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Unconventional gas developments and the politics of risk and knowledge in Australia

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ABSTRACT

Australia could become the world's largest liquefied natural gas (LNG) exporter by 2021. Especially the unconventional coal seam gas (CSG) reserves in the state of Queensland are developed at an unprecedented scale and pace. This rapid growth has intensified land use competition and, combined with concerns over associated extraction techniques such as hydraulic fracturing ('fracking'), the CSG industry has prompted heated debates about its impacts. In this paper we present findings from our ethnographic fieldwork within Queensland's gas fields and demonstrate how various actors respond differently to questions of risk and existing levels of knowledge. Highlighting this contingent nature of risk and knowledge, we caution against reductionist scientific understandings that suggest imaginary boundaries between knowledgeable experts and uninformed citizens. Rather, we argue for an anthropological perspective that allows to carefully think through the ways in which contentious subterranean resources such as CSG become known and how risks are socio-politically negotiated. This focus on the underlying politics of risk and knowledge is highly relevant to public debates over unconventional hydrocarbon developments and can address a central issue for the energy production in industrialized societies: the challenges of environmental change and the resulting socio-political negotiations of knowledge in the contemporary 'risk society'.

1. Introduction

The development of unconventional natural gas resources in Australia has been heralded by proponents as part of a 'global gas revolution', which could see Australia becoming the world's largest liquefied natural gas (LNG) exporter by 2021 [11,p. 87]. To supply this emerging industry along Australia's eastern seaboard, abundant coal seam gas (coal bed methane) reserves in the state of Queensland in the country's north-east are currently developed at an unprecedented scale and pace. The demand for unconventional gas may ultimately lead to the drilling of up to 40,000 gas wells in Queensland alone [12]. This rapid growth and the socio-cultural changes it produces in predominantly regional and rural areas have further intensified land use competition between agricultural and extractive industries, while also affecting non-agricultural landholders and regional residents more generally. In combination with controversies about associated extraction techniques such as hydraulic fracturing ('fracking'), the expansion of the coal seam gas (CSG) industry has prompted heated national debates about extractive industries and regional development, energy production, and related environmental, social, and economic impacts.

Since 2012, we have undertaken ongoing ethnographic fieldwork with the broad variety of persons involved in these debates about CSG developments in the agricultural region of southern Queensland known as the Darling Downs (see Fig. 1 below). As anthropologists concerned with social diversity, our approach is to study the societal implications of energy and unconventional gas developments 'up, down and sideways' [48,p. 317]. Among our interlocutors are therefore local landholders with and without gas infrastructure on their properties, regional town residents, Indigenous people, government and interest group representatives, anti-CSG activists, as well as urban residents, a variety of scientists and gas industry professionals. These ideal-type categories of persons may, however, overlap. While the intricacies of our interlocutors' social worlds are outside the scope of this paper, we present relevant case material from our research that is particularly illustrative of the diverse positions and engagements with the politics of risk and knowledge considered here. This case material was

Abbreviations: CMA, Cumulative Management Area; CSG, coal seam gas; EPA, (U.S.) Environmental Protection Agency; IAA, Immediately Affected Area; LNG, liquefied natural gas; OGIA, Office of Groundwater Impact Assessment.

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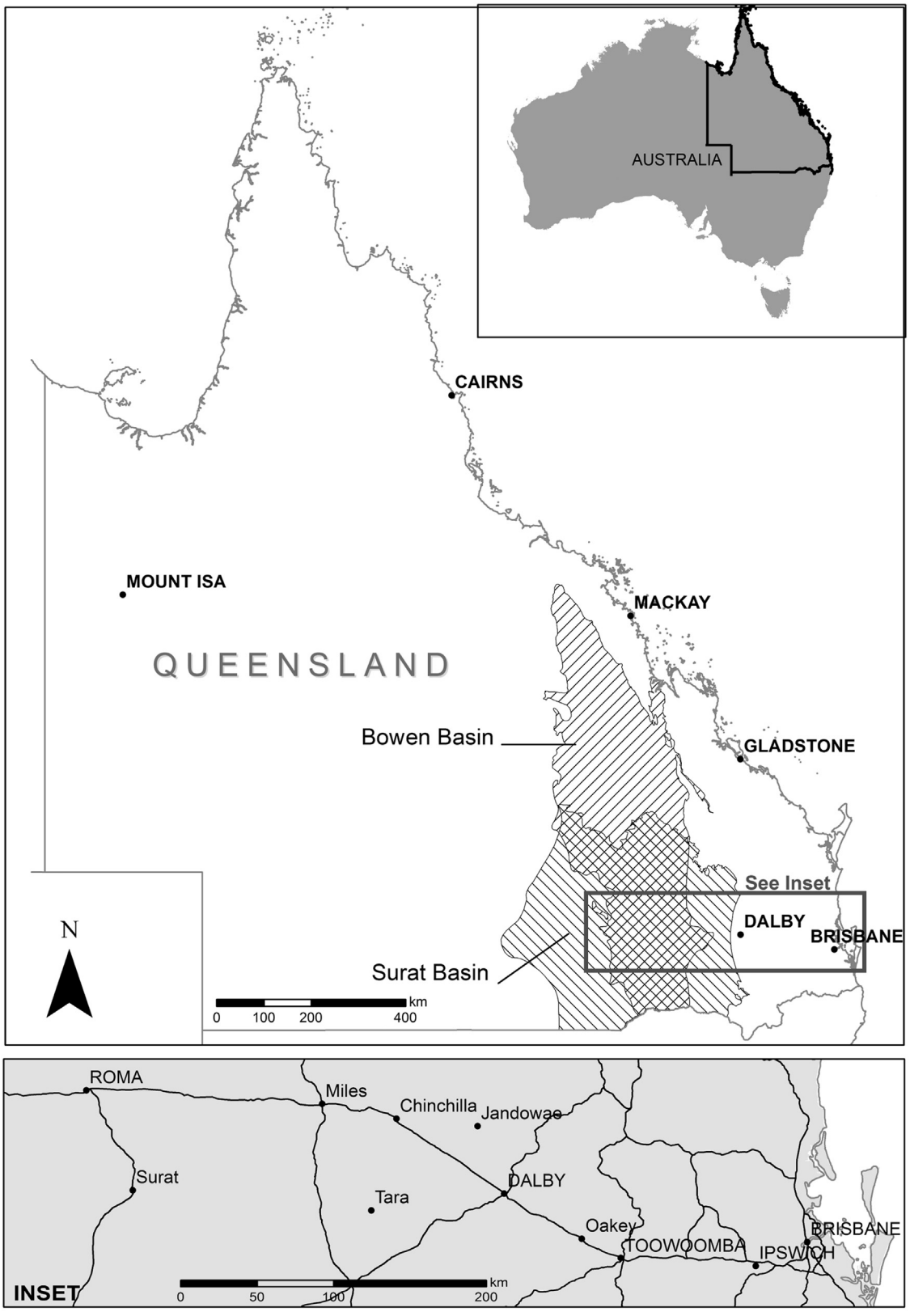

Fig. 1. The Surat and Bowen Basins and our study region of the Darling Downs (Inset), Australia.
(Source: de Rijke [13])

obtained by utilizing a range of research methods including (semi-structured) interviews, participant-observations, archival research, and textual analyses of a broad variety of publically available documents.

A notable conclusion arising from our work is that various local residents in the gas fields and representatives from broader interest groups express significant uncertainty, anxiety and concern about lacking knowledge regarding potential impacts and risks

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posed by CSG developments. While some proponents may suggest that these concerns are due to public misinformation and ignorance of existing technical expertise and scientific knowledge, we also found similar concerns among CSG-related professionals and scientists. A number of academics have also cautioned against potential qualitative and quantitative cumulative impacts of CSG extraction, arguing that impacts on, for example, groundwater resources pose "overwhelming unknowns . . . far beyond anything yet experienced" [52,p. 156]. Further, systematic reviews of studies focusing on the environmental health impacts of CSG extraction are yet to demonstrate conclusive evidence, leaving many questions unanswered (e.g. Ref. [74]). Including industry professionals and scientists into our research, we found that uncertainties and concerns about unknowns are not defined along imaginary boundaries between knowledgeable experts and misinformed citizens. We therefore question the usefulness of contrasting lay and expert knowledge in such risk debates and focus on the entanglements of different modalities of knowledge in the actual lived encounters with CSG.

In doing so, we suggest an anthropological perspective that goes 'beyond risk' [53] to more carefully think through the entangled and often hybrid ways in which contentious subterranean resources such as CSG become known in the first place (e.g. Ref. [54]) and, crucially, how unknowns are socio-politically negotiated among diverse sectors of society. In doing so we stress the need to resist reductionist scientific conceptions of these processes (see e.g. Roscoe's 'scientism' [55]). Instead, crucial questions about the cultural politics of risk and knowledge must be asked. Such an approach is highly relevant to public debates and the anthropological literature on unconventional gas, as well as emerging research into unknowns and ignorance in their own right (e.g. Refs. [17,28,41]). As de Rijke [14,p. 17] noted, "[a]nthropology, with its commitment to understanding local individuals and groups in their holistic cultural contexts is well suited to contribute to these debates surrounding gas extraction and energy" (cf. Refs. [58,68]). We argue that focusing on the cultural politics of knowledge and risk in unconventional hydrocarbon debates addresses a central issue for industrialized societies: envisioned energy futures, the management of environmental change, and the growing need for insights into the socio-political negotiation of knowledge to manage these challenges in the contemporary 'risk society' [7].

This article first provides an overview of the developing CSG industry in Queensland. This overview serves to identify those aspects of the industry important to current societal risk debates. We follow this overview with a brief evaluation of the social scientific literature on risk and knowledge relevant to our approach. After setting out the details of our research methods, we then provide an analysis of the research data. Based on our analysis, we conclude that risk debates about unconventional gas developments are driven by the negotiation of concepts that are inherently sociocultural. This article thus brings to the fore the importance of social scientific analyses in understanding the variety of responses to new energy initiatives.

2. The coal seam gas industry in Queensland, Australia

Approximately 7000 unconventional gas wells have been drilled in Queensland over the past decade [10,p. 43]. The targeted geological formations are largely coal seams (also called coal beds) in the Surat and Bowen Basins of southern and central Queensland. Over the next decades, up to 40,000 gas wells may be drilled in these regions to support the LNG export facilities established on Curtis Island near Gladstone. Similar to the unconventional gas developments in the United States and Europe, the coal seam gas industry has been subject to intense opposition. This opposition has resulted in the emergence of an unusual national activist movement called 'Lock the Gate', which integrates progressive environmental and conservative agricultural concerns in its aim to halt unconventional gas and coal mine developments in regions deemed inappropriate for such initiatives. This includes the Darling Downs region in southern Queensland known predominantly for its agricultural qualities despite the longstanding socioeconomic importance of the oil, gas and coal mining industries in the region.

The rapid development of the coal seam gas industry in the Darling Downs since 2009 has created intense debates about the potential negative impacts on groundwater resources important to the agricultural industry, social impacts including human health concerns, as well as concern about the fragmentation of landscapes, fugitive gas emissions, power relationships and governance, and rural socioeconomic futures more broadly (e.g. [15,pp. 44–48]. A major factor in the emergence of these concerns is the geographic footprint and material organization of unconventional gas developments. While each gas well has a relatively small footprint of about 1 ha or less, the collective footprint of thousands of wells, gathering lines, pipelines, tracks, compressor stations, water treatment facilities and so on, is significant. In comparison to extractive developments such as coal mines, these developments lack clearly defined boundaries and spread across the regional landscape as productive gas-bearing coal seams are explored, developed and connected to locations for processing and export.

Additional to these issues, concerns emanating as a result of earlier shale gas developments in the United States have influenced Australian responses. In particular, the release of the activist documentary film *Gasland* contributed to international concern about unconventional gas developments generally, and the technology of hydraulic fracturing in particular. Because our expertise lies outside the fields of natural science such as engineering and hydrology, we cannot comment on the accuracy of the various concerns depicted. However, as anthropologists who conduct qualitative research in this area, we are well-placed to elicit the social and cultural aspects which can be seen to drive the emergence of such unprecedented opposition to new hydrocarbon developments.

Firstly, we note how the term 'fracking', colloquially used in reference to the technology of hydraulic fracturing, has effectively conjured up notions of the extreme. Similar to other hydrocarbons that require significant energy input to extract them, such as the oil contained in Canadian tar sands, unconventional gas developments have been labeled among some as a form of 'extreme energy' (e.g. Ref. [63]). While hydraulic fracturing technologies have been employed in the oil and gas industry for decades, the term 'fracking' has only recently gained societal traction in public debates. A number of factors are important to this development. The emergence of the notion of 'extreme energy', in combination with increased concern about the implications of global climate change and related energy futures, is one factor. Further, the term is fundamentally perceived as the fracturing of boundaries thought stable both physically and culturally (e.g. Ref. [23]). In her classic outline of purity and danger as eminent cultural categories, the anthropologist Douglas [18] provided an effective framework for understanding how social conflict arises in settings where developments are perceived to potentially result in 'matter out of place'. The perceived threat that fracking might cause matter to cross subterranean boundaries and potentially enter the domain inhabited by humans at the surface is fundamental to the unprecedented reactions to this technology.

In many discussions, the term fracking has clearly come to represent the entire industry even though the industry itself is heterogeneous, fracking technologies have been used for decades without significant societal debates, and fracking itself is but a part of various extraction technologies (cf. Refs. [23,76]). Further, in the Australian coal seam gas industry, fracking is used infrequently as the coal seams are more porous than shale, and gas flows readily to

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the well as the coal seams are depressurized [11,p. 43]. However, the uptake of fracking in international societal debates brings to the fore the powerful character of cultural categories that associate danger with potential boundary crossings and matter out of place. Coupled with the diffuse geographic boundaries of surface developments, associated debates about impacts, intensifying concerns about global climate change and the need to reduce reliance on fossil fuels, fracking has brought to the debate a sense of societal doom previously absent from oil and gas conflict. In this context we situate our discussions of risks and unconventional gas in Australia.

3. Risk, knowledge and unconventional gas

3.1. The ontology of risk

Risk has become omnipresent in the rhetoric of the corporate world, private planning, and many popular pastimes. Viewed from a social scientific perspective, we regard risk as an essentially modern phenomenon that addresses "not *actual* but rather *potential* dangers" [3,p. 8—original emphasis]. It is, however, not merely the assessment of those dangers, but especially the attempts to actively manage them that embeds risk deeply in late modern societies. Risk therefore refers first and foremost to societal negotiations rather than the mere product of calculative rationalizations of potential impacts' likelihood and severity. As such, risks form part of a culturally biased normative system as "a joint product of knowledge about the future and consent about the most desired prospects" [19,p. 5]. Risk may hence be understood in the logic of anticipation as "a systematic way of dealing with hazards and insecurities induced and introduced by modernization itself" ([5,p. 21]; [7,p. 9]; also [27,p. 22]). As we will argue, the concept of induced risk is productive in understanding societal debates about the potential impacts from CSG and other natural resource developments.

Giddens [27,pp. 26–29] elaborates on Beck's thoughts by introducing the distinction between external ('natural') risks, which more or less affect all societies, and manufactured risks, which are predominantly created by human applications of techno-scientific capabilities. In late industrial and highly technological societies, a shift has occurred because "[o]nce the source of safety, science and technology had become the source of risk" [19,p. 10]. For Beck, this shift is typified by the emergence of novel societal relations: the risk society. The key transition relates to prior concerns with the distribution of 'goods', while risk society is driven by the distribution of 'bads', that is risks [20,p. 8]. As noted, however, risks are not objective calculations, but "characterize [. . .] a peculiar, intermediate state between security and destruction, where the *perception* of threatening risks determines thought and action" [6,p. 135—original emphasis]. Fundamentally, then, it is "cultural perception and definition that constitutes risk" (*ibid.*). Similar to Marx's relations of production, the concept of relations of definition is important for Beck to emphasize the contested nature of risk [1,p. 4]. That is, since "the ontology of risk as such does not grant privilege to any specific form of knowledge" (*ibid.*), it becomes important to understand the cultural politics of risk definition.

We therefore argue for a perspective that investigates the socially negotiated processes of risk and knowledge. To do so, we understand knowledge, similarly to risk, not as a static object, but rather as part of ongoing socio-cultural practices of sense-making. This viewpoint entails a deflational concept of knowledge that marks a "shift from thinking about a putative object that a concept could describe to thinking about the practices in which the concept is used" ([56,p. 199]; [57,p. 69]; [60]). Here, knowledge is not regarded as an external static possession, but forms as a 'capacity to act' [67] part of the ongoing (cognitive) acting and being of knowing individuals, who experience and (co-) construct their life worlds (e.g. Ref. [43]).

In the first place, however, members of risk societies face a lack of certainty, especially in light of often multiple and conflicting knowledge claims. As Beck argues, "[l]iving in world risk society means living with ineradicable non-knowing [. . . and] living in the milieu of manufactured non-knowing means seeking unknown answers to questions that nobody can clearly formulate" [7,p. 115]. This is especially evident in contestation about the role of scientific knowledge during contemporary environmental controversies. While the "connection between the language of risk and that of science is intimate" [77,p. 129], science's inability to deliver certainty leads to risks being raised above scientific debates and into the public sphere ([31,p. 62]; [36,p. 34]). As Yearley notes, however, "official agencies are commonly left with no alternative but to demand 'more and better' science; yet there are few grounds for thinking that further steps down the same path will resolve the problems" ([77,p. 138]; also Evensen [22]). We therefore argue that these unsettled debates, clearly emerging also in the context of unconventional hydrocarbon developments, demand a careful, empirically-grounded investigation of the politics of risk, knowledge, and uncertainty.

3.2. Anthropology and coal seam gas

We find the need for in-depth social scientific investigation has so far not been met sufficiently in relation to unconventional gas developments generally, and Australian coal seam gas developments especially. We agree with Willow and Wylie [75,p. 223] that "[w]hile actual and potential environmental degradation resulting from fracking has received a significant amount of scholarly attention [. . .,] sociocultural consequences have been comparatively overlooked". Where these have been investigated, researchers have largely relied on quantitative rather than qualitative enquiries (*ibid.*). In Australia, much exploratory social scientific research on CSG has focused on understanding public perception (e.g. Refs. [35,37]), but some in-depth qualitative work has been published (e.g. Refs. [13–15,24,25,42,46,62,70,72]). This gap in existing social scientific research is problematic, especially because "gas comes with many unknowns" [29,p. 55] that are subsequently enrolled in broad societal debates and "conflicting visions and experiences of rural life", specifically in extractive regions [64,p. 262]. Some of these unknowns of CSG developments, at least initially, "are overwhelming and pertain not just to the projections of impacts but also to methods of trying to discover and validate ways of assessing potential impacts" [52,p. 156]. These concerns, however, emerge not merely around potential impacts on the physical environment, such as groundwater, but span a large spectrum from socio-cultural, to psychological, and health-related issues [15,pp. 44–48]. For example, Cartwright argues that the potential health implications of fracking – what she terms eco-risk- "are terrifyingly complex" and that our "ability to make visible/diagnose/quantify are far behind the questions that we are faced with in this situation . . . [,w]e just don't know" [9,p. 206]. These complex risks and uncertainties remain with some members of the population we engaged with in Australia.

4. Research methods

We address the questions raised above on the basis of ongoing ethnographic fieldwork conducted since 2012 with a broad variety of persons involved in debates about the operational and proposed gas fields along Australia's eastern seaboard. Our primary geographic focus has been the Western Darling Downs region in the southern part of the state of Queensland and the Northern Rivers

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region in the northern part of New South Wales (see Fig. 1 above). While a large-scale CSG industry has been established in the Surat and Bowen Basins of the State of Queensland, the State of New South Wales has only been subject to exploratory activity and a state-wide moratorium on new CSG licences currently limits further developments. To investigate the debates in these regions' gas fields we bring together focused [32], theoretically informed [51], and multi-sited [44] ethnographic approaches.

Among our interlocutors are local landholders with and without gas infrastructure on their properties, town residents, Indigenous people, government, industry and interest group representatives, anti-CSG activists, a variety of natural scientists, gas industry professionals, as well as residents of the urban centres of Toowoomba and Brisbane. As such, we draw on findings from the iterative analysis of approximately 100 semi-structured interviews, participant observations, informal conversations, archival research, and textual analyses of a variety of publicly available documents. While not the main focus, we further include a significant amount of secondary data such as social media videos, blogs, and discussion groups in our analysis. We also keep systematic records of media accounts that emerge in relation the CSG developments in Australia and, to a degree, unconventional hydrocarbon developments internationally.

5. Findings

5.1. Embodied practice, uncertainty and knowledge

Since we do not regard risk exclusively in quantifiable terms but as culturally negotiated normative considerations, debates about risk and uncertainty emerge through, and are informed by, various ways of knowing. We address different forms of risk knowledges and encountered uncertainties by exploring indicative responses from local residents, scientists, and industry representatives. In doing so, we focus especially on how actors come to know CSG and its risks.[1]

Local landholders and residents living in close geographic proximity to CSG developments and infrastructure are immediately confronted with the (potential) impacts of CSG and thus the need to make sense of associated risks. We found that phenomenological or embodied understandings of CSG, through direct sensory experience or via associated environmental changes, play an important part in how actors come to know CSG and its risks. This becomes especially important in light of the 'immateriality' of gas (e.g. Ref. [14,p. 17]), which constrains direct sense-making. Landholders often perceive impacts through the embodied practices of their everyday lives. For example, a woman who lives on a rural property just outside the Immediately Affected Area (IAA)[2] of groundwater impacts has regularly inspected her property's water bore for years. With CSG wells now drilled nearby, she can identify changes in water pressure when the nearby gas wells are operating and when activity is restricted. This led her to question the accuracy of the modelled groundwater impacts, noting her farm was located outside the IAA declared by the State. For other residents, impact knowledge goes beyond engagements with water pressure, and may include a sense of all-encompassing embodied change, varying from agricultural production and domestic activities to new concerns about the composition of air in the region. As a small-scale farmer noted:

> My story is: I moved here seven years ago and spend everything on my house, my farm. I have pigs, I have choocks [i.e. chickens] – everything was really good. Come Christmas time, this Christmas just past, [a gas company] went and drilled a well nearby and, boom, our bore went bad. [. . .] Now the water in my bore is no good to even water crops, so I can't grow crops or grass to feed the animals. . . . This is unbelievable. Just on the top of our bore . . . all the meters, even [the company's meters] read 50 per cent gas coming out the top, methane gas. Now, we can't do anything about it because we don't know what to do, because they told me not to close the bore because it can blow up. So I just leave it open, so everybody else, my next door neighbour, can breathe it in. . . . It comes straight out. . . . We used to bath in it, but we don't bath in it anymore. . . . I don't know what to do. I'm ready to sell and leave.

Some local residents are therefore confronted with uncertainties about the human health impacts of CSG extraction. One landholder explained the bodily experience of CSG and resulting uncertainty in an open letter:

> So I watched my children and my husband (and myself) continue to get sick, the rashes and blood noses started, then the smell wafted in and we had to ask ourselves 'is it the gas', and so the journey began.

Especially among local residents, sense-making of CSG and its risks involves direct and indirect phenomenological experiences – knowing through everyday embodied practices – and coming to terms with the immediacy of new lived uncertainties. However, these uncertainties are not exclusive to local residents but can, albeit in different forms, also be observed among (often external) scientists who investigate the impacts of CSG.

Leaving aside the more fundamental debate about definitions of scientific knowledge, we draw here on responses from natural scientists employed within academia and as independent consultants working on different aspect of CSG developments. One noticeable finding is that among some of these actors, too, knowledge about potential, especially long-term, impacts and risks remains unsettled. For example, many interlocutors working on future groundwater-related impacts noted the heavy reliance on scientific modelling conducted by the State. While usually emphasizing the high and improving quality of the modelling, concerns were frequently raised about the scale of the modelled geographic area, the complexity of hydrogeological and ecological systems, the ambiguities of the modelling process, and the need to understand modelling output as conceptual working tools that are subject to review and improvements over time. One senior academic groundwater scientist explained in response to a question about the exact impacts of CSG developments for local farmers and residents:

> [T]hat's the million dollar question. I still don't think we know definitely and perhaps we never will, but at least the way I see the structure now . . . I think you'll see some very good studies.

However, the scientist noted the political nature of hydrological modelling and scientific research, and referred to the difficulties of obtaining adequate data in the first place.

> [T]he companies are taking water quality samples, levels, doing all sorts of tests for their own commodity, and also trying to

[1] We describe these differentiations in the Weberian sense of ideal types, which is not to say that ways of knowing do not overlap and form complex entanglements in the lived encounters with CSG. Our intention is therefore not to ascribe these responses solely to any one (in itself idealized) actor group and to dissociate these from one another, but rather to draw attention to the existing diverse forms of knowledge emerging in relation to CSG.

[2] The IAA is a modelled geographic area in which bores are predicted to be impacted by groundwater drawdown within the first three years of CSG developments. The impact modelling was conducted by the Queensland State Government in the Brisbane-based Office of Groundwater Impact Assessment (OGIA) and is associated with the declaration of a Cumulative Management Area (CMA) that spans parts of the Surat and Bowen Basins. Landholders with affected bores in the IAA are entitled to so-called Make Good agreements with the tenement-holding CSG company.

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understand their risks, and nobody has that data. Well, the companies have that data and keep that data and they will not release it.

These statements resonate with the account of an independent hydrogeologist who stressed the need to separate modelling from magic[3]:

No, I don't think we've already caught up [with the industry's scale and pace]. But I think they are still working on this. . . . Farmers have got to really take models in blind faith. Because they are never going to understand them. And half the people in the department never understood them . . .. And people didn't realize you've got to update these things. The model isn't magical.

While this account suggests that improvements of the existing model and, crucially, of the public's understanding of the models' output may increase existing knowledge and reduce uncertainties, a senior natural resource management consultant and agricultural scientist was more pessimistic:

There is a fellow at [a university] who has done a significant review of the groundwater models, and [it] basically says there are seven models and none of them agree. But we knew that.

During interviews, scientists frequently emphasized that ambiguities remain and, more fundamentally, that scientific research, knowledge gaps, and uncertainties are inseparable (cf. Ref. [4]). Scientific knowledge, in their view, is ultimately unlikely to provide answers that conclude current risk debates and the public's demand for certainty.

The resulting tension is not merely rooted in the nature of scientific enquiry, but also related to the characteristics of subterranean resource and unconventional gas developments. That is, locating and extracting commercial quantities of oil and gas is inherently imbued with uncertainties, and this is especially so in the case of unconventional gas developments and its subsequent conversion to LNG, which, at the Queensland scale and pace, is a world-wide novelty (e.g. Ref. [34,pp. 42,49 & 57]).[4] How, then, do CSG industry professionals engage with questions related to knowledge, uncertainty, and risk?

Among industry representatives we found such a diversity of concerns and responses that we may speak of different cultures of knowledge and risk, even within companies. For example, a company environmental ecologist described concerns with the company's reservoir engineers' approaches to environmental impacts, but noted that, ultimately, both were secondary to the company's economist who was said to make the important decisions mainly based on cost calculations. For CSG industry professionals, uncertainties, risks, and indeterminacies are omnipresent in their daily work practices and communications. On a macro-level, risks are of course also apparent in the repercussions of the collapse of oil and gas prices throughout 2015, which may lead to some corporate regret about the A$70 billion investment decisions made some years ago. However, for the present purpose we focus primarily on the micro-level and the practices around CSG developments. On the work floor, uncertainties often lead to a tendency to normalize risk and potential unknowns as part of the extraction process. For instance, an experienced groundwater specialist previously employed in a senior company position described the inevitable risks within the industry:

Obviously risk management from a localized event, they [i.e. incidents] are going to happen. You drill 5,000 holes in the ground, something is going to go wrong. It has to, the law of averages is against you. They are human beings doing this. You've got a lot of uncertainties.

While accidents do of course occur in any industry, our intention is to highlight the embeddedness of these uncertainties among industry representatives. This is also evident in the procedures to locate and prove underground gas reserves. Leaving aside the systematic exploratory process of moving from so-called 'found' resources, to 'probable', to 'proven' reserves,[5] a revealing dynamic of uncertainty occurs around the location of so-called 'sweet spots' and 'hit or miss' rhetoric. For example, during a bus tour of one major gas processing facility in the Darling Downs, the leading technical officer noted how wells have their own 'identities', which is to say that some wells produce more gas than others and/or at higher levels for longer periods of time. For the technical officer this was due to some hitting a better spot – the colloquial 'sweet spot' – but the production level of wells did not appear to be easily predictable even within the same gas field.[6]

His account of 'sweet spots' and unpredictable well production and depletion rates resonates strongly with the perspective of a drilling and hydraulic fracturing expert who described the process of well construction. He noted that "there's still a lot of uncertainty about the geological model, but [now] you have more precision in your data stream. . . . [A]s we gain more knowledge, we have more precision". During drilling itself, he explained, uncertainty about the underground geology was not unusual. This means that going back and forth in different directions with the drill head in an attempt to follow the coal seam is a normal procedure. The embeddedness of risk and inexact subterranean knowledge in drilling is even more apparent in some aspects of the subsequent hydraulic fracturing process. Referring to the 'stimulation' of an unlined laterally drilled coal seam gas well, the expert described such fracking operations as a 'spray and pray' process as only limited knowledge and control was available to determine underground effects. Another subterranean uncertainty well-known among drillers is the so-called 'thief zone'. This porous subterranean zone may be hit during the drilling process, leading to an unexpected rapid loss of drilling mud. As for 'sweet spots', however, locating these zones with certainty is difficult.

In summary, during our research among industry professionals we encountered an almost omnipresent engagement with limited knowledge, uncertainty, and risk. However, compared to the concerned responses from, for example, local residents and landholders, these are dealt with by industry professionals as a normal and integral part of the industry's practice. In the following section we examine how these differences play out within the context of wider public risk debates.

5.2. Reading science: pure and polluted

Our findings and analysis of publicly available documents, including media, government and industry reports, reveals that 'science' is used to argue for and against the industry. The different responses to a draft study of hydraulic fracturing and drinking water impacts by the American Environmental Protection Agency

[3] cf. Biersack [8,p. 80] for a contrasting view of geologists and mining technicians held by the Paiela people of Highland Papua New Guinea as the 'shamans of Paiela modernity'.

[4] For example, contrary to the number cited above, at the time of writing, revised forecasts halved estimates to 20,000 wells in Queensland [50,p. 14]. This significant discrepancy in predicted well numbers, however, adds further uncertainties for many residents, as expressed by landholders during a consultation meeting in March 2016.

[5] Explained by a driller.

[6] de Rijke et al. [16] have similarly described knowledge of the peculiarities of subterranean water resources at the farm level among irrigators in the same region.

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(EPA) in 2015 provide a good illustration of the ways in which science is read by different stakeholders. For example, the American proponent website 'Energy from Shale', concluded in a headline that:

> Following a five-year information gathering period, the EPA confirmed what industry experts already knew: Safe hydraulic fracking doesn't threaten our drinking water. The EPA's study results disprove the scaremongering tactics utilized by fracking opponents. The main takeaway from the study can be summarized by a single quote, found in the EPA's draft report: "We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States."

Opponents, however, read the report differently. An American environmental news website, for example, opened its review of the study with the statement that:

> Last week, the U.S. Environmental Protection Agency (EPA) released 1000-plus draft pages of its "Hydraulic Fracturing Drinking Water Assessment." The report took almost five years to produce and essentially tells us (in great detail) what we already knew: Fracking and drinking water are a bad combination. On top of that, the EPA finally admitted that water resources have already been contaminated by fracking: "We found specific instances where one or more mechanisms led to impacts on drinking water resources, including contamination of drinking water wells".[7]

In early 2016, the EPA's own Science Advisory Board, after a review of the draft study, was considering a more nuanced evaluation. A University of California engineering professor and board member, for example, reportedly suggested changes to the conclusion about widespread, systemic impacts, and:

> faulted the document for trying "to draw a global and permanent conclusion about the safety or impacts of hydraulic fracturing at the national level" given the "uncertainties and data limitations described in the report".[8]

We hence observe three very different readings of the same study: the first ignored certain details and highlighted the general conclusion, the second highlighted certain details and ignored the general conclusion, and the third advocated for a better articulation of the relationship between general conclusion and details. The risks associated with uncertainty, thus, are interpreted differently among diverse sectors of society, in this case leaving the scientists in between gas industry proponents and opponents with diagonally opposed readings of the same document.

Perhaps reflecting an acceptance that a focus on science itself is politically ineffective in such cases, proponents may also describe threats to the industry as a risk to national energy security and economic development (e.g. Ref. [46]). For example, in a media release entitled 'Activists campaign against energy security and jobs', the Australian Petroleum Production & Exploration Association – Australia's oil and gas lobby group – claimed that opposition to unconventional gas developments 'is really a campaign against the energy that powers our homes, Australian jobs and investment in our economy'. Among other issues, opponents of unconventional gas developments, however, maintain a strong focus on existing scientific uncertainty and argue for the application of the precautionary principle to halt the industry. Consequently, Australian regulators have found it difficult to act decisively in these circumstances (e.g. Refs. [13,69]). We therefore agree with Williams et al. [73,p. 12] who concluded their study of public perceptions of fracking in the UK with the observation that:

> the fracking problem is not just about the existence of objective risks, nor just about the public's ability to understand them, but also about the institutional ability and willingness to recognise, encounter and accommodate diverse and polyvalent public views, and that broader consideration of possible uncertainties and areas of ignorance, and broader, more plural, deliberation around innovation choices and the social desirability of fracking are justified, necessary and rational.

We have argued that these 'diverse and polyvalent public views' are fundamentally related to the interplay of different ways of knowing and ongoing sociocultural practices of sense-making. On the one hand, we observe a focus on scientific knowledge as pure, universal and reflective of truth, leading to arguments that more science will settle the debate. On the other hand, we find views of science as inherently incomplete and therefore insufficiently reliable for decision-making purposes. This view has gained particular societal traction since the emergence of a phenomenon now commonly referred to as 'frackademia': the asserted usurpation of academic research and intellectual rigour in service of the unconventional hydrocarbon industry (e.g. Ref. [61]). Indeed, diminishing public research funding and a concomitant increase in requests for funding from industry has led to considerable concern about research integrity in Australia generally (e.g. Refs. [38,39]). Leaving aside some of the fundamental questions about the relation between funding and integrity, we argue that in the context of CSG such dynamics have contributed substantially to a public view of science and scientific institutions as potentially 'polluted'.[9] As noted above, the potent sociocultural categories of purity, danger and pollution are important to the unconventional gas and risk debates. The emergence of 'frackademia', in combination with an industry-supportive Australian political economy of 'adaptive management' and the celebration of 'the new gas age' [46], has thus exacerbated tensions to which science itself has no answers. Nevertheless, science remains a central concern in current Australian debates.

Throughout our fieldwork it has become apparent that the debate about CSG has to some degree been 'scientized' (cf. Ref. [59]) with frequent calls for 'science over emotions' by a variety of actors. We therefore agree with Evensen [22] who observes scientized discourses around the regulation of shale gas[10] developments in the United States that, he argues, are characterized by a 'cryptonormativism', or the "tendency of political figures [and actors *per se*] to cloak normative statements with science as a way of justifying their positions" (515). Constructing and stating the 'mere facts' of scientific enquiry suggest a de-politicized and independent claim that is untainted by individual political motivations and agendas and, therefore, more legitimate. Put differently, by referring to the output of distant centres of calculation [33], actors frequently attempt to utilize evidence that is framed as the product of de-politicized, 'placeless expertise' (e.g. Ref. [53]), conforming with the modern discourse of science as pure, value-free, and a 'culture of no culture' (e.g. Refs. [26,45,47]). However, as we have described above, 'pure' and 'polluted' science are inextricably linked sociocultural

[7] http://ecowatch.com/2015/06/15/brune-epa-fracking-report/ (accessed 11.01.16).

[8] http://www.bloomberg.com/news/articles/2016-01-07/the-u-s-epa-called-fracking-safe-now-its-scientists-disagree (accessed 11.01.16).

[9] See Espig and de Rijke [21] for challenges of researching CSG debates, including an anecdote of local reactions as a result of activist perceptions of academic institutions as polluted.

[10] Shale gas is another form of unconventional gas, but similar to CSG in the controversies its development sparks.

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categories ultimately to be negotiated in the broader context of large resource projects and desired futures.

6. Conclusion

In the debates about unconventional gas developments we have observed certain attempts to draw imaginary lines between experts and lay persons to establish legitimacy. These attempts to create authority and legitimize knowledge claims are, of course, intrinsically related to societal power and efforts to influence decision making processes, especially in circumstances of unsettled science and risk debates (e.g. Aitken [2] on wind power planning controversies; Lysaght and Kerridge [40] on stem cell research; Tuckwell [71] on environmental contest in mining developments; and, more generally, Stehr [66]). As we have noted, however, the ontology of risk itself grants no privilege to any specific form of knowledge, such as science over more experiential forms of knowledge. Such privileges are socially and politically negotiated among diverse sectors of society.

The (perceived) risks and uncertainties associated with modelling and subterranean peculiarities faced by scientists, industry professionals and other 'external' experts are, with the exception of on-the-ground drillers, less embodied and physically immediate than those faced by the residents and local landholders in the Queensland gas fields. For example, expert scientists often readily acknowledge the limitations of their models and scientific studies, but also defend them for their value in understanding complex natural processes (e.g. Ref. [4]). However, these uncertainties may lead non-experts who are not accustomed to them to either dismiss those models and scientific projections as 'guess work', with others taking them at face value as established 'facts'. Without necessarily dichotomizing the experts' 'abstracted' experiences of CSG with the 'lived' realities of non-experts – especially local residents and landholders – (cf. Ref. [49]), we nonetheless argue that the latter are confronted daily and unavoidably with uncertainties that impact their immediate surroundings, domestic activities and personal bodies. While differences in knowing risks and dealing with uncertainties therefore clearly exist, both 'external' professionals and 'local' persons confront these in complex and entangled ways, which ultimately undermines the boundaries and levels of legitimate participation some may wish to draw between so-called expert and lay actors.

The differences among various categories of persons in the process of knowing and experiencing risk also contribute to varying levels of demanded certainty about potential impacts. We found that landholders and residents in close geographic proximity to CSG activity generally request a higher level of certainty than 'external' industry professionals and scientists. This demand, however, often stands in contrast to those professionals and scientists' limited ability to satisfactorily deliver such guarantees. Consequently, and perhaps unsurprisingly, unknowns and uncertainties about CSG developments are less readily accepted and normalized by local landholders. However, given the propinquity of some CSG activity to the everyday life-spaces of these residents, combined with the immateriality of gas and perceptions of fracking as potentially leading to 'matter out of place', our findings highlight that risk and knowledge cannot be regarded merely as objective categories and issues best left to knowledgeable 'experts'. Rather, we argue that both concepts must be understood as socio-culturally informed practices of sense-making by those involved. The role of risk and knowledge in resource contests are thus continuously negotiated and, following Douglas [18] and Douglas and Wildavsky [19], subject to cultural sentiments regarding purity and danger, and discursive exchanges over acceptable and desired futures.

Our findings and analyses raise some important issues for unconventional energy developments in contemporary societies. Firstly, negotiating induced risks and existing levels of knowledge of potential impacts forms an intrinsic part of these projects and cannot be avoided by resorting to 'expert' authorities. In fact, our research indicates that ignoring or disregarding lived experiences and expertise as 'lay' frequently reinforces existing power imbalances and spurs controversy. Secondly, an appropriate response to the contingent and processual nature of these negotiations requires a consideration of political dimensions. That is, public and institutional frameworks may productively allow for the articulation and meaningful incorporation of varying accounts. To be clear, creating such spaces will only be fruitful if the authority, legitimacy, and validity of various positions are not solely judged against notions of 'pure' and 'polluted' knowledge. While the emergence of 'frackademia' may limit the public role of some scientific institutions in risk debates, presupposing a form of 'pure' science would also be inconsistent with the view held by a significant number of scientists for whom uncertainty is omnipresent. We therefore, thirdly, caution against a scientization of these discursive exchanges and negotiations, and advocate a critical engagement with the politics of risk and knowledge inherent within them. That is, the management of energy resource projects and other initiatives of significant societal import would be assisted by thorough qualitative research on who regards what at risk, how that is so, and who, and on what basis, is subsequently considered able to legitimately participate in the decision making process (cf. Ref. [65]).

With global energy needs and especially the demand for natural gas predicted to significantly increase over the next two decades [30], unconventional hydrocarbon reserves and extractive fracking technologies may become increasingly important not just in North American and Australia. Given the intense public opposition to these developments in recent years, it is important to understand the social dynamics that occurred in areas with operational projects and the debates that emerged around them. The data on risk and knowledge debates obtained from a variety of actors in the CSG development areas of Queensland, as well as our analysis of publicly available documents regarding such studies as the American EPA fracking and drinking water assessment, provide critical insights into the social complexities and intricacies of relevance to unconventional gas developments generally. Such understandings may contribute to an appreciation and institutional incorporation of the politics of risk and knowledge inherent within new and globally significant energy debates.

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