From the seam to the stove: greenhouse gas assessment and the Coal Seam Gas industry in Australia

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ABSTRACT Coal Seam Gas (CSG) is a relatively new source of natural gas in Australia commonly advocated as lower greenhouse gas (GHG) emissions alternative to coal. This study investigates how GHG emissions have been, and potentially could be, assessed within the Australian CSG industry. The research involved a document analysis of several Environmental Impact Statements (EISs) and consultant reports prepared as part of the Environmental Impact Assessment (EIA) process for major CSG projects in New South Wales (NSW) and Queensland (Qld). There were found to be inconsistencies in the conduct of greenhouse assessment by the CSG industry, including how complete and transparent assessments were, as well as how effectively they addressed project emission intensity and cumulative impacts. There were also found to be large inconsistencies between assessments carried out for Qld projects and those for NSW projects, likely because of differences in how assessment requirements are applied by planning bodies. This study also highlights how alternative assessment approaches, such as Cumulative Impact Assessment (CIA) and Strategic Environmental Assessment (SEA), have potential to enable a broader and more consistent understanding of emission sources that cross a range of geographical and project boundaries.

KEY WORDS Coal Seam Gas; greenhouse gas assessment; fugitive emissions; Environmental Impact Assessment; Strategic Impact Assessment; Cumulative Impact Assessment

Introduction

With a global imperative to reduce greenhouse gas (GHG) emissions, there is a need to restructure the Australian energy sector by expanding zero or low-emissions energy sources. One option being considered is coal seam gas (CSG), a newly developed natural gas resource (i.e. methane) currently at commercial development in New South Wales (NSW) and Queensland (Qld).

CSG development encompasses a range of geographical scales, from the level of individual pieces of equipment, through to fields comprising thousands of gas wells, dozens of processing facilities and hundreds of kilometres of pipeline, all of which may be administered by different companies and government bodies. CSG therefore potentially represents a significant geographical issue. The spread of responsibility for GHG emissions across these multiple scales inhibits an understanding of the link between local actions and global impacts, and conversely, may complicate the implementation of top-down measures (such as state regulations) aimed at assessing and mitigating emissions at local scales (Ortolano & Shepherd 1995; Kates & Wilbanks 1998, 2003; Bulkeley 2000).

The purpose of this article is to assess the effectiveness of GHG assessment undertaken by the Australian CSG industry within the framework of Environmental Impact Assessment (EIA). Though the social costs and benefits of resource development generally, and CSG development specifically, is a crucial area of research that has, among other influences, informed legislation about the assessment of potential social impacts in Queensland (see Franks, et al 2009; Franks 2012; de Rijke 2013; Franks and Vanclay 2013; Michell and McManus 2013), this article focuses specifically on GHG emissions as an important environmental consideration for this development. The article begins with an overview of the CSG industry in Australia, as well as frameworks for GHG assessment. The research methods are then outlined, followed by the presentation of findings from a document analysis of the Environmental Impact Statements (EISs) and associated consultant reports of eight major CSG projects across NSW and Qld. Specifically, this article examines the effectiveness of these assessments based on criteria chosen by the author, including the degree of consistency between assessments, their completeness and transparency, as well as how effectively they addressed project emission intensity and cumulative impacts. These aspects were further examined in light of state planning requirements that dictate the content of each assessment. Findings from the analysis are then used to discuss possible alternatives or supplements to EIA, namely Cumulative Impact Assessment (CIA) and Strategic Environmental Assessment (SEA). As will be discussed, these approaches have the potential to provide a broader understanding of the potential trans-boundary impacts of CSG and their implications in terms of sustainable development.

CSG in Australia

CSG extraction is a relatively young, rapidly expanding industry in Australia with the potential to become a significant component of the energy sector both domestically and internationally through exports to Asia. Commercial extraction of conventional natural gas has occurred since the 1960s, with the majority of current production occurring offshore of Victoria and Western Australia (Australian Petroleum Production and Exploration Association [APPEA] 2013b). Advances in drilling and hydraulic fracturing ('fraccing' or 'fracking') made in the late 20th Century, however, allowed for the extraction of CSG from previously inaccessible geological formations.

In 2012, CSG comprised about 23% of natural gas produced in Australia for domestic consumption (excluding exports of liquefied natural gas) (APPEA 2013). CSG reserves are concentrated in eastern Australia (Leather *et al.* 2013), with commercial production occurring exclusively in Qld (97.5%) and NSW (2.5%) (O'Kane 2013). The International Energy Agency (IEA) projected that CSG production in Australia could grow from 6 billion cubic metres (bcm) in 2011 to 100 bcm in 2035 (IEA 2013).

In Qld at least four large coal seam gas to liquid natural gas (CSG-LNG) projects (including gas fields, pipelines, processing and export facilities) are currently in the planning and construction phases, with the potential to contribute to Australia becoming the largest exporter of LNG in the world by 2018 (Leather *et al.* 2013). The Camden Gas Project (operated by AGL) remains the only commercial CSG project in NSW, supplying 5% of NSW gas demand (AGL 2014). Two projects planned for NSW – the Narrabri Gas Project) and the Gloucester Gas Project - reportedly have the potential to supply 50% and 15% of the existing NSW gas market, respectively (Santos 2013a; AGL 2013).

EIA, CIA and SEA: three frameworks for GHG assessment

EIA is a well-established process combining administration, planning, analysis and public participation in order to assess the potential effects of specific proposed developments on the physical and social environment (Howitt 1989; Sadar 1994; Elliot & Thomas 2009; Bond & Pope 2012; Michell & McManus 2013). An Environmental Impact Statement (EIS) is the primary documented product of EIA outlining these potential effects.

That EIA addresses individual projects may produce a number of constraints. As Manuilova *et al.* (2009) note, EIA limits an understanding of global and regional environmental effects. Elliot and Thomas (2009) identify EIA as site-specific, temporally constrained and limited in coverage of cumulative environmental effects. Further, Marsden and Dovers (2002, p. 24) argue that "EIA misses regional impacts, cumulative impacts of multiple projects over time, and may allow environmental death by a thousand small cuts".

In contrast, Cumulative Impact Assessment (CIA) and Strategic Environmental Assessment (SEA) aim to assess actions beyond the direct spatial and temporal boundaries commonly addressed in EIA. Specifically, CIA recognises that the aggregate of environmental effects may be greater than the sum of the individual effects. In this regard, CIA extends on EIA by considering actions that have additive, synergistic and indirect effects (Brueckner *et al.* 2013), crowd and lag in time and space, as well as materialise only after passing thresholds (Elliot & Thomas 2009; Porter *et al.* 2013; Sadar 1994).

Extending on EIA and CIA, SEA looks beyond individual projects and examines broader policies, plans and programs (PPPs) at the regional or sectoral level across extended spatial and temporal scales. It is ideally undertaken during the early stages of decision making (Marsden & Dovers 2002; Elliot & Thomas 2009; Tetlow & Hanusch 2012). To use an example, the NSW Department of Planning (DEP) has undertaken an SEA of growth centres in Sydney to plan for an expected population growth of 1.7 million people by 2036 (Department of Environment and Planning [DEP] 2010). Traditional project-based assessment (EIS) may, however, be inhibiting the adoption of more cumulative and strategic perspectives, especially for developing industries. Ball *et al.* (2012) examined 35 environmental impact assessments for developments within the South Saskatchewan River catchment, Canada, and found a lack of consistent methodology and terminology across the assessments inhibited the sharing of information, limiting the potential to upscale from the project-level to the broader catchment-level and to be strategic in the consideration of potential impacts at a policy, plan or programme level. By taking a broader spatial approach and a longer temporal view, SEA is potentially more accommodating of the principles of sustainable dev elopment, and may enable these principles to 'trickle down' to decision making at the scale of individual developments (Shephard & Ortolano 1996; Arce & Gullón 2000; Marsden & Dovers 2002; White & Noble 2013). Though SEA is recognised at the federal level in Australia under the EPBC Act, it was a marginal activity (Elliot & Thomas 2009) until given greater emphasis in the Rudd government until late 2012.

Methods

This study involved a document analysis of greenhouse assessments and associated consultant reports within the EISs for eight major CSG projects across NSW and Qld between 2007 and 2013 (Table 1 and Table 2). The purpose of this analysis was to identify the strengths and limitations of project-specific approaches to greenhouse assessment, as well as to investigate the potential need for broader approaches, such as through CIA and SEA.

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INSERT TABLE 2 HERE

The first part of the analysis identified the regulatory requirements for each assessment. As part of EIA, proponents must request that the required content of the EIS be determined by the relevant planning department. These requirements are known as the Director General's Requirements (GDRs) in NSW, and the Terms of Reference (TOR) in Qld.

Second, data published in each assessment was extracted and compiled into spreadsheets. These data were in the form of GHG emission estimates and associated activity data used in calculations by the EIS author. For example, activity data on fuel use might be used to calculate emissions from the combustion of diesel during CSG drilling. Compilation of these data allowed for an analysis of each greenhouse assessment based on the following criteria, as developed by the author:

- Completeness: the range of emission sources assessed throughout the CSG life cycle (Table 3)
- Transparency: the degree to which data were disaggregated, allowing for estimates to be traced backwards
- Time dependence: the degree to which the changing nature of emission profiles was assessed
- Geography: whether the project was NSW- or Qld-based

INSERT TABLE 3 HERE

Emission sources were also categorised based on international GHG accounting principles (WRI/WBCSD 2004):

- Scope 1: Direct emissions from sources owned or controlled by the project operator
- Scope 2: Indirect emissions from the generation of electricity purchased and consumed by the project operator, but which are produced outside of the operator's boundaries
- Scope 3: Other indirect emissions from activities of the operator, but which occur from sources they do not own or control (e.g. emissions associated with production, processing and transport of purchased fuels)

The analysis also looked at the treatment of both cumulative impacts (in particular, the impact of surrounding CSG projects) and of emission intensity (EI) in the assessments. An EI describes the quantity of GHG emissions that result from the delivery of a unit of product or service (in this case, tonnes of carbon dioxide per mega joule of CSG [t CO_2-e/MJ_{CSG}]). EIs normalise emissions to allow for comparisons between equivalent products and services (in this case, CSG delivery), and provide a concise way of communicating overall GHG impacts.

Results

The regulation of greenhouse assessment

As discussed, DGRs (NSW projects) and TORs (Qld projects) are an important source of regulatory guidance for the greenhouse assessments. The DGRs for the EISs examined in this study varied considerably (See Table 4). For example, those for Stage 2 of AGL's Camden Gas Project, issued in March 2007, contain no specific requirement for greenhouse assessment, instead requiring an assessment of dust and odour effects (HLA-Envirosciences 2007). Admittedly, the National Greenhouse and Energy Reporting Scheme (NGERS) - Australia's first national framework for mandatory emissions and energy reporting (Clean Energy Regulator 2013) - did not commence until 2008. In comparison, the DGRs for the Stage 3 EIS, issued in April 2009, featured greenhouse gases, including the requirement for a quantitative assessment of emissions (Department of Planning and Infrastructure [DPI] 2010). Even more detailed were the DGRs for Santos' Bibblewindi Gas Exploration Pilot Expansion (part of the ongoing Narrabri Gas Project). Issued in May, 2013, these specify a greenhouse assessment that differentiates between emission scopes (DPI 2013a).

Overall, there appears to be a historical progression towards more stringent DGRs, and somewhat of a strengthening of requirements following the commencement of the NGERS.

INSERT TABLE 4 HERE

Compared to the DGRs, the TORs for Qld projects (Table 5) specified a relatively high level of detail for the greenhouse assessment, more often than not requiring emission scopes to be quantified and the assessment methodology to be justified. Further, all of the TORs examined were issued after the commencement of the NGERS in 2008.

INSERT TABLE 5 HERE

Completeness

Foremost, that no project has been assigned the green evaluation for all emission sources suggests that these greenhouse assessments do not fully capture the CSG life cycle. Instead, there was found to be considerable range in emission sources covered by the EISs. Each of the eight projects reviewed was assigned between 2-9 red evaluations for the emissions sources. This represents a large range in completeness given that the CSG life cycle may be seen as comprising 12-15 of these sources (depending on whether the gas is liquefied and exported).

At one end, the greenhouse assessment for the APLNG Project may be seen as achieving the greatest level of completeness as it covered all but two emission sources. At the other end, the assessment of the QCLNG Project may be considered the 'least' complete as it failed to provide estimates for eight of the sources and only partly addressed five. This was also the only project among those reviewed that did not consider the end-use combustion of CSG, which is certainly the largest contributor to the GHG life cycle (Hardisty *et al.* 2012; Clark. *et al.* 2011; Prior & Koenders 2011). This omission was noted by the Qld Office of the Coordinator-General in its response to the EIS (Department of Infrastructure and Planning [DIP] 2010). These observations do not, however, reflect the *accuracy* of the assessments, as a relatively complete assessment may use low quality data (for example, out-dated data or uninformed estimates), and vice versa.

INSERT TABLE 6 HERE

Transparency and data aggregation

Data aggregation was another important consideration when reviewing the assessments. In this study, 'aggregation' refers to the degree to which the assessment broke down activity data. While cumulative and strategic impacts may be better understood with aggregated metrics (e.g. total emissions for a project over its lifetime), it is important that the data used to derive these metrics be disaggregated (e.g. emissions at individual stages within the project life cycle) so that, in the interests of transparency, calculations can be traced and understood by the reader.

The review of EISs and associated consultant reports demonstrated a large range of data aggregation. For example, in calculating emissions from transport diesel combustion, the consultant report for the Surat Gas Project greenhouse assessment disaggregated annual fuel use into the estimated distance travelled by both light and heavy vehicles, as well as the assumed fuel consumption for each vehicle type. This represents a high degree of disaggregation. In contrast, the QCLNG Project assessment aggregated all emissions by project phase (construction, commissioning and operation) and production stage (extraction, transmission, processing and export) instead of disaggregating by source (e.g. diesel combustion, fugitives, etc.). This may have been because a consultant report (perhaps containing less aggregated activity data) was not publicly available at the time of writing. Such a level of data aggregation limits readers' ability to evaluate the quality and rigour of the assessment methodology.

Geographical comparisons

The EIS review also demonstrated significant differences between greenhouse assessments depending on where the CSG project was based.

Overall, there was a consistent lack of completeness in the assessments for NSW projects. All were found to exclude a greater number of emissions sources compared to most of the Qld EISs, having been assigned between 6-9 red evaluations and between 1-3 orange evaluations (Table 6).

Further, most Qld assessments were found to be more transparent than NSW assessments, often disaggregating activity data to a greater extent and sometimes demonstrating calculation steps, as opposed to presenting only final estimates.

Overall, the above analysis demonstrates the inconsistencies between the levels of completeness, aggregation and time dependence that EISs are attaining, across both NSW and Qld projects. Possible explanations for these inconsistencies will be discussed later.

Emission intensity

Most of the greenhouse assessments examined gave emission intensities (EIs) for CSG, conventional natural gas and coal, presented in both thermal units (t CO_2-e/GJ) and electrical units (t CO_2-e/MWh) for cases where gas may be used for electricity generation. Interestingly, not all proponents calculated EIs from the results of the greenhouse assessment. Instead, many presented emission factors from the Department of the Environment's *National Greenhouse Accounts Factors* (NGAFs) (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education [DIICCSRTE] 2013). These include Scope 1 emission factors, which specify the typical amount of emissions from the end-use combustion of a fuel only, as well as Scope 3 emission factors, which use the Department's estimates of emissions from extraction, processing and transport of a fuel (excluding end-use).

Some assessments included only the Scope 1 emission factor (e.g. the QCLNG Project assessment). This approach frames natural gas as considerably less emissions intensive than other fossil fuels such as coal. This is because methane, on an energy density basis, produces 60% fewer emissions than coal when combusted (Day et al. 2012).

Extending on this approach, the Surat Gas Project assessment summed Scope 1 and Scope 3 emission factors to give a more detailed, though not necessarily complete, estimate of emissions. This approach considers emissions from extraction, processing, transport and combustion of the gas, but it is not possible to trace the NGAF methodology behind these values. This still frames natural gas as less emissions intensive than coal, though its apparent greenhouse benefits are less as, according to the NGAFs, producing a unit of natural gas is more emissions intensive than producing an equivalent unit of coal (DIICCSRTE 2013).

Complications in EIs also arose due to potential unrecognised differences between CSG and conventional gas. It was difficult to assess the relative intensities of different types of natural gas at the time of writing as the NGAF emission factors did not distinguish between conventional natural gas and CSG. Nonetheless, the relevant government department was, at the time of writing, in the process of developing an emission factor specific to CSG (DIICCSRTE 2013).

Until one is developed, proponents of CSG projects may continue to use emission factors that do not explicitly recognise potential differences between these two types of production.

Finally, the assessments also varied in the range of emission sources included in the calculated EIs. Many excluded Scope 3 emissions, often with the reason that they lie outside of the proponent's control. Most of the time, including all possible emission sources in the author's calculated value resulted in an increase in the EI. Inclusion of all Scope 3 emissions for the Surat Gas Project, for example, produced a calculated EI of 0.0722 t CO2-e/GJ, a 20% increase over the value published in the greenhouse assessment (0.0600 t CO2-e/GJ). Nonetheless, an increase is not necessarily inevitable as there was no material difference made to the EI for the GLNG Project when all possible Scope 3 emissions were included in the author's own calculations. Differences in EI values may also result from differences in the quality of data underlying the assessments, though it is difficult to determine quality from the EISs alone.

Cumulative impacts

All EISs examined in this study were found to address cumulative impacts, though this does not necessarily qualify them as thorough CIAs. Coverage ranged from brief statements about cumulative impacts, through to designated sections and chapters to entire reports (see Table 7).

Of particular relevance to this study are approaches to assessing cumulative GHG impacts. Most of the NSW-based EISs did not address this area, likely because cumulative impacts were not specified in the DGRs, or were specified briefly as a "general requirement". An exception was the EIS for the Bibblewindi Gas Exploration Pilot Expansion (part of Santos' Narrabri Gas Project), which briefly considered potential cumulative emissions from a future expansion (though not final outcome) of the project. No other NSW EIS took this approach.

Most of the Qld-based EISs addressed cumulative GHG impacts by considering other developments in the region. This included other CSG-LNG projects with LNG processing facilities based near Gladstone, Qld. The APLNG EIS, for example, predicted that these projects would contribute 3.2% of Australia's predicted annual emissions in 2030 (APLNG 2010). Overall, cumulative impacts received considerably greater attention in the TORs compared to the DGRs. This, however, may also be a reflection of the larger scale of Qld-based projects.

Discussion

Based on the above findings, the current set of EISs covering the CSG industry are limited in providing a consistent understanding of even the most spatially and temporally direct GHG impacts. Extending on this, it is argued that the mainstream approach of greenhouse assessment, that of project-specific EIA, is limited in addressing the spatially and temporally broader life cycle impacts of this expanding industry.

Inconsistencies

On the first point raised above, the EIS review demonstrated large inconsistencies across greenhouse assessments. Though the assessments were found to be guided in similar ways (e.g. by the NGERS), they did not appear to examine a consistent range of emission sources, nor was there consistency in how data was aggregated. In some assessments, a high degree of aggregation was found to reduce transparency by limiting an ability to trace assessment methodology.

Further, proponents took different approaches in calculating emission intensities, in some cases neglecting results from the assessment itself. This appears somewhat at odds with the project-specific scope of EIA. This is of concern given the power that emission intensities have in providing concise reflections of greenhouse impacts.

How might these inconsistencies be explained? The foremost influence on the assessments is likely to be the regulatory mechanisms of the DGRs and TORs, which were found to dictate the methodological framework of the EIS. The greater level of detail in the Qld assessment requirements may have translated into the greater levels of completeness and methodological transparency in the Qld assessments compared to those for NSW. Given that the relevant planning legislation in Qld and NSW do not directly address GHG assessment, variations in requirements may be as a result of differences in other policies, plans and more generally, environmental values that have become embedded in government over time. It is not possible to gauge these broader influences using only this document analysis.

The consequence of these inconsistencies is that they hinder comparisons of impacts across different projects, as well as an understanding the industry as a whole. As is argued in the EIS of the Camden Gas Project (PAEHolmes 2010, p. 28):

> *"…care should be exercised when comparing greenhouse gas intensities for different types of gas projects as assessments often quantify different aspects of the proposals, which can confuse benchmarking evaluations and result in meaningless comparisons."*

This means, at present, it would be difficult for policy makers and the public to look back on the set of existing greenhouse assessments and gain a strategic understanding of the industry, for example, by examining which projects have the highest or lowest emissions intensities, and hence identifying where improvements need to be made. This finding echoes that of Ball *et al.* (2012) in relation to impact assessment within water catchments, as discussed earlier.

As the analysis also demonstrated, however, there appears to be a promising historical trend towards the DGRs and TORs becoming stronger and more specific, especially following the introduction of the NGERS. This could be seen to reflect a growing awareness of the need to better account for and manage GHG emissions, as well as to reflect relevant policy developments including the Australian Government's participation in the United Nations Framework Convention on Climate Change (UNFCCC).

This trend suggests that an effective avenue towards more cumulative and life-cycle based assessment is to strengthen EIS requirements. This may involve developing standards across the CSG industry to either guide or mandate a consistent approach to greenhouse assessment. This would not only improve transparency for decision makers and the public in understanding the GHG impact of the industry, but might also ensure equality for project proponents preparing an EIS.

The 'almost' life cycle

While some assessments came close to capturing the complete CSG life cycle, other assessments were, in comparison, highly deficient. This was particularly so for Scope 3 emissions (e.g. those embodied in the production and transport of fuels), as well as those from sources significantly upstream or downstream of the operator's activities in the CSG life cycle (e.g. exploration and decommissioning activities).

One reason for this may be that the requirements governing the greenhouse assessments provided little incentive for operators to encompass the full life cycle. From the DGRs and

TORs examined, the specific types of Scope 3 emissions were not clarified, providing a degree of freedom for operators to be selective about which of these were assessed.

Further, the estimation of Scope 3 emissions is largely beyond familiar and mandatory reporting requirements. For one, the NGERS, which would require most, if not all, CSG operators to report emissions annually, does not require the reporting of Scope 3 emissions. Given that many of the greenhouse assessments were found to be based on NGERS methods, it is inevitable that Scope 3 emissions received little attention compared to Scope 1 and Scope 2 emissions. Though some assessments utilised Scope 3 estimation methods from the NGAFs, this resource does not provide methods for *all* Scope 3 emissions in the CSG life cycle, such as those from land clearing.

Overall, it is argued that EIA, and specifically, the process of preparing an EIS, has room for improvement in evaluating the life cycle GHG impacts of CSG in Australia. It could be argued that this is placing too high expectations on EIA given its inherently localised scope. Nonetheless, this remains of concern given that the EIS is one of, if not the only formalised decision-making tool within environmental planning that allows for assessment of GHG emissions.

A strategic approach to CSG

In light of this study, the focus of policy-makers should be on a broader, more strategic approach to understanding the CSG industry, perhaps through the adoption of SEA.

In relation to greenhouse impacts, an SEA of the CSG industry might first incorporate holistic methods such as Life Cycle Assessment (LCA) (Marsden & Dovers 2002). For fuels such as coal and natural gas, LCA allows for the assessment of emissions not only from the end-use of the fuel, but also from its extraction, processing and transport. Doing so would also place policy-makers in a better position to assess the long-term, trans-boundary impacts of the industry. At the time of writing, GHG LCAs of the Australian CSG industry had been conducted by the Australian Petroleum Production and Exploration Association (Clark, T. *et al.* 2011 and subsequently Hardisty *et al.* 2012) and Citi Investment Research and Analysis (Prior and Koenders 2011). Nonetheless, these addressed planned CSG projects and utilised predictive estimates from some of the EISs analysed in this study. Given that CSG has been at commercial production in Australia since 1996, there may now be potential to conduct an LCA that draws purely on measured data.

An SEA might also draw on the principles of CIA to gauge the cumulative impact of not only single projects, but the industry as a whole. The common practice within an EIS is to compare GHG emission estimates from a single project to state and national totals, but this inevitably frames the impact as negligible. Taking a cumulative impact approach, it was predicted in the EIS for the APLNG project that the operation of all planned CSG-LNG projects in just the Gladstone region of Queensland (excluding significant emissions from the end use of CSG) would comprise 3.2% of Australia's predicted annual emissions in 2030 under business as usual (i.e. increasing) emission projections (APLNG 2010). This is significant when considering that the present Government intends to reduce national emissions to 5% below 2000 levels by 2020 (Department of the Environment [DoE] 2014). Considering the cumulative impact of current and likely future projects (based on resource estimates) can provide a more strategic understanding of the industry at large (Rose 2007).

Taking an SEA approach might also avoid what Odum (1982) refers to as the environmental equivalent of economist Alfred E. Kahn's "tyranny of small decisions". This problem occurs when a large decision becomes the product of small decisions, the result being that "the central question is never addressed directly at the higher decision-making levels" (Odum 1982, p. 728). The threat of this problem is particularly evident with the currently small CSG industry in NSW. The Camden Gas Project, for example, started with about 20 production wells in 2002 (AECOM 2010), evolved through a series of over 35 Modifications and Development Applications lodged with the NSW Department of Planning and Infrastructure (DPI 2013b), and was at 95 production wells at the time of writing (AGL 2014). Further, the preliminary assessment for the Narrabri Gas Project did not, at the time of writing, consider the transmission pipeline from the outset, even though it would be fundamental to the project (GHD 2014). If not approached more strategically, there is a risk that these processes may be carried out without what Odum (1982, p. 729) refers to as a "large-scale perspective", such as that potentially achieved through an SEA.

What would the central questions be, then, when addressing the CSG industry through SEA? Given the likely GHG reductions that would result in switching to CSG for heating and electricity, it is now important to consider whether these reductions would be sufficient to contribute to the significant emission reductions needed to mitigate anthropogenic climate change, i.e., whether CSG has any place as part of a sustainable energy sector in Australia.

At least in NSW, there is already potential for policy makers to adopt a strategic outlook at this early stage of CSG development. In particular, the principles of SEA are echoed in the Independent Review of Coal Seam Gas Activities presently being undertaken by the NSW Chief Scientist and Engineer (O'Kane 2013). This review is examining the environmental and social dimensions of CSG development by drawing on technical reports and community consultations. Such an initiative could certainly have all the makings of an SEA.

Conclusion

Given an increasing urgency to address climate change, the development of Australia's CSG resources warrants an understanding of their GHG impact. This study examined different avenues to achieving such an understanding.

It first addressed a traditional planning approach to greenhouse assessment – that of project-specific EIA. In analysing a number of EISs, it was argued that there exist a number of inconsistencies in how CSG projects have traditionally been assessed. Specifically, assessments differed significantly in the number and type of emission sources considered, the level of aggregation in activity data presented, as well as in methodology used for calculating emission intensity. It appears that variations across the assessments are a product in part of the differing requirements placed on them. From an examination of the DGRs and TORs, it was found that assessments that were dictated by relatively less stringent and detailed requirements tended to attain lower levels of completeness and transparency. Further, the requirements were found to differ across NSW and Qld, though the reasons for this are likely to be varied and largely beyond the scope of this study. Nonetheless, this highlights the importance of establishing clear and firm assessment requirements, as well as the need to establish consistent requirements across jurisdictions.

Attention should now be directed towards expanding traditional environmental assessment towards alternative forms, such as CIA and SEA. In doing so, it may be possible to understand not only the potential impacts of individual CSG projects, but also the implications of CSG as an industry for Australia's sustainable development. As Ortolano and Shepherd argue (1995, p. 22), "even moderately scaled domestic projects can, collectively, have dramatic effects on the global commons." Given both the youth and rapid expansion of the CSG industry, understanding this is now crucial.

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REFERENCES

AECOM (2010), *Camden Gas Project Northern Expansion: Environmental Assessment*, AGL, Sydney.

AGL (2013), 'Gloucester Gas Project: Overview', available from: http://agk.com.au/gloucester/index.php/the-project/ (accessed 1/8/13).

AGL (2014), 'Camden Gas Project: Overview', available from: http://www.agl.com.au/about-agl/how-we-source-energy/natural-coal-seam-gas/camden-gas-project/the-project (accessed 4/2/2014).

APLNG (2010), *Australia Pacific LNG Project: Gas Fields Cumulative Impact Assessment*, Australia Pacific LNG, Gladstone.

APPEA (2013), *Quarterly production statistics 2013*, Australian Petroleum Production and Exploration Association, Canberra.

ARCE, R. & GULLÓN, N. (2000), 'The application of Strategic Environmental Assessment to sustainability assessment of infrastructure development', *Environmental Impact Assessment Review,* vol. 20**,** no. 3**,** pp. 393-402.

BALL , M.A, NOBLE, B.F. & DUBÉ, M.G. (2012), 'Valued ecosystem components for watershed cumulative effects: An analysis of environmental impact assessments in the South Saskatchewan River watershed, Canada', *Integrated Environmental Assessment an Management*, vol. 9, no. 3, pp. 469-479.

BRUECKNER, M., DUREY, A., MAYES, R. & PFORR, C. (2013), 'The mining boom and Western Australia's changing landscape: towards sustainability or business as usual?', *Rural Society,* vol. 22**,** no. 2**,** pp. 111-24.

BULKELEY, H. (2000), 'Down to earth: local government and greenhouse policy in Australia', *Australian geographer,* vol. 31**,** no. 3**,** pp. p289-308.

CLARK, T., HYNES, R. & MARIOTTI, P. (2011), *Greenhouse gas emissions study of Australian CSG to LNG*, WorleyParsons, Sydney.

CLEAN ENERGY REGULATOR (2013), 'National Greenhouse and Energy Reporting', available from: http://www.cleanenergyregulator.gov.au/national-greenhouse-and-energy-reporting/Pages/default.aspx (accessed 9/8/2013).

DAY, S., CONNELL, L., ETHERIDGE, D., NORGATE, T. & SHERWOOD, N. (2012), *Fugitive greenhouse gas emissions from coal seam gas production in Australia*, Commonwealth Scientific and Industrial Research Organisation, Australia.

DEP (2010), *Sydney Growth Centres Strategic Assessment: Program Report*, Department of Environment and Planning, Sydney.

De RIJKE, (2013) "Coal Seam Gas and Social Impact Assessment: An Anthropological Contribution to Current Debates and Practices.," *Journal of Economic and Social Policy*, vol 1, no. 3, Article 3. Available at: http://epubs.scu.edu.au/jesp/vol15/iss3/3

DIICCSRTE (2013), *Australian National Greenhouse Accounts: National Greenhouse Accounts Factors*, Department of Industry, Innovation Climate Change, Science, Research and Tertiary Education, Canberra.

DIP (2010), *Queensland Curtis LNG Project: Coordinator-General's report on the environmental impact statement*, Department of Infrastructure and Planning, Brisbane.

DOE, (2014), 'Australia's emissions reduction targets', available from: http://www.climatechange.gov.au/climate-change/greenhouse-gas-measurement-and-reporting/australias-emissions-projections/australias (accessed 01/02/2014).

DPI (2010), *Director-General's Requirements for the Camden Gas Project Stage 3 Northern Expansion*, Department of Planning and Infrastructure, Sydney.

DPI (2013a), *Director General's Requirements: Bibblewindi Gas Exploration Pilot Expansion (SSD-5934)*, Department of Planning and Infrastructure, Sydney.

DPI (2013b), 'Major Project Assessments', Department of Planning and Infrastructure, available from: http://majorprojects.planning.nsw.gov.au/page/(accessed 1/7/13).

ELLIOTT, M. & THOMAS, I. (2009), *Environmental impact assessment in Australia: theory and practice*, Federation Press, Annandale.

FRANKS, D. (2012), *Social Impact Assessment of Resource Projects,* International Mining for Development Centre, AusAID, University of Queensland, University of Western Australia. Brisbane.

FRANKS, D., FIDLER, C., BRERETON, D., VANCLAY, F, and CLARK, P. (2009), *Leading Practice Strategies for Addressing the Social Impacts of Resource Developments,* Centre for Social Responsibility in Mining, Sustainable Minerals Institute, University of Queensland. Brisbane.

FRANKS, D. and VANCLAY, F. 2013 'Social Impact Management Plans: Innovation in corporate and public policy', *Environmental Impact Assessment Review* 43, pp.40-48.

GHD (2014), *Narrabri Gas Project: Preliminary Environmental Assessment*, Santos, Sydney.

HARDISTY, P.E., CLARK, T.S. & HYNES, R.G. (2012), 'Life cycle greenhouse gas emissions from electricity generation: a comparative analysis of Australian energy sources', *Energies,* vol. 5, no. 12, pp. 872-97.

HLA-ENVIROSCIENCES (2007), *Expansion of Stage 2 of the Camden Gas Project: Environmental Assessment: Volume 2*, AGL, Sydney.

HOWITT, R.. (1989), 'Social impact assessment and resource development: issues from the Australian experience', *Australian geographer*, vol. 20, no. 2, pp. 153-66.

IEA (2013), *World Energy Outlook 2013*, International Energy Agency, France.

KATES, R. & WILBANKS, T. (2003), 'Making the global local: responding to climate change concerns from the ground up', *Environment*, vol. 45, no. 3, pp. 12-23.

LEATHER, D.T.B., BAHADORI, A., NWAOHA, C. & WOOD, D.A. (2013), 'A review of Australia's natural gas resources and their exploitation', *Journal of Natural Gas Science and Engineering,* vol. 10, pp. 68-88.

MANUILOVA, A., SUEBSIRI, J. & WILSON, M. (2009), 'Should Life Cycle Assessment be part of the Environmental Impact Assessment? Case study: EIA of CO2 Capture and Storage in Canada', *Energy Procedia,* vol. 1, no. 1, pp. 4511-18.

MARSDEN, S. & DOVERS, S. (2002), *Strategic environmental assessment in Australasia*, Federation Press, Annandale.

MICHELL, G. AND MCMANUS, P. (2013), 'Engaging Communities for Success: social impact assessment and social licence to operate at Northparkes Mines, NSW', *Australian Geographer*, vol. 44, no. 4, pp. 435.

ODUM, W.E. (1982), 'Environmental degradation and the tyranny of small decisions', *BioScience*, vol. 32, no. 9, pp. 728-29.

O'KANE, M. (2013), *Initial report on the Independent Review of Coal Seam Gas Activities in NSW*, NSW Chief Scientist & Engineer, Sydney.

ORTOLANO. L. & Shepherd, A. (1995), 'Environmental Impact Assessment: challenges and opportunities', *Impact Assessment*, vol. 13, no. 1, pp. 3-30.

PAEHOLMES (2010), *Northern Expansion of the Camden Gas Project: Greenhouse Gas Assessment*, AGL, Sydney.

PORTER, M., FRANKS, D.M. & EVERINGHAM, J. (2013), 'Cultivating collaboration: lessons from initiatives to understand and manage cumulative impacts in Australian resource regions', *Resources Policy,* vol. 38, no. 4, pp. 657-69.

PRIOR, E. & KOENDERS, D. (2011), *Coal seam gas and greenhouse emissions: comparing life cycle emissions for CSG/LNG vs. Coal*, Citigroup Global Markets.

ROSE, A. (2007), 'Gray v Minister for Planning: the rising tide of climate change litigation in Australia', *Sydney Law Review*, vol. 29, no. 4, pp. 725-34.

SADAR, M.H. (1994), *Environmental Impact Assessment*, Carleton University Press, Ottawa.

SANTOS (2013a), 'Santos seeks approval for Pilliga exploration program', available from: http://www.santos.com/Gunnedah/NewsDetails.aspx?p=616&id=1385 (accessed 15/7/2013).

SHEPHERD, A. & ORTOLANO. L. (1996), 'Strategic environmental assessment for sustainable urban development', *Environmental Impact Assessment Review*, vol. 16, no. 4, pp. 321-35.

TETLOW, M.H. & HANUSCH, M. (2012), 'Strategic environmental assessment: the state of the art', *Impact Assessment and Project Appraisal*, vol. 30, no. 1, pp. 15-24.

WHITE, L. & NOBLE, B.F. (2013), 'Strategic environmental assessment for sustainability: a review of a decade of academic research', *Environmental Impact Assessment Review*, vol. 42, pp. 60-6.

WRI/WBCSD (2004), *The greenhouse gas protocol: a corporate accounting and reporting standard*, World Resources Institute and World Business Council for Sustainable Development, Washington/Switzerland.

Project name – Operator – Basin – State	**Description**
Camden Gas Project – AGL – Sydney Basin – NSW	• The only CSG project in NSW at commercial production (since 2001) • 95 production wells supplying 5% of NSW gas supply • Northern Expansion (Stage 3) application suspended in February, 2013, by AGL due to community concerns
Narrabri Gas Project – Santos – Gunnedah Basin - NSW	• Proposal for a 25-year project comprising up to 850 production wells (in 425 well sets), associated infrastructure and a transmission pipeline connecting fields to existing distribution network • Currently at exploration and appraisal stages around the Pilliga State Forest, with no commercial production • Anticipated to produce up to 50% of NSW gas demand
Gloucester Gas Project – AGL – Gloucester Basin - NSW	• Proposal for a project comprising up to 110 production wells, a central processing facility, 15 MW gas fired electricity generation facility, transmission pipeline (95 km) and delivery station to connect to existing Sydney-Newcastle pipeline • Approved in February, 2013 • First commercial production expected by mid-2016

Table 1: Three projects in NSW that were reviewed as part of this research.

Project name – Operator – Basin – State	Description
Surat Gas Project – Arrow Energy – Surat Basin – Qld	• Expansion of existing project, including up to 7,500 production wells and associated infrastructure, 18 production facilities each comprising 6 field compression facilities and 12 processing facilities • Combines with separate but interdependent projects, including the Arrow Surat Header Pipeline (106 km), Arrow Surat Pipeline (470 km) and Arrow LNG Plant (for liquefaction and export of CSG to Asia) • Transmission pipeline approved in 2009, gas fields and LNG Plant approved in 2013 • Peak production expected in 2014
Bowen Gas Project – Arrow Energy – Bowen Basin – Qld	• Expansion of existing project, including up to 6,625 production wells and associated infrastructure; field compression facilities and gas processing facilities • Combines with Arrow Bowen Pipeline (475 km) and Arrow LNG Plant • Bowen Pipeline approved in 2013; Gas fields under assessment
Australia Pacific LNG Project – APLNG – Surat and Bowen Basins – Qld	• Development of gas fields for up to 10,000 production wells (maximum 5,000 at any one time); transmission pipeline (450 km); LNG export facility • Approved in 2011 • Under construction, with first LNG export expected by mid-2015
GLNG Project – Santos – Bowen and Surat Basins – Qld	• Development of 2,650 exploration and production wells and associated infrastructure; transmission pipeline (435 km); LNG export facility at Gladstone • Approved in 2010 • Under construction, with first LNG export expected by 2015
QCLNG Project – QGC – Surat Basin – Qld	• Development of 6,000 production wells; 27 field compression facilities and 9 central processing facilities; transmission pipelines (580 km); LNG export facility • Approved in 2010 • Under construction, with first LNG export expected by 2014

Table 2: Five projects in Qld that were reviewed as part of this research.

Emission Source	Activities
Fuel combustion: Transport	Mostly diesel-fuelled transport for: • Equipment • Materials • Waste • Employees • General activity
Fuel combustion: Stationary	Gas (CSG) or diesel powered generators that provide power to: • Construction, earthmoving and drilling activities • Gas processing equipment (e.g. pumps, separators, dehydrators) • Compression (at processing facility and in field) • Decommissioning activities
Electricity use	When gas power is not practical, grid electricity may be used use at the: • Well site • Processing facility • Water treatment facility • Compression stations
Fugitives: Flaring	• During well exploration • Flowback during hydraulic fracturing • Dewatering • Workovers: maintenance, re-fracturing and re-drilling • Pilot lights used under normal operation conditions • Upset conditions (maintenance and emergency shutdown)
Fugitives: Venting	• Workovers • Mud degassing • Flowback during hydraulic fracturing (if not flared) • High point vents for water gathering system • Acid gas removal unit (AGRU): to remove CO_2 from CSG, then vented • Nitrogen rejection unit (NRU): nitrogen discharge from feed gas also contains small quantity of methane
Fugitives: Leakage	• Diffuse emissions: potential methane leaks at and around well site • Degassing of produced water and drilling mud • Gas gathering lines, transmission and distribution pipelines • Processing facility equipment: gas compressors, dehydrators, valves, flanges, seals, caps, plugs, connection points, etc.
Water treatment	A combination of the above sources, including: • Power for water treatment facilities (gas, diesel or electricity) • Pumping of water during re-injection into the ground
Embedded emissions	Emissions associated with extraction, production and transport of life cycle inputs, including: • Non-CSG fuel (mostly diesel) • Electricity • Construction materials, including steel, concrete, polyethylene piping • Emissions from solid waste
Land clearing	• Emissions embodied in vegetation cleared for wells, pipelines and processing facilities • May also includes lost carbon sequestration from the atmosphere
End-use	• Combustion for electricity generation and/or domestic, commercial and industrial use via a transmission pipeline and gas distribution network
Export	• Power requirements for liquefaction of CSG at an LNG facility (if applicable)

operations (Qld only)	• Overseas shipping (power requirements and fugitives) • Regasification at destination (power requirements and fugitives)

Table 3: Common emission sources comprising the CSG life cycle.

Project	Date of DGRs	Requirements relating to GHG emissions
Camden Gas Project Stage 2	March 2007	• No GHG assessment requirements
Narrabri Coal Seam Gas Utilisation Project (Eastern Star Gas)	July 2007	• Direct and indirect emissions, though emission scopes are not specified • Total annual and project lifetime emissions
JULY 2008 – NGERS COMMENCES		
Gloucester Gas Project	August 2008	• Quantitative assessment, though emission scopes not specified
Camden Gas Project Stage 3	April 2009	• As above
Bibblewindi Gas Exploration Pilot Expansion	May 2013	• Scope 1, 2 and 3 emissions • Qualitative assessment of potential impacts

Table 4: Director General's Requirements (DGRs) for CSG projects in NSW between March 2007 and May 2013, with projects ordered chronologically.

Project	Date of TOR	Requirements relating to GHG emissions
JULY 2008 – NGERS COMMENCES		
QCLNG Project	May 2009	• Scope 1 and Scope 2, but does not specify Scope 3 emissions • "Off-site" and "on-site" emissions attributable to the project, upstream activities in particular • Brief description of estimation methods
APLNG Project	December 2009	• Assessment of upstream activities, though emission scopes not specified • Brief description of estimation methods
Surat Gas Project	September 2010	• Scope 1, 2 and "readily identifiable" Scope 3 emissions • Brief description of estimation methods
Bowen Gas Project	November 2012	• As above
GLNG Project	March 2013	• Scope 1 and Scope 2, but Scope 3 emissions not specified • Brief description of estimation methods

Table 5: Terms of Reference (TOR) for CSG projects in Qld between May 2009 and March 2013, with projects ordered chronologically.

Emission source	Project							
	Queensland					New South Wales		
	Arrow Energy - Surat	Arrow Energy - Bowen	APLNG	Santos – Gladstone LNG	QGC – QCLNG	AGL – Gloucester	AGL – Camden (Northern Expansion)	Eastern Star Gas - Narrabri
Non-CSG fuel combustion – Transport	Green	Green	Green	Green	Orange	Red	Green	Red
Non-CSG fuel combustion – Stationary	Green	Green	Green	Green	Orange	Green	Green	Orange
Electricity use (Scope 2)	Green	Green	Green	Green	Green	Green	Green	Red
Electricity (Scope 3)	Green	Green	Green	Green	Green	Red	Red	Red
Fuel (Scope 3)	Green	Green	Green	Red	Red	Red	Red	Red
Materials (Scope 3)	Red	Red	Green	Red	Red	Red	Red	Red
Landfill waste (Scope 3)	Red	Red	Red	Red	Red	Red	Red	Red
Water treatment	Orange	Orange	Red	Red	Red	Red	Red	Red
Land clearing	Green	Green	Green	Green	Red	Red	Red	Red
Fugitives – Venting	Orange	Red	Orange	Orange	Orange	Red	Orange	Green
Fugitives – Flaring	Green	Green	Green	Orange	Orange	Orange	Orange	Green
Fugitives – Leaks	Green	Green	Green	Orange	Orange	Orange	Orange	Green
End-use	Green	Green	Green	Green	Red	Red	Green	Green
Liquefaction (Qld only)	Green	Green	Green	Green	Red			
Export (Qld only)	Red	Red	Green	Orange	Red			

Table 6: Coverage of emission sources in the EISs reviewed as part of this research. The following colour-coding system, as developed by the author, was used to evaluate data from the greenhouse assessments: Green: the assessment provided a quantitative estimate and discussion of the emission source. Orange: the emission source was calculated with exceptions. Red: the source was not estimated with justification or not recognised at all.