER REGULATION IN NSW

In NSW there are no specific water management policies regulating the CSG industry. However, the NSW government is currently reviewing its management of CSG interactions with water. Changes to regulations during 2011 include a ban on the use of evaporation ponds; the requirement for a water licence to extract more than 3 ML of groundwater[30] a year; a ban on the use of BTEX chemicals as additives during coal seam gas drilling, and an obligation to put the details of mining approvals and conditions online.

The Water Management Act 2000 (under the NSW Water Office) is the key piece of legislation for the management of water. The Act is intended to enshrine the concept of ecologically sustainable development, i.e. development that will not threaten the ability of future generations to meet their needs.

The NSW Office of Water has a key role in the assessment of CSG activities under the EP&A Act, and is required to ensure planning and development is sustainable and consistent with the management of the State's water resources and water dependent ecosystems. The office is consulted in the initial development of environmental assessment requirements for a declared Major Project[31] and has a key role in assessing the proposal in terms of water management policy and licensing requirements. The Office is responsible for ensuring that environmental impacts have been appropriately addressed, and relevant government agencies have been consulted prior to issuing the licence or approval. The Office provides conditions for managing CSG water as part of the approval process for both exploration and production.

The NSW Office of Water's Compliance Operations Branch undertakes three types of monitoring activities:

- ***Detection activities***: aerial, ground and river survey, aerial photography and the use of satellite images.
- ***Audit and review of licences***: to verify compliance. A large number of licences, approvals, permit and authorities (licences) are granted, and generally contain conditions designed to protect the environment and the resource base.
- ***Reports of alleged breaches***: from external sources including members of the public, State Water, local councils and other government departments. All alleged breaches detected or reported are recorded, assessed and considered for action in accordance with this Policy.

Produced water

Disposal and treatment of produced water is regulated under the *Protection of the Environment Operations (PoEO) Act 1997,* although conditions may be applied under the *Water Management Act 2000* and the *Protection of the Environment Act 1979.*

Groundwater

An *Aquifer Interference Policy* is being developed by the NSW Office of Water as a component of the NSW Government's Strategic Regional Land Use Policy. An interim Aquifer Interference Regulation in NSW took effect on 30 June 2011, which requires new mining and petroleum exploration activities that take more than 3 ML per year from groundwater sources to hold a water access licence.

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[30] A typical hydraulic fracturing operation could use 1.5 – 6 ML of water.

[31] Under Part 3A of the EP&A Act

5.2 HOW ARE PROPERTY RIGHTS AND ACCESS TO LAND REGULATED?

The State owns mineral and petroleum resources and issues rights through licences or lease agreements to explore and produce to mining and CSG companies. Once an Exploration Licence has been granted by the State Government over an area of land that includes private property, the holder of the licence has the statutory right to explore for CSG within the licence area. Under the Petroleum Act of each state, landholders do not have the right to veto sub-surface mining. However, the holder of the licence must have an access arrangement with the landholder in order to gain access to the property.

The licence holder must pay the legal costs of the landholder in obtaining initial advice about the making of the access arrangement. Landholders can specify agreeing to separate access agreements for each exploration activity e.g., drilling, pilot testing and exploration.

If a landholder does not agree to an access agreement, the Mining Act and the Petroleum (Onshore) Act enables a licence holder to secure an access arrangement through arbitration. Currently, NSW mining laws are geared towards facilitating exploration activities, so in practice the determination often relates to what conditions will be attached to access arrangements, as opposed to whether an access arrangement should be granted at all (EDO 2011). The NSW Environmental Defender Office has also raised concerns relating to the uneven bargaining power of the parties, and potential financial burdens on landholders to attend arbitration hearings (EDO 2011).

There have been calls by the National Farmers Federation (NFF 2011) for tighter controls around land access agreements which would enable greater negotiation power to farmers when faced with companies seeking exploration and mining licences, and the Australian Greens party introduced a bill in August 2011 that would give farmers the right to refuse CSG drilling and mining on their land.

5.2.1 REGULATION OF PROPERTY RIGHTS IN QUEENSLAND

Queensland's Land Access Policy Framework and Land Access Code came into force October 2010[32], and outlines mandatory conditions for resource companies undertaking activities on private land and provides a best practice guide to communications. The code has the following key elements:

- Entry notice requirements for 'preliminary activities' i.e. those that will have no or only a minor impact on landholders
- A requirement that Conduct and Compensation agreements be negotiated before a company comes onto a landholder's property to undertake advanced activities' i.e. those likely to have a significant impact on a landholder's business or land use
- A graduated process for negotiation and resolving disputes about agreements which ensure matters are only referred to the Land court as a last resort
- Stronger compliance and enforcement powers for government agencies where breaches of the land access code occur.
- Companies must give landholders at least 10 business days' written notice before undertaking petroleum and CSG activities on their land. Companies must again notify landholders in writing within 10 business days of completing those activities.
- Mandatory notification applies to the following activities:
    - Carrying out and completing hydraulic fracturing - notification must include intended and actual chemicals and volumes used. However, the notification requirement only applies to

[32] Under Section 24A of the Petroleum and Gas (Production and Safety) Act 2004.

- the landowner who hosts the wellhead, not property owners who have wells beneath their land but no well head.
- Drilling, completing, altering and abandoning a well or bore,
- Carrying out and completing a seismic survey or scientific or technical survey, and
- Within two months of completing hydraulic fracturing activity, companies must also submit a detailed report to Government that includes the composition of all fraccing fluids used in each well and the potential impacts on water aquifers.

Generally, the holder of an Exploration Licence cannot enter restricted land, which is land within 100m of a permanent building used for accommodation, business, community or recreation purposes. Further restrictions apply to land within 50m of a principal stockyard, bore or artesian well, a dam or a another artificial water storage connected to a water supply.

In August 2010, the Queensland Government released "Protecting Queensland's strategic cropping land: a policy framework", which outlined its approach to protecting the State's best cropping land resources (i.e. strategic cropping land). The Government's policy is essentially that planning and approval powers should be used to protect Strategic Cropping Land (SCL) from development that leads to its permanent alienation or diminished productivity. The framework, including the SCL maps, should be considered as part of any decision on the siting of development projects in Queensland. The Government is expected to shortly release for public comment its draft State Planning Policy on SCL. It is unclear how this will affect CSG activities.

In August 2011, the Queensland Government introduced **Exploration Restricted Areas**. No mining exploration will be allowed in and around urban areas of Queensland, including regional centres, with a 2km buffer. The Areas include land bound by the South East Queensland Regional Plan as well as other regional centres and towns with a population of 1,000 or more. The restrictions are complimentary to the existing Strategic Cropping legislation. The changes will include existing tenure holders, and will prevent any exploration activities in and around urban areas across Queensland. No further Authorities to Prospect will be issued over areas covered by the restricted area.

5.2.2 REGULATION OF PROPERTY RIGHTS IN NEW SOUTH WALES

In NSW a number of conditions relating to access are listed in Section 141 of the *Mining Act 1992* and Section 69D (1) of the *Petroleum (Onshore) Act 1991.* Statutory requirements include:

- The holder of an Exploration Licence must serve the landholder with written notice of the company's intention to obtain an access agreement in respect of the land, which must contain:
    - a detailed plan and description of the area of land to which access is sought (including the number and location of boreholes);
    - a full description of the prospecting methods to be used;
    - periods during which access may be permitted;
    - parts of the land on which prospecting may be undertaken and means of access;
    - kinds of operations that may be carried out;
    - compensation to be paid to the landholder; and
    - manner of resolving disputes and manner of varying the agreement.
- A project proponent must not carry out any prospecting or erect any works on land within 200 metres of a person's principal place of residence except with the written consent of the owner.
- The holder of a production lease must not carry out mining (or CSG extraction) on land that is under cultivation, except with the consent of the landholder, or with the approval of the Minister (note that cultivation does not include grazing or fodder crops).
- A project proponent cannot carry out prospecting operations on any land otherwise than in accordance with an access arrangement agreed between the title holder and each landholder, or

determined by an arbitrator.

5.2.3 NOISE, AIR POLLUTION AND VEGETATION

The potential impacts of CSG activities on local communities can be significant, as there may be drilling activities occurring 24 hours per day for many months. Queensland and NSW have similar regulatory approaches to these issues. The regulation of noise, air pollution, and dust in both states is summarised in Table 9.

Table 9 Regulation of air pollution, noise, and vegetation in NSW and Queensland

	NSW	**QUEENSLAND**
AIR POLLUTION	Any environmental nuisance issues, such as noise, light and odour, are covered by EP&A Act approval conditions. Licences for environmental protection including waste, air, water and noise pollution control must be obtained under the PoEO Act prior to production	The Environmental Management (EM) Plan must - provide for the protection of air quality and include control procedures to minimize dust, light pollution, and odour; - include details of the specific air quality objectives to be maintained for the life of the activity; and - Companies are required to provide background air quality monitoring data and may be required to undertake air quality modeling to demonstrate that the air quality objectives are being maintained. - CSG operators must ensure that the release of dust, light, odour or any other airborne contaminants does not cause an environmental nuisance.
NOISE	Any environmental nuisance issues, such as noise, light and odour, are covered by EP&A Act approval conditions. Licences for environmental protection including waste, air, water and noise pollution control must be obtained under the PoEO Act prior to production.	The EM Plan must include a noise management plan to address how activities will be carried out using best practice noise management principles, including: - noise impact assessments - stakeholder engagement - adoption of noise attenuating technologies for plant and equipment - minimising background creep and minimising variable noise - avoiding sleep disturbance.
VEGETATION	The Threatened Species Act (TSC Act) provides for the conservation of threatened flora and fauna species, populations and ecological communities and is administered by the Office of the Environment and Heritage. The TSC Act requires proper assessment of the impacts of any action that may affect threatened species, populations and ecological communities.	The Nature Conservation Act 1992 (NCA) regulates the environmental impacts of the CSG industry through the use of industry clearing permits and Species Management Programs. The NCA protects native plants indigenous to Australia (protected plants) and regulates the clearing of individual protected plants. A clearing permit is required to clear protected plants unless an exemption applies. In general, exemptions will only apply to the clearing of least concern protected plant species. Clearing of endangered, vulnerable, rare or near threatened protected plants will require a clearing permit.

5.3 REGULATION OF CSG IN THE UNITED STATES

In the US CSG is regulated under complex set of federal, state, and local laws (Daniel, Langhus et al. 2008), and like Australia, is regulated under the same legislation as conventional gas and oil exploration and extraction. There is an added level of local regulation in the US, where cities, counties, tribes, and regional water authorities may set operational or environmental requirements, or require permits and approvals. Each oil and gas producing state has one agency with primary responsibility for permitting wells and overseeing general operations. However, land and water titles are very different in the US and Australia.

Most of the federal regulation is administered by U.S. Environmental Protection Agency (EPA). The primary federal laws governing CSG operations are the Clean Air Act (air emissions from engines and equipment), the Clean Water Act (surface discharges of water, as well as storm water runoff from production sites).

However, the CWA specifically exempts mining, gas, and oil operations, exploration, and construction from federal storm water regulations (Congressional Research Service, 2009).

The Safe Drinking Water Act (SDWA) is the main federal Act intended to ensure the quality of US drinking water. It covers (among other things) any injection of fluids into underground water supplies, as well as discharges of pollutants from any point source.

In 2005 the Energy Policy Act amended the SDWA to exempt hydraulic fracturing fluids used in gas and oil industry from the requirements of the SDWA (Congressional Research Service, 2009). There was an attempt to repeal this on June 9 2009, when the *Fracturing Responsibility and Awareness of Chemicals Act* (dubbed the FRAC Act) was introduced to both houses of Congress. It would have required the energy industry to disclose the chemicals used in fracture fluids and repealed the exemption to the SDWA. However, it was not passed.

Despite the exemption, in 2010 the EPA, relying on its emergency powers under the SWDA, issued an order to Range Production Company to stop what the EPA considered to be ongoing contamination to drinking water due to hydraulic fracturing in Texas.

The SDWA Act still covers the reinjection of produced waters from the CSG extraction process, although generally the States have been delegated the permitting authority under the Act.

It is beyond the scope of this report to compare individual state regulations covering CSG with the regulatory requirements in Australia. However, the exemption of mining and gas operations from the major legislation covering drinking water protection and storm water would not be acceptable in Australia.

5.4 GAPS IN LEGISLATION AND POLICY

Given the potential scale of CSG production in NSW and Queensland, and the corresponding scale of potential impacts, the regulatory framework should ensure that industry development proceeds in a way that does not compromise community or environmental values. The pace of development of a new type of extractive industry with widespread infrastructure poses new challenges for protection of water resources. It highlights the lack of sufficient baseline information on geology and aquifer interactions, and of modeling techniques for cumulative subsurface impacts. These gaps should be addressed urgently, in order to inform both strategic planning, regulation, and monitoring regimes.

At present the legislation is framed with a presumption of consent for mining; for example, if arbitration occurs, the determination often relates to what conditions should be attached rather than whether the consent should be given (EDO 2011, p47). It is beyond the scope of this report to make detailed recommendations regarding legislative reform; the Environment Defenders Office has undertaken a detailed review of NSW regulation of mining and CSG activities, and makes a series of 21 such detailed recommendations (EDO 2011). However, there are some key gaps in policy and regulation:

1) ***Strategic planning, regulation, and compliance monitoring of CSG should be informed by co-ordinated regional research on hydrogeolocial interactions, overseen by a body such as the National Water Commission***.

2) ***Federal legislation (the Commonwealth Environment Protection and Biodiversity Conservation Act 1999)*** should be amended to include a trigger where there may be regional impacts on water resources***.***

3) ***CSG development needs to occur within a framework of strategic planning***
   There is a need for strategic planning to avoid conflicts between mining and CSG activities and other land uses, such as housing development, agriculture, renewable energy development, or conservation. It should involve communities, as well as experts and interest groups. The importance of strategic planning is magnified by the rapid expansion of mining and CSG activities. The planned Strategic Regional Land Use Policy in NSW gives an opportunity for this process: it should include identification of competing land uses, undertake baseline studies, take cumulative impacts into account, and integrate social and environmental factors into decision making. It is prudent to halt new applications while this is underway.

4) ***Cumulative impacts need to be addressed, and both the information base and regulation concerning CSG and potential impacts on aquifers needs strengthening***
   The regulatory framework for water protection needs to be strengthened. For example, there are no mandatory requirements for monitoring of groundwater levels or individual bores before or after CSG activities, or after CSG operations are completed. More generally, there is a need for baseline information on geology and aquifers in order to properly predict the likely cumulative effects of CSG on aquifers. Without such information, it may be difficult to ascertain whether particular projects should go ahead based on principles of sustainable development. There should also be clear responsibility within the Acts for co-ordinated assessment of potential aquifer impacts and the cumulative impacts of multiple projects.

5) ***Community involvement in decisions and approvals needs to be ensured***
   It is important that the approvals process is framed in such a way as to enable community contribution to project decisions, rather than to avoid it. This includes such issues as ensuring sufficient time for public exhibition and comment, ensuring that decision makers must consider community inputs, and that notification of project applications should be as wide as possible, and also notified by Government in a co-ordinated and easily accessible way.

6) ***Regulation of access arrangements should be reformed to redress the balance between landholders and project proponents, including standard requirements for information provision.***
   Efforts should be made so that the access arrangement and notification is as standard as possible, and gives landholders sufficient time to object if they so wish.

7) ***Monitoring and reporting of fugitive emissions should be required for exploration and production well, with a view to developing minimum standards under consent conditions.***
   Fugitive emissions from oil and gas operations are projected to double by 2020, and there is considerable uncertainty on the actual emissions from CSG operations. There should be mandatory monitoring and reporting, with a view to a comprehensive review of life cycle emissions and consideration given to setting national standards for fugitive emissions. This would ensure that industry best practice is developed and followed, and that CSG development does not add an unnecessary burden to Australia's emissions.

8) ***A centralized, co-ordinated, and transparent procedure for compliance monitoring and reporting should be adopted for all exploration and production activities within NSW.***

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Appendix 1 COMPOSITION OF CSG AND CONVENTIONAL GAS COMPARED

Table 10: Typical specification for gas from CSG and conventional natural gas processing plants

Characteristic		Limit
	Coal Seam Methane	**Conventional Natural Gas**
Carbon Dioxide	≤ 3%	≤ 4%
Water Content	≤ 65 mg/cubic meter	≤ 48 mg/cubic meter
Inert Gases	≤ 6%	≤ 6%
Oxygen	≤ 0.2%	≤ 0.2%
Total Sulphur	≤ 50 mg/cubic meter	≤ 10 mg/cubic meter
Gross Heating Value	≥ 35 MJ per cubic meter (if inerts ≤ 4%)	≥ 37 MJ per cubic meter
Wobbe Index (measure of combustion energy output)	≥ 47 and ≤ 52	≥ 47 and ≤ 51
Hydrocarbon Dew Point	≤ 10 ^{o}C	≤ 0 ^{o}C

Source: Kimber & Moran, 2004 p.12-3

Table 11: Typical composition of processed natural Gas

Component	Presence Coal Seam Gas (%)	Presence Conventional Gas (%)
Methane	97	90
Ethane	0	4
Propane	0	1.7
Butane	0	0.4
Pentane	0	0.11
Hexane	0	0.08
Heptane	0	0.01
Carbon dioxide	2	2.7
Nitrogen	1	1

Source: APIA fact sheet No. 2 Gas Consumption and Usage

Appendix 2 TYPICAL CHEMICALS USED IN AUSTRALIAN CSG HYDRAULIC FRACTURING FLUIDS

Chemical	*Fraccing use*	*Common/household use example*
1-Propanol	Complexor	Used as a solvent in the pharmaceutical industry
2-Butoxyethanol	Used to reduce surface tension to aid in gas flow	Used in whiteboard cleaners, liquid soaps, cosmetics and lacquers.
Acetic Acid	pH buffer	Gives vinegar its taste
Acrylic copolymer	Lubricant	Used as a soil-repellent coating by the building industry
Ammonium persulfate	Breaker used to reduce viscosity (turns a gel into water)	Used in hair bleach, blot gels and glass cleaning products
Boric Acid	Crosslinker to increase viscosity	Used in antiseptics to treat cuts and fungal infections (athlete's foot)
Boric Oxide	Crosslinker to increase viscosity	Used to produce high strength alloys, glasses and ceramics
Carbonic acid	Crosslinker to increase viscosity	Found in soft drinks, champagne, and blood
Carboxy-Methyl Hydroxy-Propyl Guar	Gelling agent (thickens fluid to help suspend sand)	A more refined version of guar which is found in food products
Crystalline silica (cristobalite)	Proppant (holds open fractures)	Sand and gravel
Crystalline silica (quartz)	Proppant (holds open fractures)	Sand and gravel
Citric Acid	Iron control or for cleaning well bores before fraccing	Contained in orange juice
Diammonium Peroxidisulphate	Breaker used to reduce viscosity (turns a gel into water)	Used in hair bleach, blot gels and glass cleaning products
Disodium Octaborate Tetrahydrate	Gelling agent/Crosslinker to increase viscosity	Used as a fertilizer
Gas oils (petroleum), hydrotreated light vacuum	Guar liquefier	Baby oil, coolant or thermal fluid, wood conditioner
Fumaric acid	pH buffer	Used to treat psoriasis, and as a flavouring, and to make sourdough and rye bread
Gelatine	Corrosion inhibitor or gelling agent	Used to make jelly
Guar Gum	Gelling agent (thickens fluid to help suspend sand)	Used as a food thickening agent
Hemicellulase Enzyme with/without Sodium Chloride	Breaker used to reduce viscosity (turns a gel into water)	Commercial food processing of coffee
Hydrochloric Acid	Cleaning of the wellbore prior to fraccing	Used to clean swimming pool filters
Hydroxy-Ethyl Cellulose	Gelling agent (thickens fluid to help suspend sand)	Used as a placebo in medical trials
Hydroxy-Propyl Guar	Gelling agent (thickens fluid to help suspend sand)	Refined version of guar - used in food products such as cheese and ice cream
Magnesium silicate hydrate	Gelling agent	Chemically identical to talcum powder
Methanol	Used to reduce surface tension to aid in gas flow	A type of alcohol, can be used in wastewater treatment and as an alternative fuel
Mono ethanol amine	Gelling agent	Used in the manufacture of cosmetics, pharmaceuticals, and emulsifiers
Ethylene Glycol Monobutyl Ether	Mutual solvent	Used in household cleaners, fire fighting foam, and to degrease bowling pins and lanes
Muriatic Acid	Used for cleaning the well bore	Leather tanning and for cleaning
Non-crystalline silica	Proppant (holds open fractures)	Used to make glass
Poly (oxy-1,2-ethanediyl)	Proppant (holds open fractures)	Hair treatments and shampoo
Polydimethyldiallylammonium chloride	Clay control	Used in waste water treatment
Potassium Carbonate	pH buffer	Commonly used to make soap, wine, glass, dyes, and as a fire suppressent
Potassium Chloride	Clay inhinbitor	Table salt substitute
Quaternary Polyamines	Clay control	Used in waste water treatment
Sodium Acetate	pH buffer	Provides the primary flavouring in salt and vinegar potato chips
Sodium Borate	pH buffer	A component in glass, pottery, and detergents
Sodieum Bicarbonate	pH buffer	Used in cooking
Sodium Carbonate (Soda Ash)	pH buffer	Used to neutralise acid
Sodium Chloride	Breaker used to reduce viscosity (turns a gel into water)	Table salt
Sodium Hydroxide	pH buffer	Used as a buffer (adjust pH)
Sodium Hypochlorite with/without Sodium Hydroxide	Antiseptic to eliminate bacteria in water	Bleach - used in household cleaning and swimming pools to kill bacteria
Sodium Persulfate	Breaker used to reduce viscosity (turns a gel into water)	Used as a bleach in hair treatments, also as a detergent and soil conditioner
Terpenes/terpenoids/sweet orange oil	Used to reduce surface tension to aid in gas flow	Used in pharmaceuticals, contributes to the flavour of cinnamon, cloves and ginger
Tetrakis (hydroxymethyl) Phosphonium Sulfate	Antiseptic to elimate bacteria in water	Used an antiseptic to eliminate bacteria in water in farming and petroleum
Tetramethyl ammonium chloride	Clay control	A type of salt
Zirconium complex	Crosslinker to increase viscosity	Used as an alloying agent in surgical appliances

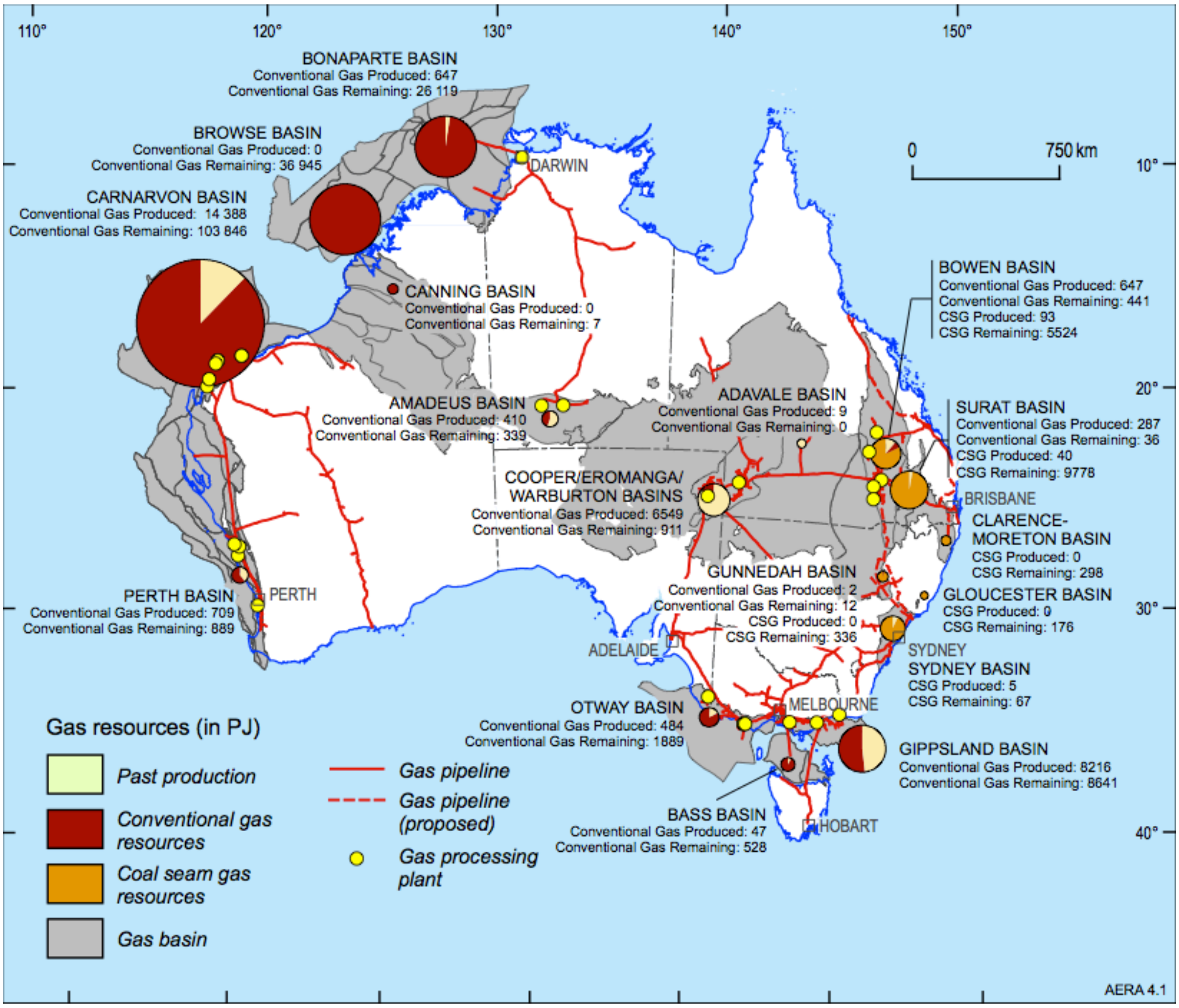
Note: All chemicals used in Australian CSG fraccing fluids are listed. Fraccing fluid mixes vary with the task, and a limited set the above chemicals are used in any single job. Reproduced from: APPEA, 2011 http://www.appea.com.au/images/stories/Policy_CSG/csg%20fraccing%20chemicals%20-%20final.pdf

Appendix 3 CSG INCIDENTS REPORTED IN MEDIA

Location	Incident	Date	Source	URL
Moranbah	BTEX chemicals found in 3 of 60 fluid samples. Arrow says unlikely to have spread to water bores.	Nov-10	Brisbane Times	www.brisbanetimes.com.au/queensland/new-coal-seam-gas-chemical-scare-20101109-17kzf.html
Surat Basin, West of Miles	BTEX chemicals	Oct-10	ABC	www.abc.net.au/news/2010-10-19/traces-of-carcinogenic-chemicals-found-in-gas-wells/2303824 origintogether.com/your-questions/faqs/
South East Qld - Darling Downs	Air pollution, land access, well ignition/eruption - Complaints re open trenches and increased turbidity of local creeks	2010	Sydney Morning Herald	www.basinsustainabilityalliance.org/cms-assets/documents/31069-783788.article-what-lies-beneath-smh.pdf
35 kilometres west of Dalby	Release of contaminated produced water	2010	Sydney Morning Herald	www.basinsustainabilityalliance.org/cms-assets/documents/31069-783788.article-what-lies-beneath-smh.pdf
Casino	CSG wells on floodplain - contamination fears	2010	Sydney Morning Herald	www.basinsustainabilityalliance.org/cms-assets/documents/31069-783788.article-what-lies-beneath-smh.pdf
Camden	Foam shooting into air, proximity of wells to houses.	17 May 2011	AGL	http://agk.com.au/camden/index.php/faqs/ Unconfirmed you tube video of the event. www.youtube.com/watch?v=c2oo4KQ27LM
Dalby	Aquifer communication -connecting the Springbok sandstone aquifer to the Walloon Coal Measures seam below.	2009	ABC	www.abc.net.au/news/2011-07-18/queensland-response-to-fracking-ban/2798526
Berwyndale - Darling Downs	Leaking gas pipe, reduction in property value associated with proximity to gas well	Sep-11	Wall Street Journal	www.online.wsj.com/article/BT-CO-20110912-715882.html
Tara, near Dalby	Carcinogenic chemicals detected in five water bores around the town. Residents suffering headaches, nosebleeds, skin rashes, illnesses, infections, nausea and vomiting claimed as a result of produced water used to settle dust on roads. Tara residents began complaining in 2008 about leaking gas wells and the dumping of CSG water on roads, as well as a brown, oily substance in a creek.	Oct, 2010	Courier Mail	www.couriermail.com.au/business/claims-of-illnesses-and-cover-up-as-d-day-looms-for-coal-seam-gas-projects/story-e6freqmx-1225941426413
Roma	CSG industry development in floodplain	April, 2011	The Australian	www.theaustralian.com.au/national-affairs/flood-victims-blame-oil-and-gas/story-fn59niix-1226042452862
Qld - Statewide (originally raised in Tara)	34 leaking sites, five were found to be leaking at a flammable level.	June, 2011	Brisbane Times	www.brisbanetimes.com.au/queensland/leaking-csg-wells-no-threat-minister-20110606-1fowv.html#ixzz1YOgdFKPo

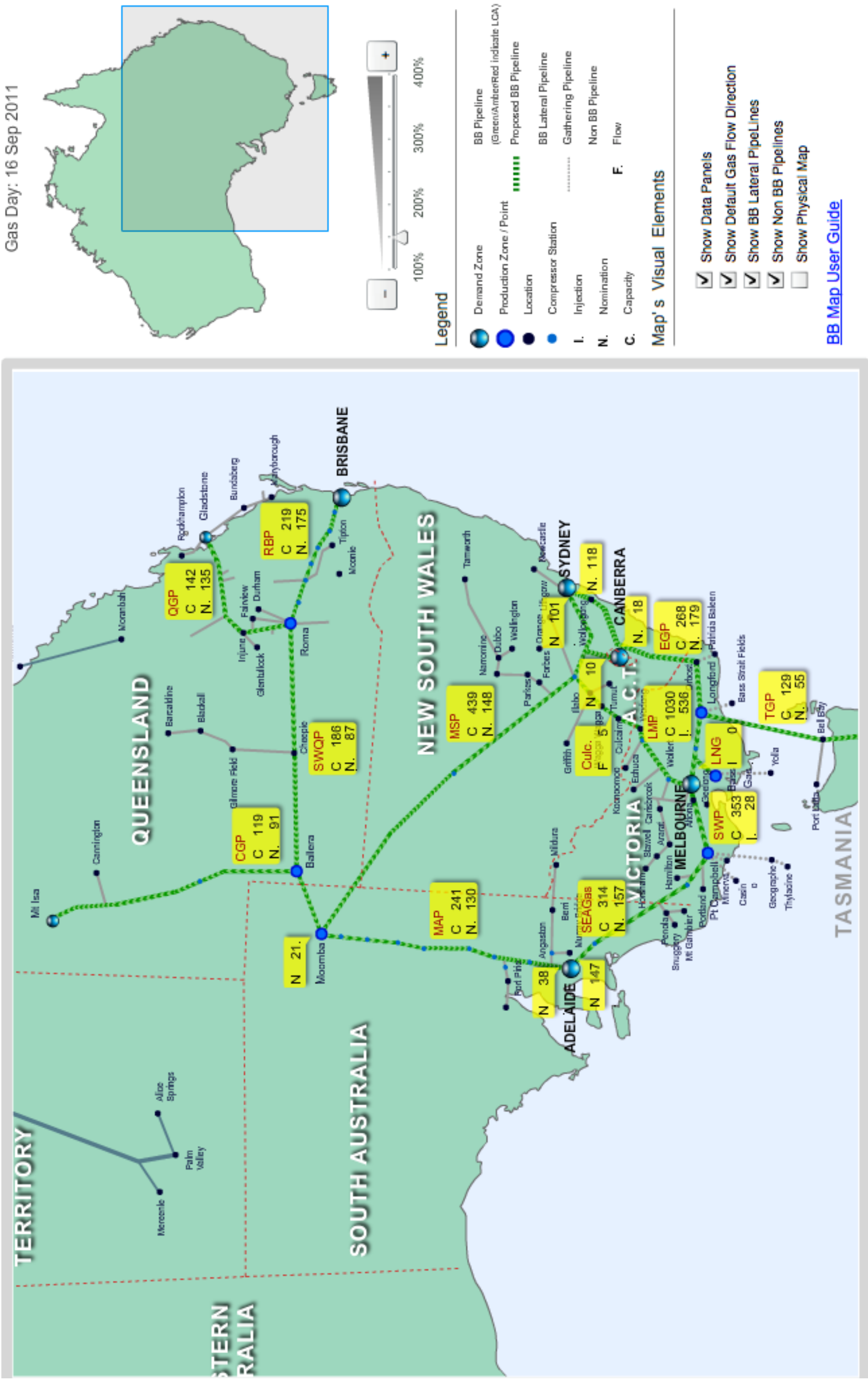
Appendix 4 CSG AND CONVENTIONAL GAS RESERVES, AUSTRALIA

Figure 19: Location of Australia's gas reserves and infrastructure.



Source: ABARE, 2010 p.84

Figure 20 Location of gas infrastructure in South Eastern Australia



Source: http://www.gasbb.com.au/mapoverview.aspx

Appendix 5 NSW CSG AND CMM PETROLEUM EXPLORATION TENEMENTS 2011

Tenement Abbreviations:

PPL	Petroleum Production Licence
PEL	Petroleum Exploration Licence
PEP	Petroleum Exploration Permit (offshore)
PPLA	Petroleum Production Lease Application
PELA	Petroleum Exploration Licence Application
PAL	Petroleum Assessment Lease
PALA	Petroleum Assessment Lease Application
PSPAUTH	Petroleum Special Prospecting Authority
PSPAPP	Petroleum Special Prospecting Application

Target Abbreviations:

CSG	Coal Seam Gas
CSM	Coal Seam Methane
CMM	Coal Mine Methane
Conv.	Conventional Natural Gas

All tenements may be viewed on an interactive by following the below link. Service provided by the NSW Department of Primary Industries. http://www.minerals.nsw.gov.au/tasmap/
An example is included for Sydney in Figure 21 and Figure 22 below.

Table 12 NSW summary of gas exploration and production licences for 2011

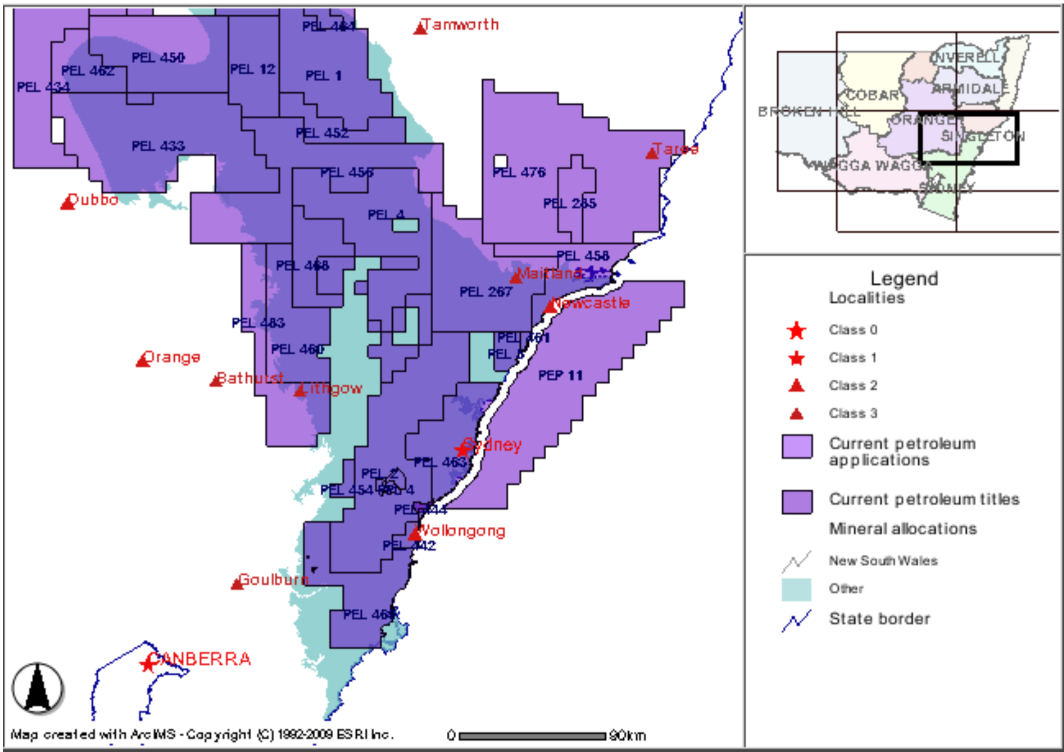
No.	Tenement
1	Petroleum Production Lease Application
6	Petroleum Production Licence
14	Petroleum Exploration Licence Application
53	Petroleum Exploration Licence
1	Petroleum Exploration Permit (offshore)
1	Petroleum Assessment Lease
7	Petroleum Special Prospecting Application
5	Petroleum Special Prospecting Authority

Table 13 NSW gas exploration, production licences and applications for 2011

Source: NSW DTIRIS, 2011

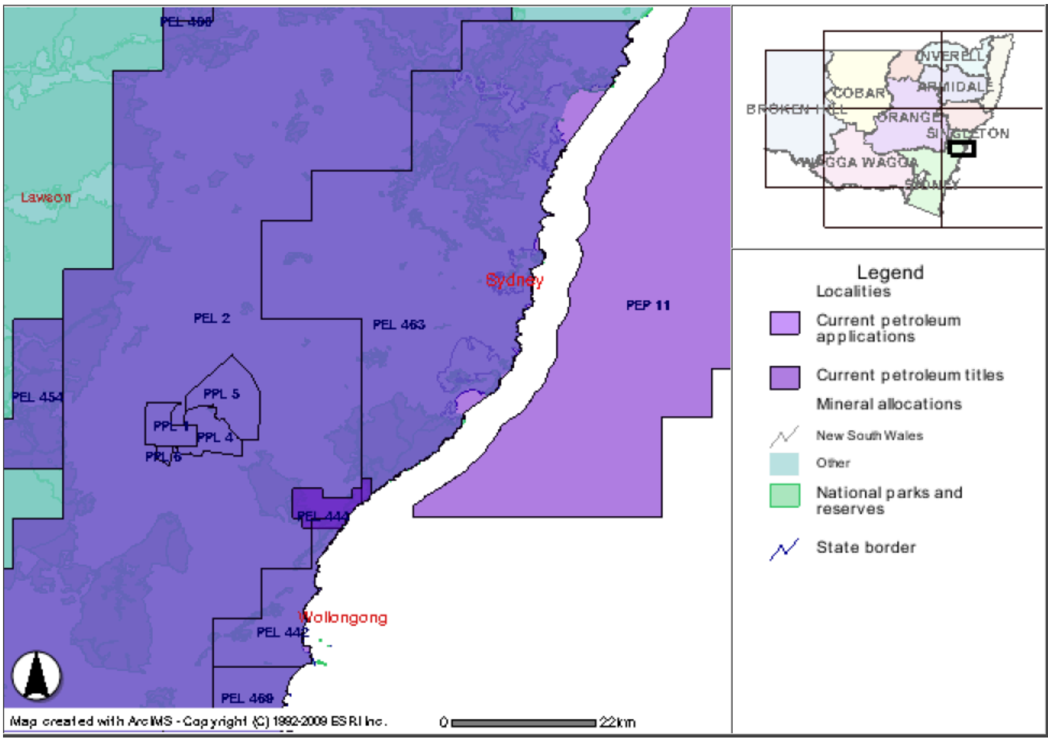
TITLE No.	BASIN	HOLDERS	TARGET	WEBSITE
PPL 1	Sydney	AGL (SG) (CAMDEN) OPERATIONS PTY LIMIT	CSM	http://www.agl.com.au/home/Pages/default.aspx
PPL 2	Sydney	AGL (SG) (CAMDEN) OPERATIONS PTY LIMIT	CSM	http://www.agl.com.au/home/Pages/default.aspx
PPL 3	Gunnedah/Surat	EASTERN ENERGY AUSTRALIA PTY LIMITED	CSM	http://www.easternstar.com.au/
PPL 4	Sydney	AGL (SG) (CAMDEN) OPERATIONS PTY LIMIT	CSM	http://www.agl.com.au/home/Pages/default.aspx
PPL 5	Sydney	AGL GAS PRODUCTION (CAMDEN) PTY LIMIT	CSM	http://www.agl.com.au/home/Pages/default.aspx
PPL 6	Sydney	AGL GAS PRODUCTION (CAMDEN) PTY LIMIT	CSM	http://www.agl.com.au/home/Pages/default.aspx
PAL 2	Gunnedah	EASTERN STAR GAS LIMITED	CSM	http://www.easternstar.com.au/
PEL 1	Gunnedah/Surat	AUSTRALIAN COALBED METHANE PTY LIMITI	CSM	x
PEL 2	Sydney	AGL (SG) OPERATIONS PTY LIMITED	CSM	http://www.agl.com.au/home/Pages/default.aspx
PEL 4	Sydney	AGL (SG) OPERATIONS PTY LIMITED	CSM	http://www.agl.com.au/home/Pages/default.aspx
PEL 5	Sydney	AGL (SG) OPERATIONS PTY LIMITED	CSM	http://www.agl.com.au/home/Pages/default.aspx
PEL 6	Bowen/Surat	ORION PETROLEUM LIMITED	Conv.	http://www.orionpetroleum.com.au/
PEL 12	Gunnedah/Surat	AUSTRALIAN COALBED METHANE PTY LIMITI	CSM	x
PEL 13	Clarence-Moreton	METGASCO LTD	CSM	http://www.metgasco.com.au/
PEL 16	Clarence/Moreton	METGASCO LTD	CSM	http://www.metgasco.com.au/
PEL 238	Gunnedah/Surat	EASTERN STAR GAS LTD	Conv./CSM	http://www.easternstar.com.au/
PEL 267	Sydney	AGL (SG) OPERATIONS PTY LIMITED	CSM	http://www.agl.com.au/home/Pages/default.aspx
PEL 285	Gloucester	AGL GLOUCESTER LE PTY LTD	CSM	http://www.agl.com.au/home/Pages/default.aspx
PEL 422	Darling/Eromanga	ORION PETROLEUM LIMITED	Conv.	http://www.orionpetroleum.com.au/
PEL 424	Darling/Murray	ORION PETROLEUM LIMITED	Conv.	http://www.orionpetroleum.com.au/
PEL 426	Clarence Moreton	METGASCO LTD	CSM	http://www.metgasco.com.au/
PEL 427	Bowen/Surat	COMET RIDGE LTD	CSM	http://www.cometridge.com.au/
PEL 428	Surat	COMET RIDGE LTD	CSM	http://www.cometridge.com.au/
PEL 433	Gunnedah/Surat	EASTERN STAR GAS LIMITED	CSM	http://www.easternstar.com.au/
PEL 434	Surat	EASTERN STAR GAS LIMITED	CSM	http://www.easternstar.com.au/
PEL 437	Surat	PANGAEA PTY LIMITED	Conv./CSM	x
PEL 442	Sydney	APEX ENERGY NL	CMM	http://www.apexenergy.com.au/
PEL 443	Eromanga	HARLOW AUSTRALIA PTY LTD	Conv.	x
PEL 444	Sydney	APEX ENERGY NL	CMM	http://www.apexenergy.com.au/
PEL 445	Clarence-Moreton	B.N.G. PTY. LTD.	CSM	http://www.arrowenergy.com.au/
PEL 447	Darling/Murray	RED SKY ENERGY LIMITED	Conv.	http://www.redskyenergy.com.au/
PEL 448	Darling	RED SKY ENERGY LIMITED	Conv.	http://www.redskyenergy.com.au/
PEL 449	Darling/Murray	RED SKY ENERGY LIMITED	Conv.	http://www.redskyenergy.com.au/
PEL 450	Gunnedah	SANTOS QNT PTY LTD	CSM	http://www.santos.com/
PEL 452	Gunnedah	SANTOS QNT PTY LTD	CSM	http://www.santos.com/
PEL 454	Sydney	APEX ENERGY NL	CSM	http://www.apexenergy.com.au/
PEL 455	Bowen/Surat	ORION PETROLEUM LTD	Conv.	http://www.orionpetroleum.com.au/
PEL 456	Sydney-Gunnedah	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 457	Clarence-Moreton	EAST COAST POWER PTY LTD	Conv./CSM	http://www.eastcoastpower.com.au/index.html
PEL 458	Sydney	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 459	Gunnedah	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 460	Sydney	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 461	Sydney	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 462	Surat	SANTOS QNT PTY LTD	CSM	http://www.santos.com/
PEL 463	Sydney	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 464	Gunnedah	MACQUARIE ENERGY PTY LTD	Conv./CSM	http://www.apollogas.net.au/
PEL 465	Surat	NORWEST HYDROCARBONS PTY LTD	Conv./CSM	http://www.redskyenergy.com.au/
PEL 466	Surat/Eromanga	NORWEST HYDROCARBONS PTY LTD	Conv./CSM	http://www.redskyenergy.com.au/
PEL 467	Surat	NORWEST HYDROCARBONS PTY LTD	Conv./CSM	http://www.redskyenergy.com.au/
PEL 468	Sydney	LEICHHARDT RESOURCES PTY LTD	CSM	http://www.leichhardtresources.com.au/
PEL 469	Sydney	LEICHHARDT RESOURCES PTY LTD	CSM	http://www.leichhardtresources.com.au/
PEL 470	Gunnedah	LEICHHARDT RESOURCES PTY LTD	CSM	http://www.leichhardtresources.com.au/
PEL 471	Eromanga/Darling	ORION PETROLEUM LIMITED	Conv.	http://www.orionpetroleum.com.au/
PEL 472	Darling/Murray	ENERGETICA RESOURCES PTY LIMITED	Conv.	x
PEL 473	Darling/Murray	ENERGETICA RESOURCES PTY LIMITED	Conv.	x
PEL 474	Murray	ENERGETICA RESOURCES PTY LIMITED	Conv./CSM	x
PEL 475	Surat	DREQUILIN PTY LIMITED	CSM	x
PEL 476	Lorne/Gloucester	PANGAEA OIL & GAS PTY LIMITED	CSM	x
PEL 477	no basin	PANGAEA OIL & GAS PTY LIMITED	CSM	x
PEL 478	Clarence-Moreton	CLARENCE MORETON RESOURCES PTY LIM	CSM	x
PEL 479	Clarence-Moreton	CLARENCE MORETON RESOURCES PTY LIM	CSM	x
PEL 480	Surat	SURAT RESOURCES PTY LIMITED	Conv./CSM	x
PEP 11	Sydney (offshore)	BOUNTY OIL & GAS NL	Conv.	http://www.bountyoil.com/
PSPAUTH 32	Darling/Murray	ENERGETICA RESOURCES PTY LIMITED	Conv.	x
PSPAUTH 33	Eromanga	NSW GEO HELIUM PTY LTD	Helium	http://www.apollogas.net.au/
PSPAUTH 34	New England Orogen	PANGAEA OIL & GAS PTY LIMITED	CSM	x
PSPAUTH 35	Sydney	PANGAEA OIL & GAS PTY LIMITED	CSM	x
PSPAUTH 36	New England Orogen	PANGAEA OIL & GAS PTY LIMITED	CSM	x

Figure 21 NSW CSG Petroleum Tenements 2011 - 90 km Scale



Source: NSW Department of Primary Industries. http://www.minerals.nsw.gov.au/tasmap/

Figure 22 NSW Petroleum Tenements 2011 - 22 km Scale



Source: NSW Department of Primary Industries. http://www.minerals.nsw.gov.au/tasmap/

Appendix 6 ACTIVE AND PROPOSED CSG PROJECTS IN QUEENSLAND

Table 14 Queensland active CSG projects

Project Name	Basin	Location
Anglo Coal (Dawson) Ltd		
Dawson Valley	Bowen	Moura area - (Baralaba Coal Measures)
Dawson River	Bowen	Moura area - (Baralaba Coal Measures)
Moura	Bowen	Moura area - Baralaba Coal Measures)
Mungi	Bowen	Moura area - (Baralaba Coal Measures)
Nipan	Bowen	Moura area - (Baralaba Coal Measures)
Daandine	Surat	Dalby area – (Walloon Coal Measures)
Kogan North	Surat	Dalby area – (Walloon Coal Measures)
Moranbah Gas Project	Bowen	Moranbah area – (Moranbah Coal Measures)
Tipton West	Surat	Dalby area – (Walloon Coal Measures)
Origin Energy		
Peat	Bowen	Wandoan area – (Baralaba Coal Measures)
Spring Gully	Bowen	Injune area – (Bandanna Formation)
Talinga	Surat	Chinchilla area – (Walloon Coal Measures)
Queensland Gas Company Limited (a BG Group business)		
Argyle	Surat	Chinchilla area – (Walloon Coal Measures)
Argyle East	Surat	Chinchilla area – (Walloon Coal Measures)
Berwyndale	Surat	Chinchilla area – (Walloon Coal Measures)
Berwyndale South	Surat	Chinchilla area – (Walloon Coal Measures)
Codie/ Lauren	Surat	Chinchilla area – (Walloon Coal Measures)
Kenya	Surat	Chinchilla area – (Walloon Coal Measures)
Santos Ltd		
Coxon Creek	Surat	Roma area – (Walloon Coal Measures)
Fairview	Bowen	Injune area – (Bandanna Formation)

Source: QLD Queensland's coal seam gas overview (February 2011) www.deedi.qld.gov.au

Table 15 Queensland proposed CSG projects

Project Name / Company	Basin	Location (area only)
ARROW ENERGY LIMITED		
Bowenville	Surat	Dalby area – (Walloon Coal Measures)
Burunga Lane	Surat	Wandoan – (Walloon Coal Measures)
Carborough	Bowen	Morandah – (Moranbah Coal Measures)
Castledean	Surat	Miles – (Walloon Coal Measures)
Dalby South	Surat	Dalby – (Walloon Coal Measures)
Dundee	Surat	Chinchilla – (Walloon Coal Measures)
Hopelands	Surat	as above
Kedron	Surat	Miles area – (Walloon Coal Measures)
Long Swamp	Surat	Dalby area – (Walloon Coal Measures)
Meenawarra	Surat	as above
Millmerran	Surat	Millmerran – (Walloon Coal Measures)
Plainview	Surat	Dalby – (Walloon Coal Measures)
S1 And S2	Surat	as above
Stratheden	Surat	as above
BOW ENERGY LTD		
Blackwater	Bowen	Blackwater– (Rangal Coal Measures)
Don Juan	Surat	Roma– (Walloon Coal Measures)
ORIGIN ENERGY		
Combabula	Surat	Wandoan– (Walloon Coal Measures)
Condabri	Surat	Miles area – (Walloon Coal Measures)
Dalwogen	Surat	as above
Gilbert Gully	Surat	Dalby area – (Walloon Coal Measures)
Kainama	Surat	as above
Kainama North	Surat	as above
Membrance	Bowen	Injune area – (Bandanna Formation)
Orana	Surat	Chinchilla – (Walloon Coal Measures)
Orana North	Surat	as above
Ramyard	Surat	Wandoan– (Walloon Coal Measures)
Woleebee	Surat	as above
QUEENSLAND GAS COMPANY LIMITED		
Aberdeen, Ridgewood	Surat	Dalby area – (Walloon Coal Measures)
Bellevue	Surat	Chinchilla – (Walloon Coal Measures)
Berwyndale And Berwyndale Deep	Surat	as above
Cameron	Surat	Wandoan – (Walloon Coal Measures)
Kenya East/Jammat/Jen/Sean	Surat	Chinchilla – (Walloon Coal Measures)
Lacerta	Surat	Roma – (Walloon Coal Measures)
Matilda John	Surat	Chinchilla – (Walloon Coal Measures)
Owen/Mcnulty/Avon Downs	Surat	as above
Polaris	Surat	Wandoan– (Walloon Coal Measures)
Woleebee Ck/Ross/Cam/Kathleen	Surat	Chinchilla– (Walloon Coal Measures)
SANTOS LTD		
Arcadia	Bowen	Injune – (Walloon Coal Measures)
ATP 631	Surat	Miles – (Walloon Coal Measures)

Source: QLD Queensland's coal seam gas overview (February 2011) www.deedi.qld.gov.au

Appendix 7 LIST OF COMPANIES ACTIVELY INVOLVED IN CSG ACTIVITIES IN AUSTRALIA

There are a 38 companies active in the CSG exploration in Australia, listed in Table 16. The growth of the CSG industry has led to considerable new entry in Queensland's Surat–Bowen Basin over the past decade. The largest producers are Origin Energy (19 per cent), BG Group (18 per cent), ConocoPhillips (17 per cent), Santos (16 per cent), Arrow Energy (now owned by Shell and PetroChina, 10 per cent), Petronas (6 per cent), and Shell and AGL Energy (4 per cent each) (AER, 2010 p.73).

Table 16 Companies actively involved in CSG exploration

Company	State(s)	Basin(s)
AGL Upstream Investments Pty Ltd	NSW	Sydney, Gloucester
Anglo Coal Australia	QLD	Bowen
Apex Energy NL	NSW	Sydney
Arrow Energy NL	QLD	Surat and Bowen
Australia Pacific LNG (APLNG)	QLD	Surat and Bowen
Australian Coalbed Methane Pty Ltd	NSW, QLD	Gunnedah and Surat
B.N.G. Pty Ltd	NSW	Clarence - Moreton
Blue Energy Pty Ltd	QLD	Bowen, Surat and Maryborough
Bow Energy	QLD	Surat and Bowen
Central Petroleum Ltd	SA	Pedirka Basin
CH4 Gas Ltd	QLD	Surat and Bowen
Clarence Moreton Resources Pty Ltd	NSW	Clarence-Moreton
Coal and Allied Ltd	NSW	
Comet Ridge Ltd	QLD, NSW	Bowen, Galilee and Gunnedah
Dart Energy	NSW	Sydney and Gunnedah
Drequilin Pty Limited	QLD	Surat
East Coast Power Pty Ltd	NSW	Clarence-Moreton, Surat
Eastern Star Gas (ESG)	SA, NSW, QLD	Otway, Surat and Gunnedah
Eneabba Gas Ltd	WA	Perth Basin
Energetica Resources Pty Ltd	NSW	Murray
Leichhardt Resources Pty Ltd	NSW	Sydney
Lucas Energy Pty Ltd	NSW	
Macquarie Energy Pty Ltd	NSW	Sydney, Gunnedah
Magellan Petroleum Australia	QLD	Maryborough
Metgasco Ltd	NSW	Clarence - Moreton
Molopo Australia Ltd	NSW, QLD	Gloucester, Bowen and Clarence-Moreton
Origin Energy Ltd	QLD	Surat and Bowen
Ormil Energy	NSW	Sydney
Pacific GTL Ltd	NSW, QLD	
Pangaea Oil & Gas Pty Limited	NSW	Lorne, Gloucester
Pangaea Pty Limited	QLD	Surat
Planet Gas Ltd	VIC, SA, NSW	Gipps, Eromanga, Wilochra, Gunnedah, Otway
Pure Energy Resources Ltd	QLD, TAS	Bowen, Duaringa, Surat and Tasmania
Queensland Gas Company	QLD	Surat
Rey Resources Ltd	WA	Canning Basin
Santos Ltd	QLD	Surat, Bowen, Gunnedah
Shell Australia	QLD	
Sunshine Gas Ltd	QLD	Surat and Bowen
Surat Resources Pty Limited	QLD	Surat
Sydney Gas Ltd	NSW	Sydney
Westralian Gas and Power Ltd	WA	Perth, Collie and Wilga Basins

Sources: NSW Department of Trade and Investment, Regional Infrastructure and Services (23/6/2011) and www.australianminesatlas.gov.au

Appendix 8 KEY LEGISLATION IN NSW

Petroleum (Onshore) Act 1991 (NSW)

The NSW Minister for Primary Industries must issue a petroleum title before exploration or production can take place.

There are three main types of petroleum titles:
(i) Petroleum exploration licence (Granted for up to 6 years)
(ii) Petroleum assessment lease (Granted for up to 6 years)
(iii) Petroleum production lease (Granted for up to 21 years)

Applications submitted for petroleum titles must be supported by plans showing the boundary of area to be covered by title, a proposed plan of works to be carried out and applicant's financial standing. The Act (Section 21) lists the grounds on which an application may be refused, for example, the Minister may decide that in the public interest it would be better not to grant the title, or to grant someone else a title over the land. The applicant for an exploration licence will be required by the Department of Primary Industies to advertise the lodgement of all exploration licence applications in a newspaper circulating throughout the State and in a newspaper circulating in the District in which the land applied for is situated. Information in relation to areas held under exploration licences or applications for exploration licences can be obtained from the Departments on-line Title services

The Act also requires the Minister to have regard to certain environmental impacts (section 74) on the land before issuing a petroleum title, specifically:
(a) the flora, fauna, fish, fisheries and scenic attractions, and
(b) the features of Aboriginal, architectural, archaeological, historical or geological interest.

The Minister may require an Environmental Impact Study (EIS) and the title may also be subject to certain conditions. Standard conditions of petroleum ***exploration*** licences and assessment leases include approval by The NSW Department of Primary Industry (bar low intensity reconnaissance).Standard conditions of petroleum ***production*** leases require the title holder to submit to the Department a petroleum operations plan prior to starting work, and to submit annual environmental management reports.

Development consent is required under the EP&A Act 1979 before the Minister (DPI) grants a petroleum production lease.

Statutory restrictions regarding access under the Act:

- A project proponent must not carry out any prospecting or erect any works on land which is within 200 metres of a person's principal place of residence except with the written consent of the owner.
- The holder of a production lease must not carry out mining (or CSG extraction) on land that is under cultivation, except with the consent of the landholder, or with the approval of the Minister (note that cultivation does not include grazing or fodder crops).
- Local Environmental Plans of certain Councils may also prohibit petroleum exploration in certain zones.
- A project proponent cannot carry out prospecting operations on any land otherwise than in accordance with an access arrangement agreed between the title holder and each landholder, or determined by an arbitrator. If there is no agreement on an arbitrator then the government will appoint one to determine the access arrangement

***Environmental Planning and Assessment Act 1979* (NSW).**

An Exploration or Production Licence cannot be issued without prior approval under the *Environmental Planning and Assessment Act 1979* (EP&A Act 1979). All petroleum production projects and most exploration activities require an Environmental Assessment under Act, which comes under Department of Planning and Infrastructure (DP&I). The objectives of the EP&A Act are to encourage:

- proper management, development and conservation of natural and constructed resources;
- public involvement;
- promotion and co-ordination of the orderly and economic use and development of land;
- ecologically sustainable development; and
- protection of the environment.

The EP&A Act is intended to use the precautionary principle to guide project approvals

The EP&A Act regulates many aspects of a CSG projects including the management of produced water, hydraulic fracturing, and injection of water into aquifers or other geological formations. Approval with a set of environmental conditions is issued by the Planning Minister following assessment of the potential environmental impacts, including impacts on water levels, as understood at the time of approval. If new information emerges then the approval can be reassessed.

There are three approval streams regulated by Parts 3A, 4 and 5 of the Act. The applicable stream is determined by the size of the project (capital cost and persons employed), the environmental sensitivity of the location and the level of petroleum production. Part 3A applied to projects considered of State significance or defined as critical infrastructure, made the consent authority the State rather than the local council, and reduced the level of community input to the approvals process.

With the recent change of government in NSW, there has been a commitment to a new planning system, and the repeal of Part 3A of the EP&A Act will come into effect on October 4th 2011. The Bill[33] introduces a new method for dealing with state significant development, and is intended to provide for additional transparency and greater local government input to decisions on significant projects.

Mining or extraction projects which would have been captured by Part 3A will now fall under the new definition of State Significant Development, so the State Government will still be the approval authority.

Protection of the Environment Operations Act 1997

The Protection of the Environment Operations (PoEO) Act 1997 is administered by the Office of Environment and Heritage (OEH), which comes under the Preimier and Cabinet Office. The Act covers environmental protection licences for scheduled activities, which includes natural gas/methane production (Schedule 1 of the PoEO Act). The owner of a premises undertaking scheduled activities is required to hold an Environment Protection Licence and must comply, at all times, with the conditions of that licence. Conditions cover (where relevant) waste, discharges to air and water, and noise. Licences are on-going, but subject to review at least once every 5 years and can be varied or suspended.

SEPP (Mining, Petroleum Production and Extractive Industries) 2007

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[33] *Environmental Planning and Assessment Amendment (Part 3A Repeal) Bill 2011*. A new State environmental planning policy (SEPP) known as the *State and Regional Development 2011* will also be enacted on 4 October 2011 which provides additional detail on the classes and thresholds for development to be considered as State significant.

Petroleum production or exploration that is not state significant requires consent under this SEPP for the purposes of:

- Petroleum production on certain types of land or in certain areas, eg on land on which development for the purposes of agriculture or industry may be carried out,
- Facilities for the processing or transportation of petroleum on land on which petroleum production may be carried out if the petroleum being processed or transported was recovered from that land or adjoining land.

It also requires the consent authority to consider whether or not condition should be imposed that are aimed at ensuring the development is undertaken in an environmentally responsible manner including conditions to protect water resources, threatened species and biodiversity.

- Most exploration and production activities fall under Part 3 of the EP&A Act and applies to development for the purpose of drilling and operation of petroleum wells that:
- has a capital investment value of more than $30 million or employs more than 100 people; or
- is in an environmentally sensitive area of State significance; or
- in the case of coal seam gas, is in one of the 16 local government areas listed in the SEPP: e.g. Camden, Newcastle City

Part 3 of the EP&A is currently being reviewed which will also have implications for development approval under SEPP 4.

Strategic Regional Land Use Policy

In May 2011, the NSW Government announced it will take a staged approach to introducing a new Strategic Regional Land Use Policy, with the intention to "strike the right balance between our important agricultural, mining and energy sectors - while ensuring the protection of high value conservation lands" (Hazzard 2011). The Policy will be based on a set of Regional Strategic Plans, intended to provide local communities with greater certainty about how their areas will change over time.

The Policy includes some transitional measures designed to address immediate community concerns regarding mining and CSG extraction. These include:

- A moratorium until the end of 2011 on the granting of new coal, coal seam gas, and petroleum exploration licences in NSW;
- A requirement that all applications for coal, coal seam gas, and petroleum exploration licences be exhibited for public comment;
- The public notification of Guidelines which will inform the assessment of impacts on strategic agricultural land from proposed development activities;
- A requirement that all new coal, coal seam gas, and petroleum extraction applications must be accompanied by an Agricultural Impact Statement;
- The exhibition of an Aquifer Interference Regulation for public comment – which once implemented, will introduce a suite of new measures to better regulate activities that impact on aquifers; and
- A stakeholder reference group consisting of the key agricultural, industrial and conservation groups will be established to advise on the policy's development and implementation.
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Appendix 9 KEY LEGISLATION IN QUEENSLAND AND FEDERALLY

Petroleum and Gas (Production and Safety) Act 2004

In Queensland CSG is regulated primarily under the *Petroleum and Gas (Production and Safety) Act 2004.* However, there are legislative overlaps between the *Petroleum and Gas (Production and Safety) Act 2004* which allows CSG mining to be carried out under a relevant petroleum lease and the *Mineral Resources Act 1989* which allows for incidental CSG exploration.

Resource companies which are granted an authority or tenure under the Petroleum and Gas (Production and Safety) Act 2004 are authorised to explore, produce, process or transport coal seam gas. A licence can cover up to 100 blocks, or approximately 7,500 square kilometres. Activities under this authority are governed by the Land Access Policy Framework which was established under the Act in 2009, which includes a Land Access Code. The Land Access Code clearly sets out expectations of resource companies in relation to communication, consultation and behaviour when operating on private land, and imposes mandatory conditions on the way in which activities are undertaken on landholders and businesses.

Environmental Protection Act 1994

Under Queensland laws, all CSG operators must be issued an Environmental Authority (EA) from the Department of Environment and Resource Management (DERM) before they can commence operations. The EA process depends on whether the activity is classified on the risk of environmental harm as level 1 (medium to high risk activities) or level 2 mining activity. Most large scale CSG projects are Level 1 and require and Environmental Impact Statement (EIS) which goes on public exhibition for comments. Projects that do not require and EIA are still assessed against environmental criteria with environment conditions imposed. Level 1 activities require an Environmental Management Plan to be prepared.

Applicants for level 1 CSG activities must submit an Environmental Management Plan (EMP) as part of the assessment process for, which must consider impacts on air quality, CSG water management, treatment and disposal, mapping and protection of remnant vegetation and other important areas of habitat for native wildlife, noise impacts, impacts on the local communities, and management and disposal of wastes.

CSG production could also be made subject to review and approval under the *State Development and Public Works Organisation Act 1974* if the project is declared to be a “state significant” by the State Coordinator General. CSG production usually falls into this category. In this case a specialised Environmental Impact Statement (EIS) is required. As mentioned above, the Environmental Authority (EA) EA process will only occur after the EIS is finalised.

The government has also made amendments to encourage transparency in the reporting of environmental incidents. The new amendments to the Environment Protection Act will require operators of petroleum, including CSG activities to report to DERM and to the land owners any serious or material environmental incidents with 24hours from when the tenure holder becomes aware of the incident. Failure to report is an offence. DERM enforces these conditions with a compliance program consisting of inspections, audits and complaint response, although some community groups have raised concern about whether DERM has sufficient resources to undertake either monitoring or enforcement (Lock the Gate Alliance 2011). Under the Environmental Protection Act 1994, DERM can prosecute CSG operators for serious breaches of operating standards and impose clean-up requirements.

Under the Act, the *CSG/LNG Compliance Plan 2011* sets out DERM’s compliance approach in each of the following areas that it regulates:

- environmental management
- vegetation management
- wildlife and ecosystems
- underground water management

- water supply – water use and service provision
- protected plants
- usage of State-owned quarry material.

The key compliance areas for the *CSG/LNG Compliance Plan 2011* are:

- audits and inspections of CSG/LNG operations (CSG operators), including the CSG Water Management Plans developed under environmental authorities (EA) and sales permits to use State-owned quarry material;
- stimulation activities including hydraulic fracturing (fraccing) activities, including the chemicals used during this process
- the regulation of the use of benzene, toluene, ethyl-benzene and xylene (BTEX) CSG/LNG Compliance Plan 2011
- notification requirements under both the EP Act and EAs, the Water Act , and the Water Safety Act
- discharges to waters (both groundwater and surface water), including impacts to drinking water
- monitoring programs

Federal Regulation

Commonwealth Environment Protection and Biodiversity Conservation Act 1999
CSG activities require approval in accordance the above act if the activity is likely to have a significant impact on a matter of national environmental significance (Part 3). The Act lists eight such matters including nationally threatened species and ecological communities. The Commonwealth Environment Minister is responsible for deciding whether or not to approve the activity. An environmental assessment must be carried out before this decision is made. However, under a bilateral agreement between NSW and the Commonwealth (permitted under the Act), the Minister may rely on an assessment carried out under Parts 3A, 4 or 5 of the NSW *Environmental Planning and Assessment Act 1979*.

Appendix 10 RECENT INTERNATIONAL REGULATORY DEVELOPMENTS (Shale gas)

A number of countries have recently taken steps to regulate the exploration and production of shale gas, and the use of hydraulic fracturing in particular. Some countries have recently banned fraccing, and some states in Canada, Switzerland and the US have placed moratoriums on the process until studies are completed. All these examples concern shale gas rather than coal seam methane, but in many instances the moratoria or halts are focused on the hydraulic fracturing.

Canada

In 2011 Quebec placed a moratorium on fraccing whilst the government conducts a 2 year study on the process. The government's key concerns were related to the proximity of shale-gas beds to densely populated communities as well as to the province's prime agricultural heartland, near the banks of the St. Lawrence.

France

The French parliament voted to ban extracting shale gas through hydraulic fracturing In June 2011 and in doing so has become the first country to enact such a ban. Companies that currently own permits for drilling in oil shale deposits on French land will have two months to notify the state what extraction technique they use. If they declare to be using fraccing, or if they fail to respond, their permits will be automatically revoked. The amount of shale gas available in France is still unknown, but a report by the European Centre for Energy and Resource Security states that Europe as a whole could meet its energy demands for approximately 60 years if it were to use its unconventional gas resources (France24, 11 May 2011).

Germany

Germany's Federal Environment Agency (FEA) issued draft proposals for new mining laws at the beginning of August 2011. The FEA's proposals included guidelines to ensure that producers assess the environmental impact of drilling each well and a ban on hydraulic fracturing (fraccing) in areas where potable water is collected. Germany's Environment Minister has ordered a review into the environmental impact of shale gas production in Germany. The Minister has also said that the country's mining laws, which have previously been perceived as favourable for producers and lacking in scope for the public to object, would likely be changed.

United Kingdom

In January 2011, UK ministers rejected a moratorium on drilling for unconventional gas sources, saying that drilling for shale gas does not pose a threat. This comes after researchers at the Tyndall Centre, University of Manchester, released a report In January 2011 concluding that extraction of shale gas risks contamination and also delays the introduction of renewable energy alternatives (Wood, et al. 2011).

United States

On 5 May, US Department of Energy head Steven Chu set up an expert panel to make recommendations on how to improve the safety and environmental performance of hydraulic fracturing, with advice to be released at the end of 2011. Several areas in the US have recently banned fraccing or issued moratoriums on new development. In June 2011, New Jersey placed a one-year moratorium on fraccing so that the State Department of Environmental Protection could further evaluate the potential environmental impacts and evaluate the findings of ongoing federal studies by the EPA. In June 2011 the New York State Assembly passed a one-year moratorium on hydraulic fracturing, and a moratorium on new drilling permits until June 1 2012 (replacing the current ban set to expire later this year).

Switzerland

In April, 2011 authorities in the Swiss state of Fribourg suspended all authorizations to prospect for shale gas on its territory for an undetermined period. The state government decided not to renew a licence granted to Schuepbach Energy to explore for shale gas. The decision was reached based on the uncertainty around the impact of drilling on the environment and pollution risks. The Swiss Federal Government remains open to exploring the potential of shale gas, despite strong opposition from the Socialists and Green parties.