Coal seam gas production: challenges and opportunities
Some ways forward in managing environmental issues and deriving economic and social benefit

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Introduction
Coal seam gas (CSG) is a methane-gas fuel, like the natural gas familiar to Australian households. This relatively newly discovered resource has both potential and opportunity to help meet Australia's current and future energy needs. However, known reserves of CSG, mainly in sedimentary coal basins in Queensland and NSW, are often in areas that are relatively populated and already in use for agricultural or other production. The reserves’ locations, their very rapid development which has outstripped the pace of relevant policy-making, and fears about failures in technical aspects of CSG operations, are factors that have together led to strong concerns among government and communities. The result has been high profile challenges and committees all ultimately aiming to ensure the industry gains and retains a social licence to operate.

Sudden invasion of the landscape by CSG operations, a completely new type of land use in these Queensland and NSW regions, has, however, highlighted an urgent need for holistic policy about managing Australia’s regional areas and their environments. This is an opportunity to improve the overall environmental management of impacts of existing and new land uses. Australia’s natural resources, such as water, landscape and native vegetation, support considerable development for human uses. But there are limits to the amount of development a landscape or catchment can bear without exceeding its capacity to provide ecosystem services such as sufficient clean water, stable soils, clean air and essential biological functions such as pollination and organic-matter turnover.

As just one more land use entering a catchment, CSG extraction can have a place, provided that place is assigned after assessment of the vulnerability of local natural resources and productivity to cumulative impacts. Methods and skills for cumulative risk assessment of landscape function exist in catchment management teams across Australia. Catchment action plans have the potential to provide the information legislators need to understand the capacity of the landscape.

Policy-makers and regulators in areas affected by the CSG developments in eastern Australia are attempting to legislate to prevent damage to economic and social productivity and community health, as well as the functioning of our natural resource assets. They are having mixed results.

Codes of leading practice, together with thorough baseline investigation and monitoring are proposed paths that should prevent the technical aspects of CSG operations from causing damage, provided there is strict compliance. At present, though, there is not a 'nationally consistent application of leading practices for the regulation of industry activities' (SCER 2013).

Legislation and regulations for vegetation management and environment protection exist or are being brought online, though they may not be consistent between jurisdictions and, further, may not currently be being applied to CSG operations. To be truly effective in
managing the potential impacts of CSG, legislators need to ensure a system is in place that assesses and manages the impacts of all land users, CSG companies included, and ensures we operate within the capacity of the landscape.

This chapter outlines aspects of CSG production systems related to the concerns demonstrated by communities and government. It summarises economic and social and environmental opportunities, as well as challenges that have arisen. If well regulated and managed, the exploration, extraction and decommissioning of operations to produce CSG and other energy resources in future should be able to have positive economic and social effects, and need not further damage the natural environment.

**Opportunity: CSG is valuable to Australia**

There is a big demand for natural gas, a relatively flexible and clean fuel which is projected to be the fastest growing non-renewable energy source in use globally over the period to 2035. Recently, the rate of discovery of reserves of conventional natural gas in Australia has slowed, in contrast to the increasing rate of discovery of unconventional natural gas resources, mainly as coal seam gas (CSG) and shale gas (AGRA 2012).

As already mentioned, our known reserves of CSG are mainly onshore in eastern Australia (Figure 1), well situated to supply demand in the eastern states, and rapidly being developed. Proved and possible reserves of CSG in Queensland at June 2011 amounted to 33,000 petajoules (PJ; Queensland Government 2012a), though inferred reserves were considerably larger and certain to increase during the vigorous exploration program under way in the Surat, Bowen and Galilee Basins. By 2012 annual production was 252 PJ in Queensland and 6 PJ from NSW, supplying some 35% of Australian east coast gas consumption (SCER 2013).

![Figure 1. Reserves of coal seam gas by basin (AGRA 2012)](image)

Conventional natural gas reserves in eastern Australia, on the other hand, were estimated at around 8000 PJ (UTS ISF 2011) and decreasing (ACIL Tasman 2012). Conventional natural gas is mostly found offshore of northern Western Australia, apart from the shrinking reserves in Bass Strait south of Victoria and the Cooper Basin in South Australia.

There is an opportunity for CSG production to supply much of our domestic energy requirement — indeed much of Australia’s heavy industry is said to rely on gas as its energy source (CT 2013) — although much of the reserve has already been on-sold to overseas markets, principally in Asia. To supply known domestic and overseas commitments including
new LNG projects, the annual CSG production will need to grow to several times the current domestic usage (around 750 PJ per year; ACIL Tasman 2012) in eastern Australia.

To meet such high demand the rate of CSG extraction in Queensland, at least, is growing rapidly, from 10 CSG wells in the mid-1990s to 4500 wells by 2011. The rate of drilling is forecast to intensify to 2014–15 (ACIL Tasman 2012). In total it is estimated that more than 14,000 wells will have been drilled between now and 2035 in Queensland.

Will so many fossil fuel wells have implications in relation to climate change? Natural gas, as in CSG, is widely considered to be an environmentally cleaner fuel than coal because it does not produce detrimental by-products such as sulfur, mercury, ash and particulates and because it provides twice the energy per unit of weight with half the carbon footprint during combustion (Cathles et al. 2012). The gas is seen by many as a fuel that can provide energy independence and reduce Australia’s greenhouse gas emissions in the process.

Nonetheless, two issues are under debate in the scientific community: first, the amounts of fugitive leaks of methane over the life of the gas field; second, the adequacy of the full life-cycle energy balance of the gas production system (Tollefson 2012, 2013).

Inevitably, production, processing, transport and distribution of natural gas, including CSG, result in fugitive greenhouse gas emissions. Knowing the scale of, and minimising, such emissions is important in reducing our climate change impact (e.g. Alvareza et al. 2012). Initiatives have commenced in Australia to collect greenhouse gas data for CSG (Commonwealth of Australia 2013). Specific challenges include confirming the primary sources of emissions and determining drivers of variance in leakage rates.

The second point, the contribution CSG can make overall as a transitional energy in mitigation of climate change, ultimately depends on understanding and managing linkages between water resource management and gas production including fugitive emissions. CSG production may use water for ‘fracking’ and must use energy for pumping, treating and transporting ‘produced’ water. This is a nexus with implications for whole of system energy analysis and greenhouse gas emissions (Australian Government 2010; Hou et al. 2012). Recognising that the issue exists is the first step.

**Challenges and concerns: CSG operations**

Communities and scientists have expressed a range of concerns about CSG operations and their outcomes. Many of the concerns have related to risks that CSG operations may lead to contamination of land and water resources and therefore damage environmental health and human and community health.

Substances used in, or mobilised during, CSG operations could be toxic to the environment and people, or could become toxic on exposure to other substances including oxygen (Batley & Kookana 2012). Examples are substances used in the ‘fracking’ process itself, or in the water pumped out during dewatering, or in fluids escaping the well or coal seam via cracks caused by fracturing pressures. Other significant concerns discussed below relate to the risk that regional groundwater pressures and surface-water flow patterns could be altered by CSG operations, affecting human and environmental water supplies, and that the ecological health of surface waters could be affected during disposal of water produced during dewatering.
In response, the industry has shown it is sensitive to the importance of building trust relationships with local communities and integrating these into contemporary business practice.

Techniques of CSG exploration, release and extraction are not new, having been in use in the USA for several decades and in Australia since the mid-1990s. Australian and US experience is continually refining processes to improve efficiencies. For extracting any mineral resource there are established best practices: for initial geological and geophysical survey, for drilling to the resource and casing the resulting well to secure just the required section and prevent cross contamination between parts of the intersected profile, for extracting the resource cost-effectively, and for finally plugging and abandoning the well.

Conventional natural gas (also largely methane) is generally extracted by drilling cased wells into naturally occurring underground ‘traps’ or reservoirs in certain rock types which release the gas at very high pressures (Figure 2). Coal seam gas, on the other hand is found only in coal seams, where it is distributed within cracks, pores and micropores either as free gas or near liquid, or adsorbed onto coal surfaces (Figure 3). The gas is usually held in place by the hydraulic pressure of water within the coal seam and overlying aquifers. Dewatering (by pumping the water to the ground surface) reduces the pressure and releases the gas. The water produced presents both challenges and opportunities, which are discussed below.

![Figure 2. Schematic geology of hydrocarbon resources: conventional natural gas, and the unconventional gases: coal seam gas (coal bed methane), shale gas, tight gas.](image)

![Figure 3. Schematic of coal seam gas within a coal seam (Geoscience Australia)](image)

After the seam has been depressurised by dewatering the CSG flows out through natural fractures. In the absence of enough natural fractures, the seam must be artificially fractured (‘fracked’) as discussed below. Once freed, the gas simply rises to the ground surface at
atmospheric pressure, is collected and then fed at low pressure to the treatment plant prior to compression into a high pressure transmission pipeline. In most cases the CSG is naturally of ‘pipeline quality’ and, apart from drying, requires minimal treatment.

Coal seams likely to be tapped for CSG in Australia occur mostly 250–1000 m below the ground surface. Seams that have plenty of natural fractures are less costly to develop as sources of CSG than those seams that are more solid and that need to be fracked to free the gas.

Most CSG production to date in Australia, particularly in Queensland, has not entailed fracking of the coal seams; this is contrary to the history of CSG production in the USA. However, as Australian production taps into deeper coal seams or those less naturally permeable, the need for fracking will increase from the current 10% of holes to upwards of 40% (UTS ISF 2011).

The aim of fracking is to force narrow fractures in the coal to open and stay open to make passage for the CSG. The fracking process forces water, augmented by ‘proppant’ materials and chemical additives, into a coal seam. The additives include some to ease the widening process and protect the equipment involved (Table 1). Coal seam gas companies now in Australia tend to publicise the names of substances they use during fracking, as requested by regulatory agencies. They are also changing to chemicals that are environmentally friendly (Batley & Kookana 2012).

<table>
<thead>
<tr>
<th>Additive type</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proppant: sand, silica, ceramic particles</td>
<td>To wedge seams open</td>
</tr>
<tr>
<td>Viscosity modifiers</td>
<td>Gelling agents (including food additives) to increase viscosity</td>
</tr>
<tr>
<td>Gel crosslinkers</td>
<td>To maintain gel stability</td>
</tr>
<tr>
<td>Gel breakers</td>
<td>To break down gel for return to surface</td>
</tr>
<tr>
<td>Mineral dissolution</td>
<td>To dissolve clay minerals</td>
</tr>
<tr>
<td>Iron complexation</td>
<td>To prevent iron precipitation</td>
</tr>
<tr>
<td>Biocides</td>
<td>To eliminate bacteria in the water</td>
</tr>
<tr>
<td>Corrosion inhibitors</td>
<td>To prevent pipe corrosion</td>
</tr>
<tr>
<td>Scale inhibitors</td>
<td>To prevent scale formation</td>
</tr>
<tr>
<td>Friction reducers</td>
<td>To reduce surface tension</td>
</tr>
</tbody>
</table>

Fracking is of environmental concern in case there is spillage of or contamination by the chemicals in use. As Batley & Kookana (2012) state:

‘The potential for fracking chemicals to contaminate aquifers or catchments that are a source of drinking water is viewed as a priority,[8] and the United States Environmental Protection Agency (US EPA) is in the process of a major study investigating the possible environmental impacts.[11]’


The underground pressures involved in the fracking process may cause unexpected cracking in strata and coal seams and unpredicted effects on groundwater resources or old wells in the area. Fracking has also been implicated in small earth-tremors, but not in Australia (e.g. ACOLA 2013, Ch. 9). The short- and long-term effects of repeated fracking operations on the components of gas wells such as their cement casing, are currently not well understood (USEPA 2011; Cohen et al. 2012).

Well-casing cement may shrink as it ages, and if so there may be potential for leakage of unwanted groundwater into the well, or of water or gas into the surrounding strata, possibly causing contamination (TRS RAE 2012; Eco Logical Australia 2013). The report notes that among North American oil and gas wells ‘fewer than 0.5% of those constructed since 2000 according to stricter standards were found to be leaky (Watson & Bachu 2009)’ whereas ‘several per cent of older oil and gas wells leaked’ (TRS RAE 2012 p. 26). To alleviate public concern with well leakage and loss of integrity (Nikiforuk 2013) the auditing of well performance with respect to failure will be important.

Well failure can include ‘blowouts’ — sudden and unplanned escape of poor quality water and/or methane gas to the surface (Michaels et al. 2010). There have been very few such events in Australia over the past 50 years. The risk of a CSG gas blowout in Australia is low.

When gas wells are abandoned, they are sealed with cementing and capping. An important UK report on hydraulic fracturing (TRS RAE 2012) notes that abandonment requirements and an abandonment plan should be part of the original well design, and subject to regulation. The report recommends on-going monitoring arrangements should be developed, for both surface gas monitoring and aquifer sampling every few years. In Australia the newly released National Harmonised Regulatory Framework for Natural Gas from Coal Seams (SCER 2013) requires that:

‘Decommissioning and well abandonment must ensure the environmentally sound and safe isolation of the well for the long term. It must ensure the protection of groundwater resources, isolation of the productive formations from other formations, and the proper removal of surface equipment’.

It cites the Queensland Code of Practice for Construction and Abandoning CSG Wells and the NSW Code of Practice for Coal Seam Gas — Well Integrity, both of which are apparently designed to ensure ‘long-term well integrity, containment of gas and protection of groundwater resources’.

Cement and steel do not have the very long-term integrity of geological materials. If CSG gas fields develop to the size and extent in Australia as in the USA, there will be a legacy of abandoned gas wells, which will need to retain integrity if we seek to avoid connections across stratigraphy over many thousands of metres, including confined aquifers and strata of water-bearing material with very different chemistry. The National Harmonised Framework (SCER 2013) also acknowledges that

‘poor or inappropriately decommissioned wells and bores, abandoned wells and bores; legacy wells and bores (including from exploration and activity in other sectors) can, via localised hydraulic connectivity cause contamination of aquifers and surface waters by chemicals, geogenics and the migration of gas. Depressurisation of coal seams may accelerate these effects.’

Continuous monitoring of well components over the lifetime of a well, even after abandonment may be appropriate (Eco Logical Australia 2013; SCER 2013).
While well integrity and fracking (because of substances involved and the process itself) are three of the four main areas of Australian CSG operations dealt with in the National Harmonised Framework (SCER 2013), the report also addresses the management and monitoring of water produced during operations. This publication by the COAG Standing Council on Energy and Resources (SCER) sets out approaches agreed between the Australian state and federal ministers responsible for resources. They are intended to help guide governments, industry and communities on leading practices for CSG operations. The Framework refers to state and federal policies, legislation and regulations to provide guidance on what constitutes leading practice. The Standing Council of ministers, via the Framework, trusts that compliance with leading practice, and rigorous monitoring, should ensure that these four technical challenges, including the important issue of water management, do not lead to environmental or human health hazards (SCER 2013).

Across the Pacific Ocean, the US Environment Protection Agency (USEPA 2013a) also sees several challenges involved in water management which need to be properly controlled during fracking. Figure 4 depicts five relevant stages, four of which apply in Australia. Note that in this country the water required for fracking for CSG production at stage 1 (Figure 4) is often sourced from the well’s own produced water, suitably treated. Other local surface or groundwater sources would only need to be tapped if the produced water were insufficient. The challenges portrayed at stages 2 and 3 of Figure 4 are discussed above in the contexts of contamination by fracking chemicals and well integrity. The challenges of stages 4–5 are discussed below.

![Figure 4. Schematic diagram of five stages involved in the fracking process with particular attention to the water management cycle (USEPA 2013b)](image)

Overall, in Australia and in the USA the management and monitoring of water produced during CSG operations as well as of groundwater aquifers intersected by CSG wells, present challenges that are both technical and environmental.

**Challenges and opportunities: water and environment**

Coal seam gas operations potentially can have an impact on the whole water system of a region, via interactions with groundwater and surface water resources and other cumulative effects. Both environmental assets and human uses could be affected.
Put simply, CSG gas production can affect water resources via the volumes extracted from the water resource and the volumes and timing of discharge, along with contaminants, into streams and groundwater aquifers. Therefore water management to minimise both extraction from, and disposal to, the surface and groundwater resources (which of course are connected components of the one hydrological system) is important if CSG gas operations are to have minimal impact on the environment.

Management of groundwater interactions and of the water produced during gas extraction operations may be problematic. On the positive side, the considerable volume of ‘produced’ water typically extracted from a CSG well, once treated for quality, is a resource that can be sold for irrigation purposes or used for restoring the pressure in overpumped aquifers.

**‘Produced’ water; ‘flowback’ water**
As mentioned above, to release the hydraulic pressure holding CSG in place underground, the coal seam or overlying aquifers are dewatered by pumping large volumes of ‘produced’ water to the ground surface. The water usually contains salts; it may also have other dissolved substances such as metals and radionuclides which can be toxic to plants, animals and humans (Vink et al. 2008; Moran & Vink 2010; NWC 2011, 2012; QWC 2012; Batley & Kookana 2012). Volumes of produced water are typically large in the early stages of production, and the volumes of gas released are small; later in the life of a well (which can be several years) the amount of water decreases and the methane production increases (Figure 5). It also appears that smaller volumes of produced water are likely to come from seams that need fracking than from those that do not.

![Figure 5. Typical changes in the rates of water and gas production from a CSG well over time (QWC 2012)](image)

The water, augmented by selected chemicals, used in the fracking process also needs to be brought back to the surface (as ‘flowback’ water) after use, during which time it may have reacted with other substances underground. This combination of fluids, chemical additives and naturally occurring substances must be stored on-site at the CSG well pad, typically in tanks or pits, before treatment, recycling, or disposal. It needs to be managed via industry best practice within an effective regulatory and compliance framework (USEPA 2013a; SCER 2013). In the United States regulations are now in place mandating re-use of this water for hydraulic fracturing, and this may be appropriate for Australia.

After treatment the ‘produced’ water from the CSG well may be disposed of by underground injection, or by measured discharge into surface waterbodies, or it may be recycled for use on-site. CSG water quality varies by region; it is typically brackish (100–10,000 mg total dissolved solids per litre) and alkaline (high in bicarbonate). Both the water itself and the substances removed from it (which can include concentrated brines) need to be carefully...
managed and stored, to minimise risks to livestock, aquatic ecosystems, wildlife and humans, such as through spillage (e.g. Batley & Kookana 2012).

Queensland and NSW have developed policies to manage co-produced water during CSG operations (Queensland Department of Environment and Heritage Protection 2012; NSW EPA 2012; NSW Government 2012, 2013a).

Direct untreated discharge of produced water to streams is unlikely to occur from CSG gas operations in Australia, and any rare discharges should be conditioned so that environmental values and water quality objectives, including water quality to meet public health objectives, are protected. This certainly is the objective of industry practice and state legislation. In such circumstances discharges to ephemeral streams should be pulsed to avoid flows in naturally dry or low-flow periods. Inappropriate disposal of even high quality treated water to ephemeral streams in arid and semi-arid regions can have serious ecological impacts (Levick et al. 2008; Smythe-McGuinness et al. 2012), changing the nature of the flow regime. Impacts of changed flow regimes on aquatic ecosystem health as a result of unnatural discharge of water, abstraction or because of changed groundwater discharge, are well known (Eco Logical Australia 2013 and references therein: Reid & Brooks 2000; Bunn et al. 1999; Bunn & Arthington 2002; McKay & King 2006; Gawne et al. 2007; Brookes et al. 2009; NSW DECCW 2009).

The National Harmonised Regulatory Framework for Natural Gas from Coal Seams (SCER 2013) lists key potential issues in produced-water management in relation to CSG, including inappropriate use and disposal with failure of monitoring and analysis, or poor management and handling, and improper management of wastes derived from treating the produced water. All of these can lead to contamination of the area and local water resources. Reinjection, for instance, could potentially ‘change background chemistry of existing water resources, and could induce seismic events’ (but see below).

The Framework recommends applying overarching leading practices augmented by baseline assessments and ongoing monitoring of all vulnerable water resources relating to the project. Ideally this will give the operator an overview of all the local region’s bores, creeks, streams, wetlands, groundwaters and groundwater-dependent ecosystems, and help in devising strategies to minimise environmental impacts and also remediate ‘legacy wells from previous water uses located on tenements held by companies’ (SCER 2013).

Opportunity: use of produced water
Reinjection of produced water into aquifers is also seen as a leading practice for beneficial use (SCER 2013).

‘Providing treated water to water users as a substitute for current aquifer extractions has the potential to reduce demand on a particular resource provided the current water extraction ceases or is reduced. … If water reinjection is adopted by the project operator for either beneficial use as an aquifer recharge mechanism or disposal, the evaluation and risk assessment of the reinjection program should include consideration of potential impacts.’ (SCER 2013)

Methods of reinjection appear so far to have received very little attention.

Use of treated produced water for irrigated agriculture and horticulture has shown promise in the short term trials (Santos 2011). Urban and industrial uses have also been suggested.
Challenges: CSG operations and groundwater aquifers

Dewatering of aquifers or otherwise depressurising coal seams to release gas is seen as cause of a range of potential impacts (Figure 6; NWC 2012; Osborn et al. 2011; Warner et al. 2012), which are listed in the National Harmonised Framework (SCER 2013) as:

- Reduced aquifer levels and pressures with volume and quality implications for other users, groundwater-dependent ecosystems and unwanted surface water interactions with groundwater over the short and long term (intergenerational equity),
- Cumulative impacts from multiple projects and local versus regional impacts,
- Altered hydraulic gradients produce mixing and cross contamination between different aquifers and between aquifers and surface waters with different quality characteristics,
- Migration of gas (and its rate) into surrounding aquifers, wells and water bores, and the surface,
- Reduced water pressure in subsurface layers enables compression of layers, alteration of hydraulic properties and subsidence at the surface.

Figure 6. Essential components of the water balance for CSG extraction (simplified)

The Queensland Water Commission (QWC 2012) explains:

‘When water is extracted from coal formations, the water from surrounding aquifers will tend to flow into the coal formations. The degree of interconnection between coal bearing formations and surrounding aquifers determines the extent to which water extraction from the coal seams will affect water levels in bores in surrounding aquifers. … A reduction in water pressure in a confined aquifer will manifest as a decline in the water level in a bore that taps the aquifer.’

If however during fracking the pressure in the coal seam is increased, the movements of water and any contaminant will be expected to be towards the aquifer.

Larger volumes of groundwater have been pumped from Queensland aquifers for productive agriculture than during CSG operations. Australian Bureau of Statistics data (cited in SCER 2013) show annual water extraction in 2009–10 at 1.9 million ML for agriculture compared to 0.017 million ML for CSG operations. Future extraction for CSG in the Surat Basin was expected to be 0.095 million ML. Large volumes cumulatively extracted can be expected to affect groundwater-dependent ecosystems such as springs, and that impact is now being assessed in some areas by the Office of Groundwater Impact Assessment in Queensland (SCER 2013).

Land subsidence might occur in relation to dewatering during CSG operations, as is generally expected when groundwater aquifers are dewatered, for any purpose. The process is well understood in over-exploited groundwater systems around the world. Land subsidence over
large areas can affect surface-water systems, ecosystems, irrigation and grazing lands (NWC 2011). The issue has been considered in environmental impact statements (EIS) in Queensland and by the Water Group in their advice to the Australian Government (WG 2010).

The National Harmonised Framework in relation to CSG (SCER 2013) refers only to subsidence that may change surface flows in the Murray-Darling Basin — a situation that, for CSG, might apply in the NSW and Surat Basin coal fields. The dewatering ‘may trigger the Commonwealth Water Act 2007, under section 255AA — Mitigation of Unintended Diversions, if the activity is a subsidence mining operation and occurs on a floodplain’ (SCER 2013).

Aquifer interference as a result of CSG operations would potentially be managed as part of an EIS process, through the use of groundwater models that help predict the effects of a particular action on surrounding aquifers (Queensland Department of Environment and Heritage Protection 2012). Aquifer interference is defined under the NSW Water Management Act 2000 as penetration or obstruction of an aquifer and interference including removal of water during mining and disposal of that water (NSW Government 2013b). It is a fact though, that models, however good, are only conceptualisations based on information available, and the deeper the aquifer the fewer the data (Frogtech 2013).

Instead of a project by project approval process using EIS, a cumulative assessment approach is essential in managing the water resource of gas fields extending over large areas and comprising tens and hundreds of wells in each development. Cumulative assessment allows the compounding influence of multiple projects to be fully evaluated. The Queensland Water Commission (QWC 2012) states that:

‘When water is extracted from a gas well, groundwater levels decline in the area surrounding the well. If there are multiple gas fields adjacent to each other, the impacts of water extraction on groundwater levels may overlap. In these situations, a cumulative approach is required for the assessment and management of groundwater level impacts.’

In Queensland, a Cumulative Management Area can be established. Within a Cumulative Management Area it is important that some independent body be responsible for assessing impacts and establishing integrated management arrangements for an underground water impact, such as to groundwater-dependent ecosystems. According to the National Harmonised Framework (SCER 2013), to manage cumulative impacts on groundwater, ‘the Office of Groundwater Impact Assessment in Queensland is assessing the cumulative impacts of activities in the Surat and southern Bowen Basins and will be producing an underground water impact report every three years, covering the total region deemed to be potentially affected by the cumulative effects of all proponents on a single groundwater resource.’

One report already submitted and approved has resulted in an ‘integrated regional water monitoring network’ also involving ‘prevention and mitigation of impacts on springs’ (SCER 2013).

**Challenges and opportunities: CSG vs natural resources**

As well as individual and cumulative impacts on groundwater and surface water resources, the rapid expansion of CSG drilling activity in recent years brings with it some significant other environmental and natural resource challenges (CSIRO 2012; NWC 2012; Williams et al. 2012; Randall 2012), such as:
loss of biodiversity through habitat and native vegetation fragmentation of the landscape, and
land use conflict and loss of landscape hydrological and ecological functions.

The scale and nature of ‘footprint’ of a CSG production field (Figure 7) illustrates a very significant fragmentation of landscape and biological habitat. The average density within CSG developments (Eco Logical Australia 2012) is approximately 1.1 well pads (and 1.6 km of road) per sq. km of land. (This compares to up to 3 or 4 well pads per sq. km in CSG gas fields in the USA.) Numerous small intrusions on the landscape for drilling CSG wells a few hundred metres apart linked by access roads can so interfere with the continuity and connectedness of patches of native vegetation and productive agricultural land that the land may no longer be usable for its former purposes.

Figure 7. Roads and other infrastructure in a CSG field near Dalby State Forest, southern Queensland. Scale widthways: 6.8 km. (Eco Logical Australia 2013)

It is possible that with time, new technology will let well pads be spaced even more widely. Using Australian-developed technology for guidance of drilling deep underground, it is now possible to drill from a vertical well for more than a kilometre horizontally along a target coal seam (e.g. Metgasco 2013). The fewer the drill pads needed at the surface, even if each is a bit larger, the less the intrusion on other land uses in an area. Fewer access roads and gas gathering systems could service multiple wells on a single pad. Flexibility in the exact location of infrastructure could be planned so as to mitigate the loss of threatened species habitat at the project level, though cumulative impacts can be more intractable (New York City Department of Environmental Protection 2009; Eco Logical Australia 2013).

Figure 7 shows that establishing gas infrastructure entails direct clearing of native vegetation to allow access and give a firebreak and workspace around the drilling site. Any such clearing is likely to, at least, introduce invasive species especially weeds, invertebrates and people, possibly increase the fire risk (while also giving better access) and cut across the home or breeding ranges of native fauna such as lizards and birds. Numerous scientific studies have confirmed the negative impacts of fragmentation of bushland on native fauna (e.g. Wiens
1985; Forman & Gordon 1986; Franklin & Forman 1987; Saunders et al. 1991; Ries et al. 2004; Cushman 2006; Fischer & Lindenmayer 2007).

At a larger scale — the ‘big picture’ — multiple small clearings are likely to have important cumulative impacts on an area’s biodiversity and capacity to continue to provide ecosystem services such as insect control, pollination, and so on. It is a situation similar to the cumulative impacts of multiple wells on groundwater, already mentioned. A single CSG well or water bore which dewaters part of a seam or aquifer may not result in significant impacts on the aquifer water level or quality, but hundreds of wells over a large area may mean a very significant cumulative impact on both water levels and water quality in surrounding aquifers. When assessing the capacity of the landscape to accommodate a new land use (such as CSG operations) without damaging existing ecosystem services and uses it is critical to assess and understand the potential cumulative impacts of the new developments in the context of existing developments, as opposed to assessing the new developments on a case by case basis.

Where a landscape has already been extensively cleared, fragmentation of remaining native vegetation can have very large impacts on the remaining biodiversity and landscape function (Hansen & Clevenger 2005; Fischer & Lindenmayer 2007) because in many cases the vegetation that is left is of high ecological value. Clearing for a single well pad and the associated service road and pipeline may intrude into but not badly fragment a patch of bushland. Clearing enough space for many well pads, roads and pipelines in a single patch of bushland is a bit like tearing a sheet of paper into many pieces — it is cumulative fragmentation and it requires careful consideration and attention (Shoemaker 1994; New York City Department of Environmental Protection 2009).

The Native Vegetation Acts in both NSW and Queensland deal well with issues of clearing of native vegetation, but CSG operations are exempt from these Acts. If there is a particular threat to threatened species then the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 can be brought to bear, as can the State threatened species legislation. Unfortunately these Acts do not easily deal with broad-scale fragmentation and cumulative loss of habitat.

There are precedents for assessing and diverting cumulative clearing. Vegetation clearing by individual farmers is known to have a large cumulative impact when the total area cleared is extensive. Such clearing was said to have been the largest factor contributing to the extinction of native species; consequently, states and territories across the country instigated laws to halt this cumulative impact by managing the clearing of native vegetation. In NSW a tool called the PVP Developer was used to help farmers understand what vegetation could be cleared, what vegetation needed to be offset if it was cleared, and what vegetation could not be cleared. While the approach did not stop a farmer from clearing, it did stop the clearing of threatened vegetation, which had the reverse cumulative impact of ensuring the retention of areas of threatened vegetation (NSW Government 2005).

Productive farming for food and fibre is also perceived to be at risk from the cumulative fragmentation and potential resource-contamination impacts of CSG operations. Both types of impact could reduce the usability of strategic agricultural land and water resources.

Impacts on landscape function and biodiversity, whether individual or cumulative, appear not to be primary concerns in the regional strategic land-use planning mechanisms of either NSW...
or Queensland. This is a major environmental and natural resource issue that has not received much attention in terms of public debate or government–industry discussions.

There is already land-use planning that looks at catchments as ‘big pictures’, however. Although funding seems now to be being reduced, catchment management teams across Australia have been collecting local data for drawing up catchment action plans aiming to manage their areas of responsibility in a holistic cumulative way. Based on such a plan, the Namoi Catchment Management Authority (CMA) has pioneered a new way to build in cumulative analysis of multiple industry development (Eco Logical Australia 2011).

The Namoi catchment supports a range of productive land uses including irrigated agriculture using groundwater resources. It also has large coal reserves and consequently there is significant pressure for additional coal mining as well as CSG extraction. The CMA took a long-term view and recognised that mining had the potential to deliver substantial benefits to the region but also that mining (not just CSG) was a potential threat to the natural resource assets of the catchment.

The CMA was able to use its detailed understanding of the natural resource assets of its region, through its catchment planning process, to assess not only the impacts of any one mining development on the natural resource assets of the catchment but also the potentially cumulative impacts of a number of mining developments.

The result of this planning process is a strategic vision for the Namoi catchment in the form of a framework inside which a risk assessment process can be undertaken for mining and coal seam gas development. Using this framework (Figure 8) and a GIS modelling tool, the CMA has produced a cumulative risk statement on the individual and cumulative impacts associated with any real or hypothetical mining scenario. A further aim is to enable mining and CSG developers to run a range of scenarios and determine how best to structure their operations to minimise, or remove completely, any negative impacts on the natural resource assets of the Namoi catchment.

While extensive grazing would appear to be a form of agriculture better at co-existing with CSG production than, say, dryland and irrigated cropping, the experience in the Namoi catchment suggests a balanced co-existence of mining and the various forms of agriculture and forestry may be possible — with careful management. For this reason, good bioregional
planning and cumulative risk assessment is a fundamental issue that requires priority attention.

Use of best practice tools including cumulative risk assessment and strategic land use planning and policies, such as the proposed Multiple Land Use Framework being developed by the Land Access Working Group under the Standing Council on Energy and Resources, is one way forward. Other examples of cumulative risk assessment have included LUCRA, the Land Use Conflict Risk Assessment (NSW DPI 2011), and methods applied in the Alligator Rivers Region of NT (which encompasses mining, indigenous values and conservation; SEWPaC 2011), and the land use impact model developed in Victoria (MacNeill et al. 2006).

Further the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) and the COAG agreement with States on these matters appears to offer means by which integrated risk management incorporating cumulative risk assessment could be achieved as part of the bioregional assessment process.

These recent changes are welcome, because although CSG could be a valuable resource, and although technical knowledge for CSG operations may be adequate, the industry still needs to have a ‘social licence to operate’ which is unlikely to be granted if rural communities and landholders fear their rights to use their land as they choose may be steamrolled by gas companies.

**Challenges and opportunities: social and economic**

A range of residential communities have challenged the CSG industry development in Queensland and NSW. They are concerned about the rapidity with which CSG operations have flourished in eastern Australia, and apparent preferential government support the industry has received (e.g. Lloyd et al. 2013).

Other communities, however, may not object to the industry. The National Harmonised Framework (SCER 2013) defines ‘community’ as both living in the location of CSG operations and as

‘people who are geographically dispersed but are linked together by a shared set of interests or experiences … a community is not a homogeneous entity … members of a community are likely to hold diverse opinions about the development of natural gas from coal seams, industry activities and projects or the petroleum industry in general.’

In interviews with active residential groups trying to combat CSG development in eastern Australia, Lloyd et al. (2013) found that companies appeared to have been ignoring any ‘rights’ landholders may have to use the topsoil of the land they have purchased and to protect their land from trespass. Lloyd et al. note accounts of company staff entering properties and paddocks with little or no notice to the local residents, bulldozing old-growth and other vegetation, and drilling for gas. Their interviewees reported unacceptable impacts on their lifestyles on their own land, resulting from drilling equipment and vehicles, continual noise, and large volumes of produced water. It seems that where companies have tried more recently to consult, widespread community antagonism resulting from early disrespect by the industry may have hindered the process (Poisel 2012; Swayne 2012; Lloyd et al. 2013). Companies may also not have used their best, most conciliatory, communicators for this ‘consultation’, according the Lloyd et al. report.
With conventional open cut coal mining, the standard practice for decades has been for the mining company to purchase the land at valuations well above commercial value. As a result, there are rarely any disputes with property holders about access. For CSG, with the intensity of well field developments proposed and the random nature of placement and spacing of wells in the Bowen and Surat Basins, total acquisition of properties is impractical and socially unacceptable. Under current mining legislation and regulation in Australia, property holders have virtually no ownership rights to minerals (including CSG) below the topsoil. They also have no real control on the ultimate ability of miners to access their private properties (Randall 2012). This is changing (Lacey et al. 2012) but there still exists much mutual distrust between developers and property holders (Queensland Government 2012b).

During 2013, the Queensland Government is expected revise the state’s ‘land access and compensation framework that governs how resource companies access private land for resource exploration and production’ (Carter Newell 2013). The aim is to prevent property holders from being ‘out of pocket’ and from erosion of their rights by activities of the resources industry, including CSG operators. The government hopes resource companies and property holders will come to agreement and that the agreement will be noted on the title to the land in question.

In NSW, in response to rising public concern, recent changes to government policy have restricted the freedom of gas companies to develop potential gas fields. According to draft legislation being prepared (as at May 2013), gas operations may not proceed within 2 km of residential areas or industry cluster areas in NSW, unless the company already possesses a Development Approval. Companies may have already completed exploration and found a potentially valuable field, but the field cannot be developed any further unless it already has received approval before mid-February 2013 (Corrs et al. 2013).

With respect to human health, a recent report by the Queensland Department of Health (2013) (drawing on the findings of a Darling Downs Public Health Unit investigation conducted in 2012, along with independent medical assessment and scrutiny), concluded that there were no adverse health impacts resulting from CSG operations near Tara, which is 300 km west of Brisbane. If operations were to become as densely spaced as they have near Dallas, Texas, USA, there could be public concern about air pollution from diesel generators, compressors and large volumes of traffic transporting waste material, produced water and residues associated with fracking operations (ANU 2012; Duncan 2012).

A comprehensive study by Krzyzanowski (2012), on environmental pathways of potential impacts to human health from oil and gas development in north-east British Columbia in Canada, sets out a very useful framework for considering issues that may determine the risk of unconventional shale gas production on matters of human health.

A need to find satisfactory solutions in policy, process and social mechanism to the social challenges confronting CSG development has been identified at most levels of society and government. These are critical to the on-going development of the CSG industry in the eastern states of Australia.

Given the proposed intensity of CSG development in Queensland over the next four years, particularly in the Surat Basin, extraordinary demands will be made on rural infrastructure, housing, and community services in health and education. Serious objections and complaints
can be expected from local communities about these infrastructure demands. In recognising this, the Queensland Government (2012c) published a guideline for the industry, stating:

‘Proponents of new or expanded major resource development projects are required to develop a social impact management plan in consultation with government and key stakeholders. The government’s desire is to work in partnership with industry and local government…’

This guideline is the result of extensive consultation that occurred between government agencies the Queensland Resources Council and the Local Government Association of Queensland. The guideline aims to help proponents prepare a suitable plan in accordance with current environmental impact assessment and resource development legislation, policies and procedures.

Stronger social impact assessment and the development of social impact management plans will not be a cure-all for social ills or a solution for community conflict. However, in this decade community health, safety and social wellbeing have increasingly been considered part of the risk management and social responsibility of resource development proponents.

In Australian jurisdictions, there is strong industry support for the role of a ‘social licence to operate’ as a complement to the regulatory licence issued by government. From an industry perspective a ‘social licence to operate’ is about operating in a manner that is attuned to community expectations and which acknowledges that businesses have a shared responsibility with government and society, to help facilitate the development of strong and sustainable communities.

From another viewpoint, that of the ‘community’ interested in CSG as an economic proposition, a brief examination of the economic modelling (see Williams et al. 2012) suggests that a rapidly growing CSG industry in Queensland and NSW has the potential to deliver very significant economic benefits (Rayner & Bishop 2013) to those states and to Australia as a whole. The amount of predicted benefit is dependent on the reliability of the estimates of size and rate of expansion of the CSG infrastructure, and on the income streams from local gas consumption and export of liquefied natural gas (LNG).

For example economic studies by the Queensland Government (Queensland Government 2013) indicate that a medium-size 28 million-tonnes-per-annum industry converting CSG to LNG could:

• generate over 18,000 jobs in Queensland, with 4300 jobs in the Surat Basin alone,
• increase gross state product by over $3 billion or 1%,
• generate private sector investment of over $45 billion,
• provide royalty returns of over $850 million per annum, which could help fund schools, hospitals and other vital services.

The analyses upon which such estimates are based nearly all show (Williams et al. 2012) that the distribution of the economic benefit can be strongly skewed so that most benefits accrue to capital cities and large centres, with many of the costs and social impacts falling on small regional and local communities and on the individual landholder. Consequently, the economic benefit from CSG production is contested in public debate, in part because of perceptions of how that benefit is or should be distributed between state capital, regional centre and local community, and particularly how the social and economic costs tend to fall on local governments, community and individuals.
Turning these economic impacts into a positive social benefit is part of the challenge before Australian governments, which hold gas resources in trust. Rolfe et al. (2011) explain that an initial economic shock or stimulus can have multiplier effects through a series of successive spending rounds (e.g. Figure 9). The size of the economic multiplier in a local or regional area principally depends (Jensen & West 2002) on the extent to which project operators purchase inputs, including labour and goods and services, from the local or regional economy, and the extent to which that money spent in the local or regional economy remains there rather than being spent in larger regional centres.

![Figure 9. Diagram to explain possible multiplier effects (Rolfe et al. 2011)](image)

In theory, there are two main ways in which resource extraction (in this case, extraction of CSG) can lead to prosperity for the local and regional communities where CSG extraction occurs. There can be time-delimited benefits — those that can only exist so long as extraction is taking place. There can also be potential benefits that will endure beyond the period of extractive operations through the actions of linked industries. Frickel & Freudenburg (1996) point out, however, that: ‘many studies have documented cases where linked industries have failed to emerge’ ‘the overall pattern of change has been toward decreasing the likelihood that natural resource extraction will lead to local or regional development’.

Ideally, economic analysis of the potential for CSG operations to benefit regional areas could underpin current public policy and management of programs, such as integrated housing strategies (e.g. Queensland Government 2012d), so that the opportunities presented by CSG can be optimised to yield sustainable economic and social benefit.

There is an increasing number of useful reports and journal publications on the social impacts of mining and CSG developments, particularly in Queensland. These studies are bringing greater clarity to some anecdotal perceptions of social impacts arising from such operations, and they are beginning to inform government policy, community awareness and action. Several studies indicate broad social issues that will need to be addressed in the projected expansion of the CSG Industry. For example (see Williams et al. 2012),

- Information sharing, communication and transparency are critical for enabling good governance and change-management at the community level, and for on-going management of regional opportunities from the CSG energy boom, and for being able to plan, to make policy decisions and to evaluate past policies.
- Gain and revenue sharing, and economic diversification, are essential to increase the social acceptability of mining operations and to increase the local economic opportunities from mining which create wealth but usually not in an evenly distributed way. Economic
diversification leveraged off the energy boom is essential to the long-term well-being of the regional communities. Evidence in the literature indicates that economic development based on mining industries alone over the long term will not allow for sustained economic growth.

- Investment in hard and soft infrastructure is crucial to meet the demands of an increased population. Investment in roads, utilities, health-care, policy, transport and other services, as well as in skills, housing, planning and soft infrastructure needs to be increased accordingly to allow local communities to deal proactively with the inter-related aspects of social change as well as maintain their communities as desirable places to live and work.

The establishment of regional development plans and the actions outlined in, for example, the Queensland Government’s Surat Future Directions Statement, indicate a way forward towards a successful CSG industry. This is an active area of policy and program development which needs the support of good applied social and economic research.

Conclusion: Opportunities to meet the challenges of CSG operations

The rapid development of the CSG industry and the subsequent challenges it has faced highlight opportunities for Australia’s legislative approaches, both in management of social and economic impacts of industries, and in balanced use of our natural resources.

For Australia’s natural resources and landscapes CSG development poses risks similar to those posed by other land use activities including other forms of mineral extraction.

In an ideal world, a clear and consistent legislative approach that managed landscapes within functional limits would guide proponents of new land uses on amounts of additional water resources that could be extracted, areas of vegetation that could be cleared, and the resilience of the catchment to further development, ensuring that other existing land uses and sustainable landscape function would not be compromised.

There are mechanisms for managing risks to landscape function; however, they are often not consistent across state and federal jurisdictions nor applicable to all landscape users in the same jurisdiction (ANEDO 2013). In response to this inconsistency and subsequent community concern new laws are being put in place specifically to address potential CSG impacts. The National Harmonised Regulatory Framework for Natural Gas from Coal Seams (SCER 2013) goes some way in trying to remove some of the inconsistencies in management of CSG across state and federal jurisdictions. As outlined above, the National Harmonised Framework unites state and federal ministers in calling on leading practices in the CSG industry and on government codes to prevent damage to Australia’s people or the environment. In some ways the Framework seems to evoke the ‘ideal world’ sketched above:

‘In order to deliver beneficial outcomes for all participants, there needs to be a shared commitment between the resources industry, other land users and governments to coexistence. Co-existence is founded on the principles of multiple and sequential land use and merit based land access which is informed by reasoned and fact-based public discussion on resource development. Co-existence should not restrict or favour one form of land use without considering the implications for other potential users and the broader benefits that accrue to the wider Australian community.’ (SCER 2013)

The Framework also acknowledges application of the precautionary principle, and the need for ‘a hierarchy of risk control measures that apply to all aspects of the development of natural gas from coals seams’ (SCER 2013).
In practical terms, it is important for all involved with CSG operations to understand the nature of the risks or hazards the industry poses, and to understand that vulnerability of the environment to these hazards or threats is more important than calculated risk.

Previously, risk management was a matter of identifying threats, calculating or guessing how likely each threat was, and then rating them. However, some events might have very low probability but we might desperately wish to avoid them. Therefore, the Risk Policy Model 2012 proposes a new risk equation (Australian Risk Policy Institute & ScottCromwell 2013) which ‘demotes’ the probability assessment, and promotes realisation of the importance of the consequences of events. By putting probability in its right place, after the assessment of how vulnerable we are to the consequences of a risk, we are able to restore the correct balance. Vulnerabilities must come first, and the events and actions that may threaten to exploit those vulnerabilities second.

The new risk equation recognises that we have to ‘measure our risks’ in terms of the magnitude of the consequences if we fail to avert some threat, not in terms of the probability of the consequences or the chance that it might not happen. Our society and economy depend on the ecological, hydrological and geochemical processes in our landscape. It is their vulnerability to failures of CSG safeguards, not the calculated probability of failure, which should define the level of risk. The new risk equation (ARPI & ScottCromwell 2013) states, that: ‘Risk is the concurrence of a vulnerability and a present or imminent (matching) threat’: Risk = Vulnerability x Threat.

This model of risk thinking is consistent with the new cumulative risk assessment approaches that are in use in the Namoi and Murray Catchment Management Authorities (MCMA 2012; Eco Logical Australia 2011, 2012, 2013). There is also now a method for establishing resilience thresholds for landscape function (NSW Natural Resources Commission 2012), which needs refinement based on research, development and better data.

It is imperative to manage the effects of CSG operations on water resources, food and fibre production systems, and biodiversity in a whole-of-landscape framework that can take account of long term cumulative impacts. This involves three key steps.

**Step 1**: Understand regional landscape capacity, and then determine if there is capacity for the development without crossing landscape limits.

**Step 2**: Update current development approval processes so that new developments can only be approved on the basis of landscape limits and the expected cumulative impacts of the existing and proposed developments.

**Step 3**: Using insights gained from whole-of-landscape cumulative risk assessment and aligned with the limits and thresholds to landscape function, establish regulation, leading practice, monitoring and compliance arrangements to manage risks.

There is some common ground between these recommendations and the approaches currently in use in both NSW and Queensland through the Regional Strategic Land Use State Planning Policy and the Strategic Cropping Land Act, respectively. The difference is that the approach proposed here requires a whole-of-landscape or catchment analysis, and use of new methods and thinking based around spatially explicit cumulative risk assessment.
Evidence-based strategic land use planning methods available (Shoemaker 1994; Gordon et al. 2009; Eco-Logical Australia 2012) can help identify very high risk areas which may be designated ‘no go’ areas. Such assessment is critical avoiding CSG or any other land use development that would compromise these limits and capacity of the catchment and thus cause the landscape to lose biophysical function.

It is feasible (Shoemaker 1994; New York City Department of Environmental Protection 2009; Eco Logical Australia 2011, 2012) to build at the bioregional level a set of cumulative risk assessment methods (e.g. Gordon et al. 2009) that seeks to avoid, mitigate and offset potential impacts prior to CSG approvals. The strategic environmental assessment process available in the Commonwealth’s Environment Protection and Biodiversity Conservation Act 1999 would appear well suited for such a purpose. It provides companies with regulatory certainty and aligns natural resource management goals for catchments, and embraces other landscape initiatives such as the National Reserve System (NRMM 2009) and the National Wildlife Corridors Plan (SEWPaC 2012).

Once the safe space for CSG operations is established by Steps 1 and 2 by using our proposed whole-of-landscape approach to cumulative risk assessment, the use of objective based regulation would seem attractive. It requires the proponent of the operation to identify the hazards and risks and describe how the risks are managed within the safe space which is established through evidence-based assessment. ‘The principle is that those who create the risk must manage it’ (SCER 2013). Such an approach can create regulatory uncertainty; but it also can provide an environment that fosters innovative practices and a clear focus on delivering the desired environmental outcome. This approach, coupled with independent audit of the environmental outcome achieved, merits attention for the future CSG industry (NSW Natural Resources Commission 2010).

Building trust is a key to securing a social licence to operate for any major resource project, including CSG operations, and it is important to have a transparent approach to collection and dissemination of reliable data. Communities are more likely to accept information as credible if it comes from a source perceived to be truly independent (Lacey et al. 2012; Lloyd et al. 2013). Opportunities should also be explored to involve local people and landowners in the collection and understanding of environmental monitoring data, because this has also been shown to increase trust. Initiatives across Australia, such as the Gasfields Commission, the establishment of regional and local consultative committees, the Royalties for Regions Program and the use of Social Impact Management Plans to proactively address anticipated impacts, are evidence of some way forward on this matter.

Social research seems to suggest that if the industry were to make a more direct financial return to communities most affected by CSG operations, that might facilitate ongoing access and help maintain the social licence to operate, as also should improved communication and collaboration with stakeholders in communities, and thoughtful investment in infrastructure, as outlined above. The challenge for the industry is to articulate an agenda which balances its own commercial needs with broader expectations about contribution to development of affected communities and regions.

In both the CSG industry and relevant research bodies, a significant step forward could come from research integrating energy, climate change, water resources, food and fibre production, and protection of biodiversity and landscape function. There are large areas of Australia where we have only moderate data about the natural resources and features relevant to CSG...
operations. The National Harmonised Framework calls for companies to establish baseline monitoring and continue monitoring their areas. Independent research bodies need also to obtain:

- baseline data against which to measure change,
- knowledge, predictive tools and appropriate data for predicting cumulative impact and change so that minor impacts can be prevented from significant consequences.

Australia has the capability to meet the challenges posed by CSG operations and to make the most of the opportunities CSG offers. With modern whole-of-landscape strategic planning in place, supported by effective regulation and governance, the exploration, extraction and decommissioning of operations to produce CSG energy has the potential to deliver positive economic and social benefit, and need not further damage the natural environment.

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