[redacted]

From: Michael Blockey [redacted]
Sent: Tuesday, 4 April 2017 2:15 PM
To: fracking inquiry
Subject: A submission
Attachments: A ban on fracking will ...doc; Ban fracking and meet our 2030 emissions target.doc

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Hello Mr Chairman
Attached is the following: i) a newspaper article on the effect of a ban on fracking on greenhouse gas (GHG) emissions in 2030. This explains the submission.
ii) a detailed analysis on the effect of a ban on fracking on greenhouse gas (GHG) emissions in 2030
Could you please have someone expert in shale gas and GHGs examine this analysis so that your panel can discuss it.
Many thanks
Dr Michael Blockey MVSc, PhD

Summary and some recommendations

A ban on fracking will substantially reduce Australia's greenhouse gas emissions

by Dr Michael Blockey

A potted history
Hydraulic fracking is needed to extract the unconventional gases (UG), coal seam gas (CSG) and shale gas (SG). Fracking releases the methane. 'Good' methane flows up the gas well. Methane that can't be captured by the gas well I call 'bad' methane. It escapes into the atmosphere and is 34 times more potent as a greenhouse gas (GHG) than CO2. Up until 2011 it was thought that methane leakage ('bad' methane) from SG wells was low,1 to 2% ie 1 to 2% of the methane extracted from a well escapes into the air.

In 2011, however, Howarth found that methane leakage from SG wells was much higher, 5.8%. Eight more studies quickly followed. The average methane leakage in the 9 studies was 5%! These findings threatened the conversion of coal-fired power plants to gas-fired ones. So the SG industry hit back. It wanted to show that methane leakage was not 5%, but 1 to 2%. So it bribed 6 research groups to 'fudge' experiments to prove this, it commissioned 2 'dodgy' literature reviews that concluded that methane leakage was 1 to 2%. It convinced the EPA to 'doctor' its figures. Our CSIRO and CSG companies collaborated in a thoroughly 'fudged' survey in which methane leakage of CSG was a ridiculously low 0.02%.

While this controversy around SG and CSG swirled, studies on conventional gas (CG) continued. CG is extracted by drilling through the 'cap' rock and allowing CG to flow up the well. No fracking is required so methane leakage is low. Ten surveys shows it is 1.9%. And it can be reduced to 1.17% by practical and affordable means.
From all this, we can conclude that CSG/SG has a methane leakage of 5% and the methane leakage of CG is 1.17%, four times lower.

We can use these findings to reduce our GHG emissions. We have pledged to lower our 2030 GHG emissions to 27% below 2005 emissions. Our GHG emissions were 584 million tonnes in 2005. A 27% reduction would see GHG emissions in 2030 dropping by 158 million tonnes compared to 2005. The National Greenhouse Inventory, however, predicts that our 2030 GHGs, instead of being 158 MT less than 2005 levels, will be 566 MT more than 2005 levels in its 'business as usual' model and 286 MT more than 2005 GHG emissions if 'emissions reduction measures' are used.

The investigation and its results
This dire forecast begs the question: were we to extract only CG, and leave CSG/SG in the ground, what would be the reduction in GHGs in 2030? This, of course, means imposing a ban on fracking. Practical? Yes. Whilst we use large tonnages of CSG/SG now, we have vast reserves of CG, sufficient to meet the future needs of the power generation industry, the LNG industry and the manufacturing/residential industries.
I sought to answer this question in an investigation. Inputs used were:
i) CG alone is used in 2005. Its methane leakage was 1.9%. CG in 2030 had a methane leakage of 1.17%. In 2030, the mix of gas used was 63% CSG/SG and 37% CG. This mix has a methane leakage of 3.58%.
ii) growth in gas usage from 2005 to 2030 was predicted to be 0.4% pa in power

generation, 4% p a in LNG production, 0.2% pa in manufacturing and 1% pa in residences.

Sector	GHGs generated in 2005 (in millions of tonnes of CO_2)	GHGs generated in 2030 when there is no ban on fracking	GHGs generated in 2030 when a ban is imposed on fracking	Reduction in GHGs due to the ban on fracking (in millions of tonnes of CO_2)	
Electricity generation	22	69	43	26	
LNG	8	129.2	51	78	
Manufacturing and residential	73	157	51	106	
All sectors	103	355	145	210	

The ban on fracking reduced GHGs produced in 2030 by an amazing 210 million tonnes (Table). There are two ways to look at this.

Firstly, Australia has pledged to lower its GHG emissions from 584 million tonnes in 2005 to 430 MT in 2030. Assume that fracking continues into 2030. In this case, the 210 million tonnes of GHGs generated from CSG extraction with fracking would make up half of the 430 million tonnes of GHGs we pledged to generate in 2030. Let me put this into context. One industry, namely the extraction of CSG using fracking, will produce so much in GHGs, 210 million tonnes, that all the other industries will have to restrict their GHG output to 220 million tonnes for Australia to meet its 2030 pledge of producing 430 million tonnes of GHGs. One could conclude that CSG extraction using fracking is the heaviest polluter in Australia, by a country mile! How would other industries feel about restricting their GHG output to 220 MT, having to invest millions in pollution reduction gear while the CSG miners belch out 210 million tonnes/year and do nothing to lower it? Angry!!

Secondly, the 27% reduction in GHGs on the 2005 level of 584 million tonnes is 158 MT, from 584 to 430 MT. Imposing a ban on fracking will reduce GHG emissions in 2030 by not only 158 MT, the reduction we pledged for **all** Australian GHG emissions, but with 52 MT in surplus (210 less 158=52).
To meet our pledge to reduce GHGs by 27% we will need that 'extra' 52 MT because other industries are expected to fall well short of their target of a 27% reduction. Take transport. Its pledge is to emit 22 MT of GHGs less in 2030. It has no hope of achieving this. Instead, the transport industry will generate 35 MT more in 2030 than in 2005. It will fall short of its target by 57 MT (22+35=57). The 'extra' 52 MT almost covers this shortfall.

Some recommendations on how to have a ban imposed on fracking

1. **CSG activists 'maintain their rage' by continuing to show that fracking damages human and animal health**.
It is state and territory governments that impose a ban on fracking. CSG activists have convinced the Victorian and NT governments to impose a ban /moratorium on fracking. They pointed out that the methane released at fracking is contaminating soil, groundwater and ground level air. They presented evidence that this methane damages human and animal health. As well as outlining these known ill-effects they listed the unknown ill-effects.
There are enough known and unknown ill effects of fracking for the other governments to

adopt the precautionary principle, namely to impose a ban on fracking until it can be proven to do no harm. In this regard, state and territory governments, faced with pressure to impose a ban on fracking, find themself between a rock and a hard place. On the one hand, they want to protect their people from harm. On the other hand, they are somewhat addicted to the royalties the CSG/SG miners pay!
Governments trapped between a rock and a hard place would appreciate a solution that releases them from their discomfort. That solution is to do with GHG emissions from CSG/SG mining and our pledge to reduce GHGs by 27% by 2030.

2. **GHG emissions from CSG/SG mining and our Paris pledge**.
We have pledged to lower our 2030 GHG emissions to 27% below 2005 emissions. Our GHG emissions were 584 million tonnes in 2005. A 27% reduction would see GHG emissions in 2030 dropping by 158 million tonnes compared to 2005. The National Greenhouse Inventory (NGI), however, predicts that our 2030 GHGs, instead of being 158 MT less than 2005 levels, will be 566 MT more than 2005 levels in its 'business as usual' model and 286 MT more than 2005 GHG emissions if 'emissions reduction measures' are used.
It is the states and territories who will be tasked with reducing our GHG emissions. Were they informed that a ban on fracking would lower GHG emissions by 210 million tonnes they would be mightily interested. Look at it from their point of view. All of them would be using some 'emissions reduction measures'. The NGI is predicting they will emit 286 MT **more** than 2005 levels and they are supposed to produce 158 MT **less than** 2005 emissions. This is a shortfall of 444 MT. By banning fracking, thus having no CSG/SG mining in 2030, their GHG emissions are lowered by almost half, 210 compared to 444 MT! This is a most welcome solution!

3. Enlisting the support of other GHG generating industries.
It would be valuable to have other industries on our side as we try to convince state/territory governments to impose a ban on fracking. Such industries are all the ones generating GHGs less the CSG/SG miners. Let's call them the 'majority' industries and the CSG/SG miners the 'minority' industry. One would put the following case to the 'majority' industries:
i) Australia's pledge in Paris was that we would emit 430 MT of GHGs in 2030
ii) the CSG/SG industry will emit 210 MT in GHGs in 2030, leaving the 'majority' industries to restrict their GHG output to 220 MT
iii) the 'majority' industries will need to invest millions in pollution reduction gear to meet their emission target of 220 MT.
iv) while the 'majority' industries are investing heavily to meet their GHG emissions of 220 MT, the CSG/SG miners are doing nothing to lower their GHG emissions
v) in fact, they are being helped by the Federal Department of Environment and Energy (DEE) to do nothing. How?The DEE hasn't the funds to monitor methane levels at CSG/SG gas wells. So, it assumes all gas wells have the same methane leakage. And, instead of the assumed methane leakage being the proven 5%, it uses CSIRO's ridiculously low figure of 0.02%! With this 'arrangement' in place the CSG/SG miners see no need to lower their GHG emissions.
The 'majority' industries, which include the CG miners, will feel angry about this and will want to support the CSG activist organisations as they pressure state/territory governments to impose a ban on fracking.

4. Enlisting the aid of the LNG buyers. Climate change activists like Bill McKibbin have been active in encouraging universities, superannuation funds etc to dispose of their investments in fossil fuel companies. This is called divestment. CSG activists could ask

LNG buyers to practice divestment of a different type. They could ask those buying LNG from Gladstone to insist that their LNG is made from CG, not from CSG. They would have to pay no more for the CG-based LNG. The CSG companies that own the Gladstone plants are unlikely to refuse this request because there is so much LNG around the world that the buyers could easily buy LNG elsewhere.

How would the case to switch to CG-based LNG be put? That the large amount of methane released during fracking makes humans and animals sick. That the 210 MT of CO_2 belched into the atmosphere as a result of fracking is half of the 430 MT Australia has pledged in the Paris agreement, that Australia won't meet its pledge if fracking continues.

Will the LNG buyers be swayed by this argument? Very likely. Oil and gas companies have embraced corporate social responsibility (CSR) much more than other industries. Most accept climate change and wish to do what they can to reduce CO_2 emissions.

If most of the LNG buyers demand CG-based LNG, then CSG production in Queensland and NSW will decline markedly. It may get so low that the Queensland government can impose a ban on fracking with a minimum of jobs lost.

4. Outlining a 'plan' to federal, state and territory governments. The 'plan' is bold**:**

i) impose a ban on fracking. This would close down the CSG/SG gas fields in Queensland, NSW and the NT.

ii) increase the output of CG wells in WA so that this boost in output equals the pre-ban production of CSG in Queensland, NSW and NT. The WA CG fields could cope because their CG reserves are vast.

iii) if the Gladstone LNG plants, mired in debt in 2016, are financially viable in 2030, pipe CG from the Cooper etc Basins in central Australia and Gippsland etc Basins in southern Australia to make LNG at Gladstone. AGL is already piping CG from the Gippsland Basin to Gladstone.

iv) ensure there is enough CG from eastern Australian gas fields for use in power generation, manufacturing and residential uses. This is called domestic reservation. This should overcome the problem of a domestic gas shortage.

A ban on fracking will substantially reduce Australia's greenhouse gas emissions

by Dr Michael Blockey

Farmers and environmentalists, the world over, are strongly opposed to unconventional gas (UG) mining, like shale gas (SG) and coal seam gas (CSG). Their objection is that UG requires hydraulic fracking and fracking results in methane escaping from gas wells into the surrounding soil, groundwater and into the air.

Farmers on agricultural land worry that this methane in the groundwater they are pumping up to irrigate crops could contaminate their crops. They are concerned that the methane-rich water they are pumping to the surface to be used for stock water and household use could affect their health and that of their animals. And they are even more concerned about the air at 'ground level', the air that they and their animals breathe. They worry that if it is 'methane-rich,' it may make them and their animals sick.

In Australia, UG activists have fought to stop UG mining on the basis that it contaminates soil, water and 'ground-level' air. New information reveals that there is a fourth weapon to use in the battle to end UG mining.

Imagine there are three levels being contaminated with escaped methane, namely the soil, the groundwater and moving up, the air at ground level. Move up further and there is the atmosphere. The new information shows that the methane that escapes at fracking, the methane that contaminates the soil, the groundwater, the 'ground-level' air, ends up in the atmosphere.

Once in the atmosphere, methane, a greenhouse gas 34 times more powerful than carbon dioxide, greatly raises the level of greenhouse gases (GHGs). By 2030, Australia has pledged to reduce its GHGs from its 2005 level of 584 to 430 million tonnes (MT), a drop of 158 MT. The National Greenhouse Inventory, however, forecasts our 2030 GHGs to be 716 MT, some 286 MT more than we pledged.

This investigation asks two questions:

i) how much in GHG emissions will CSG/SG mines in Australia belch into the atmosphere in 2030?

ii) if fracking and the mining of CSG/SG is banned, will the GHG emissions 'not generated' be enough to help us meet our pledge to lower GHGs in 2030 by 158 MT?

Extracting natural gas.

Conventional gas (CG)

This is found in sandstone and can be extracted using conventional methods, namely drilling through the 'cap' rock and allowing CG to flow up the well. The methane that flows up the well and is piped away to the power station I call 'good' methane. When burnt, 'good' methane converts to CO_2, a gas with a global warming potential (GWP) of 1. This means that 1 kg of 'good' methane converts to 1kg of CO2.

Unconventional gas (UG)

In Australia and in the US we have two forms of unconventional gas. One is shale gas (SG), the other coal seam gas (CSG). Without fracking, neither can be extracted. Fracking consists of pumping water and sand down the gas well and into the space between the layers of shale/coal seam. The sand remains to keep them apart. The methane that flows up the well and is piped away to the power station is 'good' methane. Methane that can't be captured by the gas well I call 'bad' methane. The water that is pumped into the gas well, so called fracking water, is rich in 'bad' methane. It is forced to the surface and pumped into flow back ponds. 'Bad' methane escapes from these ponds into the air. Methane also gets into the air from leaks from pipe connectors and from the pipes themselves. Once in the air it becomes 'bad' methane. The pipes and connectors in CG extraction also leak. So CG mining does release some 'bad' methane.

The leakage from flow back ponds and pipes/connectors are called point emissions. There is another form of emissions from UG wells. It is called diffuse methane leakage and it comes from faulty well casings, both vertical and horizontal. It travels into overlying soil and groundwater aquifers, then to the surface and from there escapes into the atmosphere. Because it can't be captured by the gas well, diffuse leakage is 'bad' methane.

This next part is crucial! Remember that when 1kg of 'good' methane is burnt to generate power, it converts to 1kg of carbon dioxide (CO_2). Methane that escapes into the atmosphere, 'bad' methane, does not convert into CO_2. It remains as methane. The bad news is that methane in the atmosphere has a GWP of a whopping 34! This means that 1 kg of 'bad' methane escaping into the atmosphere is equivalent to 34 kg CO_2.

With 'bad' methane having such a high GWP it's important that gas extraction produces as little 'bad' methane as possible.

So what is the methane leakage from CG and UG mines? Let's start with CG mines.

Methane leakage from CG mines.

Table 1 shows the results of 10 studies.

Table 1
Methane leakage from conventional gas (CG) mining
(as a % of total gas production)

Study	Methane leakage
EPA (1996)	1.10%
Hayhoe et al (2002)	2.30%
Jamarillo et al (2007)	1.10%
EPA (2010)	2.50%
Howarth et al (2011)	2.30%
Ventakash et al (2011)	2.20%
Stephenson et al (2011)	1.30%
Hultman et al (2011)	2.20%
Burnham et al (2011)	2.60%
Cathles et al (2012)	1.60%
Average of 10 studies	**1.90%**

An average of 1.9% of the total gas production from CG mines escapes into the atmosphere. Can it be reduced by best practice? Yes. The World Resources Institute (WRI) has devised three methods that reduce methane leakage from CG wells by 38%. This would reduce methane leakage in CG mining from 1.9% to 1.17%.

What about UG mines?

Robert Howarth from Cornell was the first to accurately measure methane leakage in shale gas (SG) mines. He found it was 5.8% of the total gas production, much higher than the 1 to 2% previously thought. His pioneering work stimulated a flurry of research on methane leakage. Eight more studies were published in the next 2 years (Table 2). Methane leakage in these studies ranged from 3 to 7%. The average was 5%, close to Howarth's 5.8%.

Table 2
Methane leakage from shale gas mines in the US
(as a % of total gas production)

Author	**Methane leakage**	**How methane leakage were measured**
Howarth et al (2011) **Study 1**	From 3.6 to 7.9%, average **5.8%**	Used EPA data in a bottom-up study
Petron et al (2012) **Study 2**	Only emissions from flowback and venting were measured. This was 2.7% of gas production. However, this is only 55% of all emissions. If all emissions are included, it would be **4.5%**	A top-down study. They collected air samples for atmospheric methane downwind of oil and shale gas wells. Methane and alkane levels downwind of oil and gas wells were 10 times higher than upwind levels. Industry gave them flowback and venting losses of methane. For their analysis they removed all samples downwind of feedlots, NG and propane processing plants and wastewater treatment plants. Some 77% of methane was from gas wells. This amounted to 2.3 to 7.7% , average of 4%**,** of gas production. Top-down studies measure 1.6 times more emissions than bottom-down studies. So 2.7% was the methane leakage had it been a bottom-down study.
Karion et al (2013) **Study 3**	From 6.2 to 11.7%, average of 8.9% The bottom up estimate would have been **4.9%**, the top down estimate of 8.9% divided by 1.8.	A top-down study. Used atmospheric measurements of methane downwind of an oil and gas field in Utah containing 4800 gas wells in a 40 by 60k area. Excluded methane from natural seepage and cattle activities. They knew the gas production of these wells. They calculated that 6.2 to 11.7% of production from the wells was lost in methane leakage.
Miller et al (2013)	Atmosphere over US contains CH4 equivalent to **7 to 8%**	A top-down study. Measured methane in 12,700 samples over 2 years in many parts of the US. They measured anthropogenic methane levels in these parts,

Study 4	of global (US?) methane production Dividing 7.5% by 1.6 gives a bottom-up estimate of **4.7%.**	then excluded estimates of methane derived from natural wetlands, ruminant and population sources to get CH4 levels from gasfields. Atmospheric methane was 7/8% of global (US?) methane production. This is 1.6 times higher than had the study been bottoms-up.
Hughes (2011) **Study 5**	Bottom-up estimate of 6 to 8%, average 7%	Hughes interpreted Skone's data to show that if his inputs were the correct ones, he would have got the same result as Howarth et al: I) emissions same as EPA, namely 3.9 cf 2.4% ii) used the correct gas production, 1.24 cf 3.0 iii) GWP of 105 and 33, not 72 and 25 Combining these 3 would have produced a bottom-up estimate of 7%.
Wennberg et al (2012) **Study 6**	Top-down estimate of methane leakage is 4.25% The bottom-up estimate would be 4.25% divided by 1.5, namely **2.83%**	Top-down study. Measured atmospheric methane in the LA area. Some 89% of methane came from natural gas systems. This comprised 2.5 to 6%, an average of 4.25% of the gas delivered to customers.
Pierschl et al (2013) **Study 7**	Top-down estimate of methane leakage was 4.4%. Divide this by 1.5 to get the bottom-up estimate, namely **2.9%**	Top-down study. Measured atmospheric methane in the LA area. From the total methane measured they attributed much of it to methane leakage from natural gas operations. This amounted to 4.4% of gas produced.
Brandt et al (2013) **Study 8**	Bottom-up estimate of 3.6 to 7.1%, average 5.4%	The EPA bottom-up estimate of methane leakage is 1.8%. Brandt believes this is very much underestimated. It should be 1.8 to 5.4% higher, making it 3.6 to 7.1%, average 5.4%
Caulton et al (2014) **Study 9**	Top-down and bottom-up estimate of 2.8 to 17.3% (the two are the same), with a midpoint of **7%.**	Top-down study. Measured atmospheric methane from an airplane over a 2800 square km area of the Marcellus shale gasfield. Their top-down measures of methane were the same as bottom -up estimates of methane. Some 22 to 67% of the methane they measured came from shale gas wells. Methane emissions were 2.8 to 17.3% of gas production
	Average of 9 studies	**5.00%**

Note that in each of the 9 studies methane leakage is higher than 2.8%. This is highly relevant because work by Alvarez shows that when methane leakage is higher than 2.8%, the GHGs generated by using UG are higher than when coal is used. In short, in all these studies, UG mining was 'dirtier' than using coal, an average of 35% 'dirtier'.

The Empire strikes back!

From about 2000 it was thought that methane leakage from shale gas mining and burning was 1 to 2%. From that figure, it was calculated that shale gas mining and burning generates about 40% less GHGs than burning coal. The belief that shale gas was 40% 'cleaner' than coal led to a rapid transition from coal-fired power stations to gas-fired ones, from 5% gas-fired plants in 2002 to 32% in 2012.

Remember that over the period 2011 to 2014, nine studies were published (Table 2) and they showed that methane leakage from shale gas (SG) mining was not 1 to 2%, but 5%! This means that shale gas is not 40% 'cleaner' than coal. It is 35% 'dirtier'!

The SG industry greatly feared the response of the power generators to this news. Would those who had converted to gas revert to coal? Would those still with coal-fired plants decide to keep using coal?

There are 8,000 power generators in the US. That's 8,000 customers either using natural gas now or contemplating a coal-to-gas conversion. Would this new information see the the SG miners losing all of that enormously lucrative business?

The SG miners decided to do everything they could to discredit the research of Howarth and the 8 other scientists while at the same time commissioning research that created their 'untruth'.They were fighting for their survival. If they needed to resort to lies and deceit, they would. And they did!

They launched a dirty tricks campaign comprising six, carefully planned attacks.

Attack 1 was to bribe six research groups to show that shale gas produced 40% less GHGs than coal. Science has changed since I was a scientist. No longer is the pursuit of truth the objective for all scientists. The aim for many scientists today is to produce the 'untruth' the client has commissioned!

And they delivered on the contract. In four of the six studies they calculated how much lower the lifecycle GHG emissions of shale gas were than those of coal- study 1 (44%), study 2 (39%), study 3 (42%) and study 5 (36%) (Column 3: Table 3). Interestingly, the average was 40%!

Equally interesting is how they achieved these results. Howarth et al used the EPA estimate of fugitive emissions of 3.9% (Column 1: Table 3) In each of studies 1 to 6, they stated they used EPA data. However, only one of them did, study 1 (Column 2:Table 3). The others used methane emissions much lower than the EPA estimates-study 2 (38% lower), study 3 (38% lower), study 4 (59% lower), study 5 (51% lower), study 6 (83% lower) (Column 2:Table 3). Their methane leakage was, on average, 54% lower than the EPA emissions. That's how they got lifecycle GHG emissions of natural gas to be 40% less than those of coal.

This is not science. It's cheating. It is putting into ones' model the inputs that will give the desired result!

Attack 2 came from a scientist stridently supportive of their industry. He was the attack dog paid to find flaws in Howarth's work. There were none!

Attack 3 was to commission a literature review by the Canadian Natural Gas Initiative (CNGI). This is a partnership represented by the Canadian Association of Petroleum Producers, Canadian Gas Association, Canadian Energy Pipeline Association, Canadian Natural Gas Vehicle Alliance and the Canadian Society. The literature was sparse, comprising Howarth's experiment and the six 'dodgy' studies. CNGI's instructions were to show that Howarth had it all wrong, that the long-held belief that SG has 40% lower GHG emissions than coal had been re-affirmed. And, being an industry group, it delivered on its contract!

Table 3
Results of 6 'shonky' studies on methane leakage from shale gas wells

Study	**Methane leakage**	**Lifecycle GHG emissions of shale gas compared to coal**
EPA 2011	3.90%	Not calculated
Hultmann et al (2011) Study 1	3.70% Only 5% lower than EPA figure of 3.9%.	Yet 44% lower than coal A very strange result!
Skone et al (2011) Study 2	2.4%. Some 38% lower than EPA of 3.9%	39% lower than coal
Jiang et al (2011) Study 3	2.4%. Some 38% lower than EPA of 3.9%	42% lower than coal
Cathles et al (2011) Study 4	1.6%. Some 59% lower than EPA of 3.9%	Not calculated
Burnham et al (2011) Study 5	1.9%. Some 51% lower than EPA of 3.9%	36% lower than coal
Stephenson et al (2011) Study 6	0.67%. Some 83% lower than EPA of 3.9%	Significantly lower than coal, no figure given
Average of studies 2 to 6	**1.80%, 54% lower than the EPA figure**	**40.00%**

Shortly after attacks 1,2 and 3 were launched, the results of the 8 studies were published. How did the SG industry respond to this unwelcome news? It launched attacks 4,5 and 6!

Attack 4 was to commission another review of the literature (Brandt et al 2013), with the review to show that methane leakage was much, much lower than 5%. How could the reviewer conjure this conclusion from 8 studies averaging 5% in methane leakage? Easy! He excluded from the review four studies showing high methane leakage. And while he included another three studies with high methane leakage, he dismissed them, saying they were 'unlikely to be representative of typical SG system leakage rates'. There were only two studies the reviewer regarded as 'representative', and surprise, surprise, they were the lowest of the 8 studies.

Attack 5 was to engage in some regulatory capture, the regulator being the EPA. From its sampling of many SG gas wells, the EPA produces estimates of methane leakage in the various stages of SG extraction. Researchers like Howarth used the EPA figures to calculate methane leakage in the gas wells they were studying. The SG industry convinced the EPA that their estimates of methane leakage were too high. It 'pressured' the EPA into halving them. This meant that researchers using EPA estimates in their studies would report methane leakage half of what it really was, an average of 2/3% rather than the actual figure of 5%!

Attack 6 was another attempt to demonstrate that Howarth and others were wrong in saying methane leakage averaged 5%.Two of the industry studies claimed methane leakage was only 0.4 to 0.7%. Howarth exactly replicated these studies and found that methane leakage in his replication was 0.5%. The problem was that to get methane leakage as low as 0.4 to 0.7%, extraction of shale gas would be hopelessly unprofitable! Hung by their own petard?

Dirty tricks from Australian CSG miners

There have been no estimates of methane leakage from SG mines in Australia. But there has been one survey of coal seam gas (CSG) mines. I include it here to show you that CSG miners here are just as dishonest and deceitful as shale gas miners in the US!
When the CSG miners in Australia became aware of Howarth's work in 2012 they launched their own dirty tricks campaign.
The **first** act of deceit was a survey of CSG wells to determine the level of their methane leakage. It was conducted by the CSIRO with the backing of the CSG industry and the Federal Department of the Environment (DE). It was not so much a survey but an attempt to demonstrate that methane leakage was so low it was of no consequence. It found that methane leakage was a ridiculously low 0.02%! Remember the average was 5% in the US. Why was it so low? The 'survey' was 'fudged' in two ways!
Fudge 1 was a strategy that Big Pharma uses, namely measuring only what will give you the desired result. There are 8 phases in CSG extraction (Table 4). The CSIRO workers measured methane leakage in only 2 of them. And these were phases in which they knew fugitive emissions are very low!
Fudge 2 was to abandon the scientific practice of drawing a sample representative of the population. Instead, five CSG companies volunteered their gas wells for this study. They knew which of their gas wells had the lowest methane leakage. And guess what? These were the ones placed on the list submitted to the CSIRO workers!

But why, I hear you ask, would the CSIRO do the study knowing how fatally flawed it was. Because it was held hostage by the DE. When the DE gave it the funds to do the 'survey,' it was on the condition that much needed future funding to CSIRO would be assured only if it found that methane leakage in this 'survey' was very low!

The **second** act of deceit was the CSG miners convincing the DE, the regulator, that CSG wells need not be monitored. Its thinking was that if we aren't being monitored we can spew into the atmosphere as much methane as we like. How did they convince the DE of this? The DE is responsible for monitoring methane leakage from CSG mines. However, it is so starved of funds (intended?) it can't spend money on monitoring. It consulted with the CSG industry and between them they concocted a novel form of monitoring! No monitoring would be done at all! Instead, the DE would assume all CSG mines had a similar methane leakage. And the level of the assumed leakage wouldn't be 5% as 9 very good US studies show. It would be 0.02%, the figure from the 'dodgy' CSIRO work!
Both players in this 'chummy' arrangement were happy. There would be no suspensions of 'dirty' CSG mines so the gas keeps flowing for the CSG miners and the rivers of gold 'runneth' for the government! Only the atmosphere and eventually humanity, suffers!

Table 4
EPA estimates of methane leakage from shale gas mining, from CSG extraction and actual estimates from the CSIRO (2012) study

Source of methane emissions	EPA (2011) estimates for shale gas (SG) mining	Assuming CSG estimates are the same as SG estimates	CSIRO (2012) estimates
Upstream - from flowback - from drill-out -from routine venting and equipment leaks at well site -from liquid unloading and gas processing	 1.3% 0.33% 0.3 to 1.9%, average 1.1% (the 0.3% reflects the best possible technology) 0.3%	 1.3% 0.33% 0.3 to 1.9%, average 1.1% (the 0.3% reflects the best possible technology) 0.3%	 Not measured Not measured 0.02% Not measured
Downstream - from transport, storage and distribution	0.9%	0.9%	Not measured
Total methane emissions	3.9%	3.9%	Not measured

Reducing methane leakage

We know methane leakage can be reduced in CG mining. Can the methane leakage from shale gas mining be reduced from 5% using best possible practice?
No! Remember there are two types of methane leakage from shale gas and CSG wells, point emissions and diffuse emissions.
Point methane leakage comes from point sources such as flow back ponds. Flow back is rich in methane and it makes sense for the SG miners to harvest it. Howarth says that this is too expensive for SG miners to do so it isn't done.
Diffuse methane leakage comes from faulty well casings, both vertical and horizontal. It travels into overlying sediments and groundwater aquifers, then to the surface and from there into the atmosphere. Nothing can be done to reduce this considerable leakage.
There is also a non-technical reason why methane leakage from CSG mines can't be reduced. Most of the CSG miners are climate deniers. They don't believe that the 'bad' methane they are spewing into the atmosphere is doing any harm. So why should they even try to reduce their methane leakage?

From all this, we can conclude that CG miners can lower their methane leakage from 1.9% to 1.17% and that SG miners have a methane leakage of 5% and can't or won't reduce it any further!
That's more than four times more methane leakage from shale gas mining as from CG extraction, 5% compared to 1.17%.

Translating methane leakage into GHG production

Put yourself in the shoes of a power generator trying to decide whether to use CG or SG/CSG in his furnaces. He isn't familiar with the concept of methane leakage. So the fact that SG/CSG has more than four times the methane leakage of CG doesn't mean much to him. He is, however, familiar with GHG production because he paid carbon tax from 2012 to 2014 on his GHG production.
So we need to convert methane leakage to GHG production. When we do, we find that because SG/CSG mines have 4+ times the methane leakage of CG mines, they produce an astounding 92% more GHGs than CG mines! Let me show you.
Say a CG well produces 100 kg of 'good' methane. When this is burnt, it generates 100 kg of CO_2. A CG well producing 100 kg of 'good' methane also releases 1.17 kg of 'bad' methane into the atmosphere. With methane having a GWP of 34, 1.17 kg is equivalent to 40 kg of CO_2. When 'good' and 'bad' methane are mixed in the atmosphere, their total GHG content is 140kg of CO_2.
Let's do the same exercise with SG/CSG. Say a SG/CSG well produces 100 kg of 'good' methane. When this is burnt it generates 100 kg of CO_2. A SG/CSG well producing 100 kg of 'good' methane also releases 5 kg of 'bad' methane into the atmosphere. With methane having a GWP of 34, 5 kg is equivalent to 170 kg of CO_2. When 'good' and 'bad' methane are mixed in the atmosphere, their total GHG content is 270 kg of CO_2.
And what is the GHG production of coal? Take 100 kg of coal. Coal is carbon-dense so when it is burnt this 100 kg produces 200 kg of CO2.
In summary, CG produces 140 kg of GHGs, coal produces 200 kg, some 42% more than CG in GHGs and shale gas/CSG are the 'superpolluters' spewing out 270 kg of GHGs, some 35% more than coal and a massive 92% more than CG (Figure 1).

SG/CSG 270 kg | **COAL** 200 kg | **CG** 140 kg

35% more than coal | 42% less than coal

92% more than SG/CSG

Figure 1. Coal produces 42% more GHGs than CG and SG/CSG generates 92% more GHGs than CG.

How can we use these findings for the good of humanity?

By replacing harmful UG with harmless CG we can reduce global GHG emissions. This would help keep the rise in the atmospheric temperature to below 2 degrees and, as a result, minimise climate change.
There are many industries in which UG can be replaced with CG, namely the power industry, the LNG industry, manufacturing and the domestic gas industry. It's all very well to say replace UG for CG in these industries, but do we have enough CG to do so? Let's examine these three industries to answer that question

Has Australia enough CG to replace UG with CG

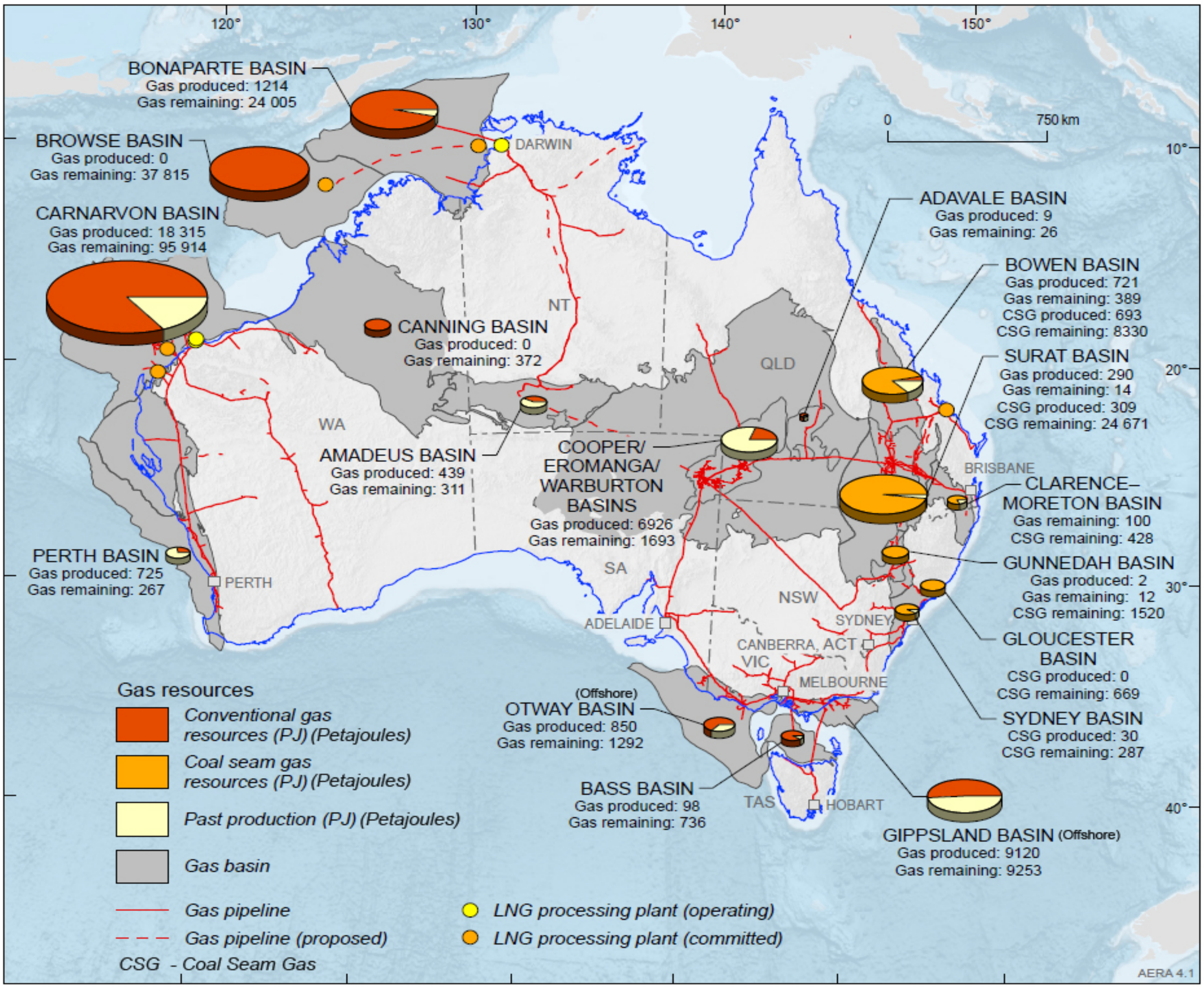
Replacing UG with CG in power generation

By 2030 it is forecast that 27% of our power will be generated in gas-fired plants. But do we have the CG reserves to replace CSG/SG with CG? Yes!
There are many large deposits of CG in Australia, namely the Otway, Bass and Gippsland Basins in southern Australia and the Cooper, Eromanga and Warburton Basins in central

Australia (Figure 1). And there is a network of gas pipelines taking CG from these deposits to the population centres (Figure 1). In WA there is a gas pipeline from the huge deposits of CG in the Bonaparte,Browse and Carnavon Basins to Perth and towns in the south west corner (Figure 1)

Figure 1

Pipelines and Major Producing areas in Eastern Australia



Replacing UG with CG in the LNG industry

Some countries have no natural gas and import it from countries like Russia, the US and Australia. To enable natural gas to be exported it is converted into liquid natural gas (LNG) by cooling it to minus 162 Celsius. This process reduces its volume by a factor of 600, similar to reducing a beach ball to the size of a ping pong ball. This allows natural gas to be transported efficiently by sea. When the LNG reaches its destination it is unloaded from ships at import terminals where it is stored as a liquid until it is warmed back to natural gas. The natural gas is sent through pipelines for distribution to power stations, businesses and homes.

When returned to its gaseous state it is used for the same purposes as natural gas, namely power generation, residential uses, manufacturing and heavy-duty vehicles.

LNG is made from both UG (shale gas,CSG) and CG. Because UG generates 92% more GHGs than CG, it makes sense to make LNG from CG only, not from UG.

But, again, is there sufficient CG to produce the the huge tonnages we will be exporting in the future? Let's examine this question. First, some history. Up until 2015 all of the LNG we exported was made from CG extracted from the North West Shelf in northern WA. And there are vast CG deposits to make the large volumes of LNG expected to be exported in 2030.

Now seven LNG plants are being constructed at Gladstone, Queensland and UG, specifically CSG, is being used to make that LNG. A certain set of events, however, could see the Gladstone plants making LNG from CG rather than from CSG. The CSG companies that are building the 7 LNG plants at Gladstone were in deep financial trouble in 2016 and market forces may end their UG mining. They have invested $70 billion in building these large LNG plants. So heavy is their investment, so high are their costs of extracting CSG and so low is the price they expect to receive for their LNG, three analysts believe their LNG venture is doomed.
So high are their costs of extraction? It is 75% more expensive to extract UG than to mine CG. Low price? When they signed the contracts with Asian LNG buyers, the oil price was high, $100/barrel, and thus LNG prices were high, $12/PJ. Now the oil price has crashed to $50/barrel and LNG prices are $6/PJ. The LNG buyers want to renegotiate the gas price to half of the contracted price.
There are three possible outcomes. First, If the CSG companies refuse to renegotiate, the LNG buyers will default on the contract and buy LNG from Russia and the US. In this scenario, the LNG plants would cease to operate and the CSG mines supplying them, 50% of their CSG mines, would be closed down.
The second scenario is that the LNG buyers are made aware by CSG activists that CSG mining produces 92% more in GHGs than CG mining. Say they are climate change 'believers' and, as a result, want to reduce GHG emissions. They resolve to buy LNG made from the gas generating the least GHGs, namely CG. They put the following proposition to the CSG companies in the Gladstone LNG plants: we will buy LNG from your plants, in preference to other plants, but it must be CG-based LNG, not CSG-based LNG. If the CSG miners agree to this proposal, the LNG plants keep operating but 50% of the CSG mines close down!
In the third outcome, the CSG companies don't agree to proposal 2. In this case, the LNG plants would cease to operate and the CSG mines supplying them would be closed down. The CSG companies have to accept proposal 2, namely to make LNG from CG. Otherwise, $70 billion investment in 7 LNG plants sends them broke!

Replacing UG with CG in miscellaneous industries

Natural gas has other uses other than in power generation and LNG production. They are residential (home heating and cooking) and manufacturing a wide variety of goods. Of all its uses in Australia, power generation uses 31% of all gas extracted, LNG production uses 19% of the 'gas cake', manufacturing accounts for 32% of gas used and residential uses account for 11% of the 'gas cake'.
With the vast resources of CG Australia has, there is enough CG to use CG only in these miscellaneous industries.

Two more reasons to replace UG with CG

The first is that it is 75% more expensive to extract UG than CG. The second is that UG mining harms humans and animals and CG extraction does not.

More expensive

There are two costs in extracting CG and UG. The first is the cost of the actual mining, the

second is the carbon tax.
A study (Energy Quest 2014) of 25 Australian gas basins, 9 UG and 16 CG, shows that average cost per petajoule of producing gas from the 9 CSG basins was 63% higher than in the 16 CG basins, 7.05 cf 4.3. There are two reasons UG extraction is more expensive. First, it is expensive to frack. And second, many, many wells must be sunk in CSG field when few are required in a CG gas field. Tellingly, Don Voelte, Woodside CEO did not take his company into CSG extraction because, for these two reasons, it was 'a tough gas' to mine.
When the carbon tax or an ETS is eventually introduced it will be levied on the GHG production from CSG and CG mines. Specifically, it will be levied on the methane leakage. So what will this tax be for CSG miners? It will be $21 for every $133 of 'good' methane produced. That's a 15.8% tax.
For CG miners the carbon tax will be much less, $5 for every $133 of CG extracted. This is a 3.7% tax.
The difference is 12.1%. Add this 12.1% higher cost of production due to the carbon tax to the 63% higher cost of extracting CSG compared to mining CG and we find that CSG mining is 75% higher in cost of production than CG mining.
In my view, this 75% higher cost of production will bring down CSG/SG extraction!

Harmful to humans and animals

It is fracking that harms humans and animals. “Bad' methane, the methane that cannot be captured by the pipe into the gas well, escapes into the soil around the gas well and then into the groundwater. This is diffuse methane leakage. People living in gas fields tap into this groundwater contaminated with methane. They use it for drinking water, for showering and for cooking. They suffer burning of the nose, throat and eyes, headaches, dizziness, nosebleeds, vomiting, diarrhoea and rashes! Livestock also suffer from drinking well water heavily contaminated with methane. They 'wither away' and die and others abort.
There is another form of methane emissions, those from flow back ponds. This flow back water, heavily contaminated with methane, sometimes escapes into stockwater. In one case, 60 cows, a treatment group, drank this water; 21 died and 16 became infertile. Another group of 36 cows on the same farm, a control group, drinking uncontaminated water remained healthy and fertile.
These are the 'known harms'. There are many 'unknowns harms'. Like, does the milk and meat of cattle grazing pastures irrigated with methane-contaminated water contain residues of methane? Do vegetables, fruit and crops irrigated with this contaminated water contain residues of methane? If so, are these residues harmful to humans?
Then there is the 'ground level' air breathed by humans and animals. Is the methane in this 'ground level' air harmful to humans and animals? There is anecdotal evidence that it is, but no experimental evidence.

Four strong reasons

So we have four good reasons to replace UG with CG, namely i) UG extraction produces 92% more GHGs than CG mining, ii) we have enough CG in Australia to replace all of the UG used at present, iii) UG extraction is 75% more costly than CG mining and iv) UG extraction, because it requires fracking, is harmful to human and animal health.
Two forces will hopefully see UG being replaced by CG. One is market forces, the other is public protest.

Market forces

The first example is two large UG gas basins, Surat and Bowen in Queensland (Figure 1). The CSG companies that are building the 7 LNG plants at Gladstone source their CSG from these basins. As discussed,they are in deep financial trouble and market forces may

end their UG mining.
The second example is the Gunnedah gas field (Figure 1). This is the site of a fascinating battle between Santos and farmers/environmentalists (Table 5). Santos has seen two other CSG companies, AGL and Metgasco, driven out of CSG mining in NSW by public protest. It is determined that won't happen to them. So it contributed $558,000 of election funds to the NSW Liberal party on the condition it enacted anti-protest laws that make it illegal to 'hinder' the operations of a CSG company. Premier Baird did as he was told and now 'hindering' could land a protester in jail for 7 years or be fined $5,500.These laws make it difficult for protesters to have the success they enjoyed in the past. Round 1 to Santos!
Enter the EEFA. It looked closely at the economics of the Gunnedah CSG mines and predicted that market forces will make Santos abandon this project. Round 2 and the fight to EEFA and the farmers/environmentalists.

Public protest
The demise of UG mining by market forces happens without activists having to lift a finger. Public protest, as the phrase suggests, requires great effort.
Public protest in Australia takes two forms. The **first** is protest directed at a CSG company. Protests against AGL caused it to abandon CSG mining in the Sydney Basin, at Camden and St Peters in Sydney, and at Gloucester, north west of Sydney (Figure 1,Table 5). Public protests at Bentley, near Lismore, forced Metgasco to stop extracting CSG there (Table 5).

A potted history of the war on CSG and shale gas mining

Gasfield	**Methods successfully used to end CSG mining**	**Methods that might end CSG mining**
Victoria	Public protest leading to a ban on fracking, state-wide and permanent	
Northern Territory	Public protest leading to a temporary ban on fracking, territory-wide	Submissions to the enquiry and public protests needed to persuade the NT government to make the ban on fracking permanent.
Surat/Bowen		Market forces likely to close down 50% of CSG mining.
Sydney	Public protest forced AGL out	
Gloucester	Public protest forced AGL out	
Bentley	Public protest forced Metgasco out. Moratorium on fracking in the north east region of NSW	
Gunnedah		Market forces will make Santos abandon the Gunnedah project.

The **second** form of public protest aims to convince governments to ban fracking or impose a moratorium on fracking. The thinking behind this is that it is the fracking used in UG mining that causes UG extraction to release so much 'bad' methane into the atmosphere. So, if fracking is banned, UG mining ceases and 'bad' methane is no longer spewed into the atmosphere.

The ban/moratorium on fracking can be regional or state-wide, temporary or permanent. The New South Wales government imposed a moratorium on exploration using fracking in the north east region of NSW as a result of Metgasco pulling out of Bentley.
The difference between a ban and a moratorium? The first is permanent, the second is temporary.
Victoria has in March 2017 banned fracking permanently over the whole state (Table 5). Victoria has little UG mining so little money in the form of royalties is paid by UG miners into Treasury. Little public protest was needed to convince the Victorian government to ban fracking.
The situation in the Northern Territory is very different. It has large deposits of shale gas in four gas fields, McArthur, Beetaloo, Georgina and Amadeus. The royalties from these fields when they are producing will be substantial. A very strong public protest was needed to have UG mining banned. And a strong protest there was. Lock the Gate coordinated a continuing public protest under the banner of 'Frack-free NT'. This galvanised the people to the extent that the Opposition Labor party pledged to temporarily ban fracking if it won office. This pledge was considered to be a contributor to its landslide win in the August 2016 election. An enquiry into fracking is being held. Those who want the ban on fracking to be made permanent are concerned Labor may find a way of lifting the ban!

An examination of Table 5 reveals two things. First, we will have to wait for market forces to close down 50% of CSG mines in Queensland and the remaining large CSG mine in NSW. Second, it reveals that farmers/environmentalists have done well in their battles with CSG miners. They have forced the miners to end their operations at Camden, St Peters, Gloucester and Bentley and to convince governments in Victoria and the NT to ban fracking.
These wins,however, are simply milestones along the way in the journey to end UG mining! There is one last, huge, mountain to climb to permanently end UG mining in Australia. It is to have all states and territories ban fracking!
How can we persuade them to do that?

Convincing the states/territories to ban fracking

I suggest a two pronged approach.
Prong 1 is the approach anti-CSG activists have successfully used against the miners. It is to show governments that methane released at fracking is contaminating soil, groundwater and ground level air. They would make the following points:
i) people living in gas fields tap into this groundwater contaminated with methane. They use it for drinking water, for showering and for cooking. They suffer burning of the nose, throat and eyes, headaches, dizziness, nosebleeds, vomiting, diarrhoea and rashes.
ii) livestock also suffer from drinking well water heavily contaminated with methane. They 'wither away' and die and others abort.
Iii) fracking water from flowback ponds sometimes spills into the drinking water of cattle. In one case, 60 cows, a treatment group, drank contaminated water; 21 died and 16 became infertile. Another group of 36 cows on the same farm, a control group, drinking uncontaminated water remained healthy and fertile.
These are the 'known harms'. There are many 'unknowns harms':
iv) like, does the milk and meat of cattle grazing pastures irrigated with methane-contaminated water contain residues of methane?
v) do vegetables, fruit and crops irrigated with this contaminated water contain residues of methane? If so, are these residues harmful to humans?
vi) is the methane in the 'ground level' air harmful to humans and animals?

There are enough known and unknown ill effects of the fracking essential in CSG/shale

gas mining for governments to adopt the precautionary principle, namely to impose a ban on fracking.
How can we convince state and territory governments to impose such a ban? A state government faced with pressure to impose a ban on fracking finds itself between a rock and a hard place. On the one hand, it wants to protect its people from harm. On the other hand, it is somewhat addicted to the royalties the CSG/SG miners pay!
Governments trapped between a rock and a hard place would appreciate a solution that releases them from their entrapment. Such a solution is prong 2!

Prong 2
The solution is to do with Australia meeting its pledge made to the Paris Agreement, the pledge that we will lower our carbon emissions so that, by 2030, they are 26/28% below our emissions in 2005. The National Greenhouse Inventory demonstrates that we will be generating much more GHGs in 2030 than we did in 2005. Its 'business as usual model' predicts we will produce 992 million tonnes in GHGs in 2030, some 562 MT more than the 430 MT we have pledged to emit. Even with 'emission reduction measures' in place, we will produce far more than we have pledged. We have pledged to generate 430 MT in 2030, yet with these measures in place we will produce 712 MT, 282 MT short of our reduction target.
State and territory governments are the ones tasked with meeting that seemingly impossible target. Is there something substantial they can do, something they have not yet considered, to reduce their GHG emissions? Yes, they can impose a ban on fracking, the thinking being that no fracking means no UG mining, no spewing of methane into the air.
As I outlined earlier, gas is used in three industries, namely electricity generation, LNG production and the manufacturing and residential use industries.
Let's start with the power generation industry, testing the hypothesis that a ban on fracking would substantially reduce the greenhouse gas (GHGs) emissions from that industry.

Hypothesis 1– a ban on fracking will substantially reduce GHG emissions from power generation

Step 1 – what were the GHG emissions in 2005?

From data published by the Bureau of Resources and Energy Economics (BREE 2014) I determined the electricity generation in 2005. It was 229 Terawatt hours (TWh). Some 182 TWh (79%) came from coal, 40TWh (17%) from gas and 7TWh (4%) came from renewables (Table 6)
How much in GHGs were produced from this coal and gas?
Coal: every KWh of power generated from burning coal produces 0.99 kg of CO_2 (US EIA 2014) So 182TWh generated from using coal produces 180 billion kg or 180 million tonnes.
Gas: every KWh of power generated from burning gas produces 0.55 kg of CO_2 (US EIA 2014.) This is the figure for CG, the only gas to be used in 2005. Little or no fracking was done in Australia in 2005. So 40 TWh generated from using gas produces 22 billion kg of GHGs or 22 million tonnes.
The renewables (hydro, wind, solar) produce no GHGs.
So the GHG emissions from electricity generation in 2005 were 202 (180+22=202) million tonnes.

Step 2 – what were the GHG emissions in 2030?

Let's calculate the amount of electricity generated from the use of coal, gas and

renewables. Predicting power generation 13 years into the future is difficult so it is not surprising that the predictions vary greatly. Predictions were made in 3 studies (Table 6). All forecast that coal would make up 40+% of the energy mix, much less than its 79% contribution in 2005 (Table 6). It was in the mix of gas and renewable energy that the three varied. One believed gas usage would rise to 40% (from 25% now) and renewables would rise to only 17% of the mix (Table 6). Another said that gas usage would decline to 15% while renewables would jump to 37% in 2030 (Table 6).
I have averaged the three predictions of the energy mix in 2030. It is 44% coal, 27% gas and 29% renewable energy (Table 6). And the power generation in 2030 is 292 TWh, with 126 TWh from burning coal, 79 TWh from gas and 83 TWh from wind, solar and hydro (Table 6)

Table 6
Contribution of coal, gas and renewables to power generation in 2005 and 2030

Study	Year	Power generated from burning coal (% in brackets)	Power generated from burning gas (% in brackets)	Power generated from renewable energy (RE) (% in brackets)	Power generated from coal, gas and RE
BREE (2014)	2005	182 TWh (79%)	40 TWh (17%)	7 TWh (4%)	229 TWh
BREE (2014)	2030	134 TWh (43%)	126 TWh (40%)	54 TWh (17%)	314 TWh
McKinsey Australia and Energy Insights (2016)	2030	131 TWh (48%)	41 TWh (15%)	101 TWh (37%)	282 TWh
Blockey in 2016	2030	114 TWh (41%)	70 TWh (25%)	95 TWh (34%)	279 TWh
Average	2030	126 TWh (44%)	79 TWh (27%)	83 TWh (29%)	292 TWh

How much in GHG emissions was produced by generating 126 TWh from burning coal and 79 TWh from the use of gas?
Coal: every KWh of power generated from burning coal produces 0.99 kg of CO_2 (US EIA 2014) So 126 TWh generated from using coal produces 124.74 billion kg or **124.74 million tonnes.**
Gas: by 2030 both CSG/shale gas and CG will be used. There is, however, no published information on the proportions of CSG/SG and CG that will be used in 2030. It seems reasonable to assume that the proportions used in 2030 will reflect the reserves of CSG/SG and CG available then. I have calculated the reserves in 2016 which I assume will reflect the reserves in 2030 (Table 6). Those reserves will be 63% CSG/SG and 37% CG (Table 6). We know that every KWh of power generated from burning CG produces 0.55 kg of CO_2 (US EIA 2014.) We also know from Figure I that the mining and burning of CSG generates almost twice as much in GHGs, 1.93, than the extraction and burning of CG (270 divided by 140 equals 1.93). So if every KWh of power generated from using CG produces 0.55 of CO_2, then every KWh of CSG/SG produces 1.062 kg of CO_2 (1.93 by 0.55= 1.062). And how much CO_2 will a mixture of 63% CSG/SG and 37% CG produce? It will be 87.3 million tonnes (63 by 1.062 plus 37 by 0.55 divided by 100 = 87.3).

So every KWh of power generated from the use of the 63%/37% mixture of CSG/SG and CG will produce 0.873 kg of CO2.
Knowing how much GHGs are produced from burning a mix of 63% CSG/SG and 37% CG, namely 0.873 per KWh, we can calculate how much in GHGs the generation of 79 TWh produces. It is 79 by 0.873, 69 billion kg or **69 million tonnes**
The total GHG production from using coal and gas to generate power in 2030 is 124.74 plus 69 million tonnes. This equals **193.74 million tonnes.**

Table 6
Natural gas reserves in Australia in 2016

State/territory	**Basin**	**CG, CSG or shale gas**	**Reserves in petajoules**
WA	Bonaparte, Browse,Carnarvon	CG	158000
Victoria	Otway, Bass , Gippsland	CG	11290
South Australia/Qld	Cooper, Eromanga, Warburton	CG	1700
Queensland	Bowen, Surat, Clarence/Morton	CSG	33760
New South Wales	Gunnedah, Gloucester, Sydney	CSG	2350
Northern Territory	Amadeus, Beetaloo, McArthur, Georgina	Shale gas	257276
		Total CG reserves (as a % of all reserves)	171,700 (37%)
		Total CSG and shale gas reserves (as a % of all reserves)	293,386 (63%)

Remember that Australia has pledged to emit 27% less GHG emissions in 2030 than we did in 2005. Our GHG emissions from power generation in 2005 were 202 million tonnes. And our 2030 GHG emissions were 194 million tonnes. We reduced GHG emissions from power generation by only 4%, not by the 27% we pledged in Paris.

Can our GHG emissions from power generation in 2030 be reduced by banning fracking? Yes. We would use only CG instead of a mix of 63% CSG/SG and CG. We would use a gas that produces 0.55 kg of CO2 instead of a gas emitting 0.873 kg of CO2. Instead of 79 TWh producing 69 million tonnes of CO2 when a mix of 63% CSG/SG and 37% CG was used, this 79 TWh emit 43 million tonnes of CO2, a reduction of 26 million tonnes.

Hypothesis 2– a ban on fracking will substantially reduce GHG

emissions from LNG production

Step 1 – what were the GHG emissions, in 2005, produced from mining the gas from which LNG was made

First, we need to know how much LNG was exported from Australia in 2005. It is 12 million tonnes of LNG (BREE 2013: WA Department of Trade 2014). It all came from Western Australia. Queensland had just started CSG extraction in 2005. Therefore, the 12 million tonnes was all made from CG. To make 12 million tonnes of LNG we need 16.56 billion cubic metres of CG (1 million tonnes LNG needs 1.38 billion cubic metre of gas). 1333 cubic metres of CG weighs 1 tonne. So 16.56 cubic metres will weigh 12.42 million tonnes (16.56 billion divided by 1333=12.42 million tonnes).

Note that there are 3 processes in LNG production, the mining of CG, compressing the CG into LNG, converting from LNG to CG so that the CG can be burnt. When we export the LNG for use overseas we don't burn it here, we don't produce any GHGs here from burning. The GHGs that are emitted into our sky come from mining CG.

What GHGs are produced in mining CG? Table 1 tells us it is 1.9% of the output from CG wells. The World Resources Institute has devised ways of reducing methane leakage from CG wells by 38%. But in 2005 those methods were not yet devised. The methane leakage in 2005 would have been 1.9%.

So, if CG wells were extracting 12.42 million tonnes of CG in 2005 how much methane would have escaped into the atmosphere? It would have been 0.236 million tonnes (1.9% of 12.42 = 0.236). This is equivalent to 8.02 million tonnes of CO2 (0.236 by 34= 8.02)

Step 2 – what were the GHG emissions, in 2030, produced from mining the gas from which LNG was made

First, how much LNG do we expect to export in 2030? We know what we exported in 2015, 24 million tonnes. WA contributed 15, Queensland 8 million tonnes and the NT 1 million tonnes (Table 8). BREE (2014) and the Department of Industry in the Reserve Bank (2014) predict a tripling of LNG exports from 24 MT in 2015 to 85 MT in 2019. This huge increase of 7/8% p a is expected to happen at all three hubs (Table 8).

Predicting the growth in LNG exports is as difficult as predicting power generation in 2030. One of the 2 studies (BREE 2014) says that growth from 2019 to 2030 will be 2.6% in WA, 6.7% in Qld and 4% in the NT. Another report predicts growth in LNG exports to be 2.2%, 2.7% and 3.1% in WA, Qld and NT, respectively (BREE 2013).

Table 8

Expected tonnages of LNG to be exported from WA, Qld and the NT

	LNG exports in 2015 (million tonnes)	Expected LNG exports in 2019 (million tonnes)	Growth in LNG exports from 2015 to 2030 (million tonnes)	Expected LNG exports in 2030 (million tonnes)
Western hub (WA)	15	43	2.4% p.a	55.8
Eastern hub (Qld)	8	35	4.7% p a	58
Northern hubs (NT)	1	7	3.6% p a	10.3
All 3 hubs	24	85		124

The average of both studies is 2.4% in WA, 4.7% in Qld and 3.6% in the NT (Table 8). The

expected LNG exports in 2030 from WA, Qld and the NT are expected to be 55.8, 58 and 10.3 million tonnes, respectively (Table 8). These three hubs, between them are expected to produce 124 million tonnes of LNG (Tables 8 and 9).
To make 124 million tonnes of LNG we need 171 billion cubic metres of gas (Table 9). The conversion is 1 million tonnes LNG needs 1.38 billion cubic metre of gas. This gas weighs 128.5 million tonnes (divide 1.38 billion cubic metres by 1333).
The 60 million tonnes of gas comes from Queensland is CSG. The methane leakage from mining CSG/SG wells is 5% of the gas flow (Table 9). This flow of 60 million tonnes would release 3 million tonnes of methane which is equivalent to 102 million tonnes of CO2 (Table 9).

Table 9
Calculating the CO2 emissions from mining gas in the three LNG export hubs

Hub	Expected LNG exports in 2030 (million tonnes) (1)	Volume of gas to produce this LNG (billions cubic metres) Multiply (1) by 1.38 to get (2)	Weight of this volume of gas (million tonnes) Divide (2) by 1333 to get (3)	Type of gas used to make LNG and its methane leakage (as a %) (4)	Methane leakage from mining the gas (in million of tonnes) Multiply (4) by (3) to get (5)	This methane leakage expressed in CO2 equivalents (in million tonnes) Multiply (5) by the GWP of 34
WA	55.8	77	58	CG (1.17%)	0.68	23.1
Qld	58	80	60	CSG (5%)	3	102
NT	10.3	14	10.5	CG (1.17%)	0.12	4.1
All hubs	124	171	128.5			129.2 million tonnes of CO2

Some 68.5 million tonnes used to make LNG in WA and NT was CG (58 million tonnes from WA and 10.5 million tonnes from NT: Table 9). CG has a methane leakage of 1.17% (Table 9). So the methane leakage from the WA and NT gas wells would be 0.68 and 0.12 million tonnes, respectively (Table 9), the equivalent of 23.1 and 4.1 million tonnes, respectively (Table 9) in CO2 emissions.
Mining CG at all three hubs would generate 129.2 million tonnes of CO2 in 2030 (102+23.1+4.1=129.2).

Can our GHG emissions from mining gas for LNG production in 2030 be reduced by banning fracking? Yes. The 128.5 million tonnes of gas, a mixture of CSG and CG, generated 129.2 million tonnes of CO2 (Table 9). Had fracking been banned no CSG would have been available. We would have access to CG only. The 128.5 million tonnes of CG would generate 1.504 million tonnes of methane. This is equivalent to 51 million tonnes of CO2.
So, using CG instead of CSG to make the 124 million tonnes of LNG we expect to export in 2030 reduces GHG emissions from LNG production from 129.2 to 51.1 million tonnes, a drop of 78 million tonnes.

Hypothesis 3– a ban on fracking will substantially reduce GHG emissions from gas used in manufacturing and residences

Natural gas has other uses other than in power generation and LNG production. They are residential (home heating and cooking) and manufacturing a wide variety of goods. In 2005 manufacturing used 36% of the gas extracted and residential uses accounted for 12% of the gas mined.

Step 1 – what were the GHG emissions, in 2005, produced from mining the gas used for manufacturing/residential use?

In 2005, 426 PJ of gas was used in manufacturing. Another 142 PJ was used in residences. Using a conversion factor of 1PJ equals 200,000 tonnes, 426 PJ becomes 85.2 million tonnes and 142 PJ becomes 28.4 million tonnes. Together, they total 113.6 million tonnes.

In 2005 the gas extracted was CG. CSG mining had barely begun in Queensland then. Methane leakage then would have been 1.9%. The World Resources Institute has devised ways of reducing methane leakage from CG wells by 38%. But in 2005 those methods were not yet devised.

So, if CG wells were extracting 113.6 million tonnes of CG in 2005 how much methane would have escaped into the atmosphere? It would have been 2.16 million tonnes (1.9% of 1113.6=2.16). This is equivalent to 73.4 million tonnes of CO_2 (2.16 by 34=73.4)

Step 2 – what will be the GHG emissions produced from mining the gas used for manufacturing and residential uses in 2030?

There are three predictions of the growth of gas usage in manufacturing from 2005 to 2030. The first, an industry prediction (Gas Today 2008), forecasts the gas usage to grow at 8.6% p.a. This, I believe, is wildly optimistic. I rejected it The second estimate is based on the population growth from 2005 to 2030. Since most of our manufacturing is devoted to producing goods for domestic consumption, I assume that gas usage in manufacturing will grow at the same rate as population growth, namely 1% p.a. The third prediction, a 0.2% p.a growth from 2005 to 2030, is based on the assumption that Australia will continue to export much of its manufacturing to China (Ibis World 2017).

I believe the third prediction of growth in gas usage from 2005 to 2030, namely 0.2% per annum. By 2030, gas usage in manufacturing would have risen from 85.2 to 92.8 million tonnes.

Gas usage for residential purposes would be expected to grow at the same rate as population increase, namely 1% p.a. So gas will have increased from 28.4 to 36.4 million tonne. This is also the increase in gas used for residential purposes in the report 'Energy use in the Australian residential sector 1986 to 2020'.

Gas used for manufacturing and for residential purposes will be 129.2 million tonnes (92.8+36.4 =129.2)

How much in GHGs would be produced in mining 129.2million tonnes? In 2030 the gas extracted will be a mixture of 63% CSG/SG and 37% CG. CSG/SG mining has a methane leakage of 5% while CG extraction has methane leakage of 1.17%. A 63%/37% mix of CSG and CG will have methane leakage of 3.58%((0.63% by 5%= 3.15) plus (0.37% by 1.17%= 0.43, 3.15 + 0.43 =3.58%). The methane leakage from the 129.2 million tonnes of the mixture will be 4.626 million tonnes (129.2 by 3.58%=4.626). This is equivalent to 157.3million tonnes of CO_2.

(Table 10).

To what extent will a ban on fracking reduce CO_2 emissions from manufacturing and

residential use in 2030? We would use only CG, with a methane leakage of 1.17% instead of a 63/37 mixture of CSG/SG that has a methane leakage of 3.58%. With 100% of gas wells having methane leakage of 1.17% their actual methane leakage would be 1.512 million tonnes of methane, (129.2 by1.17=1.512). This is the equivalent to 51.4 million tonnes of CO2 (1.514 by 34= 51.4). This is 105.9 million tonnes of CO2 less than the 157.3 MT the 63/37 mixture of CSG and CG generated (Table 10).
So a ban on fracking would reduce the CO2 emissions from manufacturing/residential uses of gas by 105.9 million tonnes, from 157.30 to 51.4 million tonnes.

By how much will a ban on fracking reduce GHG emissions from the gas extraction industry in 2030?

We know that the gas the miners will supply to its users in 2030 will generate 355 million tonnes of GHGs, made up of 69 MT from power generation, 129 MT from LNG production and 157 MT from manufacturing and residential uses (Table 10).

Table 10

The reduction in GHG emissions in 2030 due to imposing a ban on fracking, by sector

Sector	Gas used in 2005 (in millions of tonnes)	GHGs generated in 2005 (in millions of tonnes of CO2)	Gas used in 2030 (in millions of tonnes)	GHGs generated in 2030 when there is no ban on fracking	GHGs generated in 2030 when a ban is imposed on fracking	Reduction in GHGs due to the ban on fracking (in millions of tonnes of CO2)	
Electricity generation	Gas was 17% of the mix in power generation	22	Gas will be 27% of the mix in power generation	69	43	26	
LNG	12.4	8	128.5	129.2	51	78	
Manufacturing and residential	113.6	73	129.2	157	51	106	
All sectors		103		355	145	210 (59%)	

Were CSG/SG not mined because of a ban on fracking, methane leakage would drop substantially from 3.58% to I.17%. The reduction in GHGs produced should be substantial. And indeed it is! The ban on fracking reduces GHGs produced in 2030 from 355 to 145 MT, by a hefty 59%, by 210 million tonnes (Table 10).

Two stories

From this figure of 210 MT come two stories. In the 'no fracking' story, fracking has been banned by 2030 and no CSG/SG is mined in Australia. The result is a reduction of 210 MT in GHGs emitted in 2030. In the 'fracking' story, fracking has not been banned in 2030. The CSG/SG mined then will generate 210 MT in GHGs.
Let's put the 'no fracking' story into the context of our pledge in Paris to lower our GHGs by 27%, from 584 million tonnes in 2005 to 430 MT in 2030. That 27% reduction equals 158 MT. That 158 MT reduction is supposed to come from **all** industries. Yet, by banning

fracking, the gas extraction industry, on its own, has lowered its output of GHGs by much more than 158 MT. It has lowered it by 210 MT, 52 MT more than our pledge of 158 MT. That 'extra' 52 MT can be used to help other industries meet their pledge of a 27% reduction in GHGs. Take transport. Its pledge is to emit 22 MT of GHGs less in 2030. It has no hope of achieving this. Instead, the transport industry will generate 35 MT more in 2030 than in 2005. It will fall short of its target by 57 MT (22+35=57). The 'extra' 52 MT almost covers this shortfall.

The 'fracking' story also has as its backdrop our pledge to lower our GHG emissions from 584 million tonnes in 2005 to 430 MT in 2030. Say fracking continues into 2030. The fracking and CSG extraction will generate 210 million tonnes of GHGs. This output of GHGs is almost half of the 430 million tonnes of GHGs we pledged to generate in 2030, 210 out of 430. Let me put this into context. One industry, namely the extraction of CSG using fracking, will produce so much in GHGs, 210 million tonnes, that all the other industries will have to restrict their GHG output to 220 million tonnes for Australia to meet its 2030 pledge of producing 430 million tonnes of GHGs. One could conclude that CSG extraction using fracking is the heaviest polluter in Australia, by a country mile!
This a shocking fact. But it is one we can use to convince other industries to support our bid to have a ban imposed on fracking. How? The answer is presented in the next section (Some thoughts..).

Some thoughts on campaigning to have a ban imposed on fracking

1. **CSG activists 'maintain their rage' by continuing to show that fracking damages human and animal health**. It is state and territory governments that impose a ban on fracking. CSG activists have convinced the Victorian and NT governments to impose a ban /moratorium on fracking. They pointed out that the methane released at fracking is contaminating soil, groundwater and ground level air. They presented evidence that this methane damages human and animal health. As well as outlining these known ill-effects they listed the unknown ill-effects.
There are enough known and unknown ill effects of fracking for the other governments to adopt the precautionary principle, namely to impose a ban on fracking until it can be proven to do no harm. In this regard, state and territory governments, faced with pressure to impose a ban on fracking, find themself between a rock and a hard place. On the one hand, they want to protect their people from harm. On the other hand, they are somewhat addicted to the royalties the CSG/SG miners pay!
Governments trapped between a rock and a hard place would appreciate a solution that releases them from their discomfort. That solution is to do with GHG emissions from CSG/SG mining and our pledge to reduce GHGs by 27% by 2030.

2. **GHG emissions from CSG/SG mining and our Paris pledge**. We have pledged to lower our 2030 GHG emissions to 27% below 2005 emissions. Our GHG emissions were 584 million tonnes in 2005. A 27% reduction would see GHG emissions in 2030 dropping by 158 million tonnes compared to 2005. The National Greenhouse Inventory (NGI), however, predicts that our 2030 GHGs, instead of being 158 MT less than 2005 levels, will be 566 MT more than 2005 levels in its 'business as usual' model and 286 MT more than 2005 GHG emissions if 'emissions reduction measures' are used.
It is the states and territories who will be tasked with reducing our GHG emissions. Were they informed that a ban on fracking would lower GHG emissions by 210 million tonnes they would be mightily interested. Look at it from their point of view. All of them would be using some 'emissions reduction measures'. The NGI is predicting they will emit 286 MT **more** than 2005 levels and they are supposed to produce 158 MT **less than** 2005 emissions. This is a shortfall of 444 MT. By banning fracking, thus having no CSG/SG

mining in 2030, their GHG emissions are lowered by almost half, 210 compared to 444 MT! This is a most welcome solution!

3. Enlisting the support of other GHG generating industries. It would be valuable to have other industries on our side as we try to convince state/territory governments to impose a ban on fracking. Such industries are all the ones generating GHGs less the CSG/SG miners. Let's call them the 'majority' industries and the CSG/SG miners the 'minority' industry. One would put the following case to the 'majority' industries:
i) Australia's pledge in Paris was that we would emit 430 MT of GHGs in 2030
ii) the CSG/SG industry will emit 210 MT in GHGs in 2030, leaving the 'majority' industries to restrict their GHG output to 220 MT
iii) the 'majority' industries will need to invest millions in pollution reduction gear to meet their emission target of 220 MT.
iv) while the 'majority' industries are investing heavily to meet their GHG emissions of 220 MT, the CSG/SG miners are doing nothing to lower their GHG emissions
v) in fact, they are being helped by the Federal Department of Environment and Energy (DEE) to do nothing. How?The DEE hasn't the funds to monitor methane levels at CSG/SG gas wells. So, it assumes all gas wells have the same methane leakage. And, instead of the assumed methane leakage being the proven 5%, it uses CSIRO's ridiculously low figure of 0.02%! With this 'arrangement' in place the CSG/SG miners see no need to lower their GHG emissions.
The 'majority' industries, which include the CG miners, will feel angry about this and will want to support the CSG activist organisations as they pressure state/territory governments to impose a ban on fracking.

4. Enlisting the aid of the LNG buyers. Climate change activists like Bill McKibbin have been active in encouraging universities, superannuation funds to dispose of their investments in fossil fuel companies. This is called divestment. CSG activists could ask LNG buyers to practice divestment of a different type. They could ask those buying LNG from Gladstone to insist that their LNG is made from CG, not from CSG. They would have to pay no more for the CG-based LNG. The CSG companies that own the Gladstone plants are unlikely to refuse this request because there is so much LNG around the world that the buyers could easily buy LNG elsewhere.
How would the case to switch to CG-based LNG be put? That the large amount of methane released during fracking makes humans and animals sick. That the 210 MT of CO2 belched into the atmosphere as a result of fracking is half of the 430 MT Australia has pledged in the Paris agreement, that Australia won't meet its pledge if fracking continues. Will the LNG buyers be swayed by this argument? Very likely. Oil and gas companies have embraced corporate social responsibility (CSR) much more than other industries. Most accept climate change and wish to do what they can to reduce CO2 emissions.
If most of the LNG buyers demand CG-based LNG, then CSG production in Queensland and NSW will decline markedly. It may get so low that the Queensland government can impose a ban on fracking with a minimum of jobs lost.

4. Outlining a 'plan' to federal, state and territory governments. The 'plan' is bold**:**
i) impose a ban on fracking. This would close down the CSG/SG gas fields in Queensland, NSW and the NT.
ii) increase the output of CG wells in WA so that this boost in output equals the pre-ban production of CSG in Queensland, NSW and NT. The WA CG fields could cope because their CG reserves are vast.
iii) if the Gladstone LNG plants, mired in debt in 2016, are financially viable in 2030, pipe CG from the Cooper etc Basins in central Australia and Gippsland etc Basins in southern

Australia to make LNG at Gladstone. AGL is already piping CG from the Gippsland Basin to Gladstone.
iv) ensure there is enough CG from eastern Australian gas fields for use in power generation, manufacturing and residential uses. This is called domestic reservation.This should overcome the problem of a domestic gas shortage.

Summary

Australia has pledged to restrict its greenhouse gas (GHG) emissions in 2030 to 430 mT. We have no chance of meeting this pledge. Official predictions are that GHG emissions in 2030 will be 716 mT, 286 mT more than our pledge.

Is there a 'magic bullet' we can 'pull out of a hat' to meet that shortfall of 286 mT? There is! We can ban fracking, and with it, the extraction of unconventional gas (UG). The investigation described in this document shows that banning fracking and extracting conventional gas (CG) only instead of a mix of UG and CG, lowers GHG emissions in 2030 by 210 mT!

The reason why a ban on fracking so dramatically reduces GHG emissions is four-fold:

i) 5% of the gas (methane) extracted in UG mining escapes into the atmosphere.

ii) only 1.17% of the methane extracted in CG mining goes into the atmosphere,

iii) UG mining has 4 times more methane leakage than CG mining, 5% compared to 1.17%, because fracking must be used in UG mining and it isn't in CG mining,

iv) methane is a highly potent GHG so a small rise in methane leakage, say from 1.17 to 5%, greatly boosts GHG emissions.

This investigation looked at the four industries using natural gas, namely power generation, LNG production, manufacturing and the residential industry. It calculated how much gas (UG and CG) each was predicted to use in 2030 and the GHGs each would emit, assuming fracking continues. Then it calculated, for each industry, how much CG would be used in 2030 and the GHGs emitted on the basis that fracking was banned. Imposing a ban on fracking lowered the GHGs generated in 2030 from 355 to 145 mT, a drop of 210 mT.

States and territories will have the task of restricting GHG emissions in 2030 to an impossibly low 430 mT. They can't meet that target. They can if they ban fracking. Because the ban wers GHG emissions by 210 mT, it will reduce the shortfall of 286 mT to 76 mT.

This ban on fracking solves another problem states and territories have, one that places them between a rock and a hard place. On the one hand, they know that fracking and UG mining are harmful to humans and animals and that they have a duty of care to protect their health.On the other hand, they are somewhat addicted to the royalties the UG companies pay them.

Imposing a ban on fracking, they will come to realise, solves their two problems. First, it ends UG mining, greatly reducing methane leakage from gas extraction, the methane that is harmful to humans and their animals. Second, banning fracking and ending UG extraction would lower GHG emissions in 2030 by 210 mT. This reduces the shortfall of 286 mT by 210 mT.

Imposing a ban on fracking, of course, leaves Australia dependent on CG. Do we have enough to supply these four industries? Yes! The Carnarvon Basin in WA has enough CG to supply the LNG industry for 150 years. And the Browse and Bonaparte basins in WA, along with the Bass Straight and Cooper Basins in the eastern states, can supply the power generation, manufacturing and residential industries in the eastern states for 75 years. And exploration will no doubt unearth more CG basins in the future.

All up, no UG will be needed!

Lastly, will the powerful UG industry exert so much political pressure that imposing a ban on fracking will not be possible? Public protest in Victoria, NSW and the NT has weakened the UG lobby and in Queensland, market forces are driving the UG miners toward bankruptcy. In short, the UG miners will be so weak in a few years, that they will not mount a strong challenge to a ban on fracking.

A ban on fracking sees us meeting our 2030 GHG emissions target

Introduction

Natural gas is used for power generation, for the production of liquid natural gas (LNG), for manufacturing and for residential purposes. When gas (methane) is extracted from deep in the ground, not all of it goes up the gas pipes. Some of it escapes into the soil and groundwater around the gas wells and from there it enters the atmosphere. This is called methane leakage.

Methane leakage is four times higher in unconventional gas (UG) extraction than in conventional gas (CG) extraction, 5% compared to 1.17%. This is because in UG mining fracking is used and it isn't in CG extraction.

These figures of 5% and 1.17% for methane leakage seem small. In practice, they aren't because once in the atmosphere each molecule of methane is equivalent, as a greenhouse gas (GHG), to 34 molecules of CO2. In short, a small amount of methane acts like a large amount of CO2. And the amount of CO2 emitted is our measure of greenhouse gas (GHG) emissions.

Australia has pledged to reduce our GHGs to 430 million tonnes (mT) per year by 2030. The National Greenhouse Inventory predicts we will fall well short of this. It says we will be generating 716 mT/year, some 286 mT more than our pledge of 430 mT.

Fracking causes huge tonnages of methane to enter the atmosphere. Were governments to impose a ban on fracking, would we meet our pledge of 430mT of GHGs in 2030, would we meet this shortfall of 286 mT?

Yes! If we continue 'business as usual', namely extracting UG using fracking and extracting CG without fracking as well, we would generate 355 mT of GHGs in 2030. Were we impose a ban on fracking and extracted only CG, the GHG production in 2030 would drop from 355 to 145 mT, a drop of 210 mT. This reduction of 210 mT would enable us to almost meet the shortfall of 286 mT!

The investigation described here shows:

i) that methane leakage in CG extraction averages 1.17%

ii) that methane leakage in UG mining averages 5%

iii) that the UG industry bribed scientists to conduct 'dodgy' experiments/surveys showing that methane leakage from UG mines was 1 to 2%.

iv) that a ban on fracking will substantially reduce GHGs generated in power generation, in LNG production, in manufacturing and in residential use

v) that the UG miners will stoutly defend fracking but will be defeated by a combination of public protest and market forces.

vi) that we have sufficient reserves of CG in Australia to meet our needs in LNG production for 150 years and our domestic needs for 75 years.

Extracting natural gas.

Conventional gas (CG)

This is found in sandstone and can be extracted using conventional methods, namely drilling through the 'cap' rock and allowing CG to flow up the well. The methane that flows up the well and is piped away to the power station I call 'good' methane. When burnt, 'good' methane converts to CO_2, a gas with a global warming potential (GWP) of 1. This means that 1 kg of 'good' methane converts to 1kg of CO2.

Unconventional gas (UG)
In Australia and in the US we have two forms of unconventional gas. One is shale gas (SG), the other coal seam gas (CSG). Without fracking, neither can be extracted. Fracking consists of pumping water and sand down the gas well and into the space between the layers of shale/coal seam. The sand remains to keep them apart. The methane that flows up the well and is piped away to the power station is 'good' methane. Methane that can't be captured by the gas well I call 'bad' methane. The water that is pumped into the gas well, so called fracking water, is rich in 'bad' methane. It is forced to the surface and pumped into flow back ponds. 'Bad' methane escapes from these ponds into the air. Methane also gets into the air from leaks from pipe connectors and from the pipes themselves. Once in the air it becomes 'bad' methane. The pipes and connectors in CG extraction also leak. So CG mining does release some 'bad' methane.
The leakage from flow back ponds and pipes/connectors are called point emissions. There is another form of emissions from UG wells. It is called diffuse methane leakage and it comes from faulty well casings, both vertical and horizontal. It travels into overlying soil and groundwater aquifers, then to the surface and from there escapes into the atmosphere. Because it can't be captured by the gas well, diffuse leakage is 'bad' methane.
This next part is crucial! Remember that when 1kg of 'good' methane is burnt to generate power, it converts to 1kg of carbon dioxide (CO2). Methane that escapes into the atmosphere, 'bad' methane, does not convert into CO2. It remains as methane. The bad news is that methane in the atmosphere has a GWP of a whopping 34! This means that 1 kg of 'bad' methane escaping into the atmosphere is equivalent to 34 kg CO2.
With 'bad' methane having such a high GWP it's important that gas extraction produces as little 'bad' methane as possible.
So what is the methane leakage from CG and UG mines? Let's start with CG mines.

Methane leakage from CG mines.

Table 1 shows the results of 10 studies.

Table 1
Methane leakage from conventional gas (CG) mining
(as a % of total gas production)

Study	Methane leakage
EPA (1996)	1.10%
Hayhoe et al (2002)	2.30%
Jamarillo et al (2007)	1.10%
EPA (2010)	2.50%
Howarth et al (2011)	2.30%
Ventakash et al (2011)	2.20%
Stephenson et al (2011)	1.30%
Hultman et al (2011)	2.20%
Burnham et al (2011)	2.60%
Cathles et al (2012)	1.60%
Average of 10 studies	**1.90%**

An average of 1.9% of the total gas production from CG mines escapes into the atmosphere. Can it be reduced by best practice? Yes. The World Resources Institute (WRI) has devised three methods that reduce methane leakage from CG wells by 38%. This would reduce methane leakage in CG mining from 1.9% to 1.17%.

What about UG mines?

Robert Howarth from Cornell was the first to accurately measure methane leakage in shale gas (SG) mines. He found it was 5.8% of the total gas production, much higher than the 1 to 2% previously thought. His pioneering work stimulated a flurry of research on methane leakage. Eight more studies were published in the next 2 years (Table 2). Methane leakage in these studies ranged from 2.66 to 7%. The average was 5.05%, close to Howarth's 5.8%.
This table needs explanation. Howarth et al (2011) used EPA data to measure methane leakage. This is called a bottom-up study. Most of the subsequent studies of methane leakage were top-down, namely air samples of methane were collected in the atmosphere. Top-down measurements are known to be 1.6 times those in bottom-up studies. Top-down measures of methane leakage in these studies have been converted to bottom-up measures by dividing top-down measures by 1.6.

Table 2
Methane leakage from shale gas mines in the US
(as a % of total gas production)

Author	**Methane leakage as if it was measured in a bottom-up study**	**How methane leakage were measured**
Howarth et al (2011) **Study 1**	**5.8%**	Used EPA data in a bottom-up study
Petron et al (2012) **Study 2**	**4.5%**	A top-down study. They collected air samples for atmospheric methane downwind of oil and shale gas wells. Methane and alkane levels downwind of oil and gas wells were 10 times higher than upwind levels. Industry gave them flowback and venting losses of methane. For their analysis they removed all samples downwind of feedlots, NG and propane processing plants and wastewater treatment plants. They found that 77% of methane was from gas wells. This amounted to 2.3 to 7.7% , average of 4%**,** of gas production. However, these were only the emissions from flow back and venting. Such emissions comprise 55% of all the emissions from gas wells. All of the emissions would have been 7.3% of gas production (4% divided by 55% =7.3%). Top-down studies measure 1.6 times more emissions than bottom-down studies. So 7.3% in a top-down study would be 4.5% had it been a bottom-down study.

Karion et al (2013) **Study 3**	**5.6%**	A top-down study. Used atmospheric measurements of methane downwind of an oil and gas field in Utah containing 4800 gas wells in a 40 by 60k area. They excluded methane from natural seepage and cattle activities. They knew the gas production of these wells. They calculated that 6.2 to 11.7%, average 8.9% of production from the wells was lost in methane leakage. The bottom up estimate would have been 5.6%, the top down estimate of 8.9% divided by 1.6.
Miller et al (2013) **Study 4**	**4.7%**	A top-down study. Measured methane in 12,700 samples over 2 years in many parts of the US. They measured anthropogenic methane levels in these parts, then excluded estimates of methane derived from natural wetlands, ruminant and population sources to get CH4 levels from gasfields. Atmospheric methane was 7/8% of global (US?) methane production. This is 1.6 times higher than had the study been bottoms-up. Dividing 7.5% by 1.6 gives a bottom-up estimate of 4.7%.
Hughes (2011) **Study 5**	**7%**	Hughes interpreted Skone's data to show that if his inputs were the correct ones, he would have got the same result as Howarth et al: I) emissions same as EPA, namely 3.9 cf 2.4% ii) used the correct gas production, 1.24 cf 3.0 iii) GWP of 105 and 34, not 72 and 25 Combining these 3 would have produced a bottom-up estimate of 7%.
Wennberg et al (2012) **Study 6**	**2.66%**	Top-down study. Measured atmospheric methane in the LA area. Some 89% of methane came from natural gas systems. This comprised 2.5 to 6%, an average of 4.25%, of the gas delivered to customers. The bottom-up estimate would be 4.25% divided by 1.6, namely 2.66%
Pierschl et al (2013) **Study 7**	**2.75%**	Top-down study. Measured atmospheric methane in the LA area. From the total methane measured they attributed much of it to methane leakage from natural gas operations. This amounted to 4.4% of gas produced. Divide this by 1.56 to get the bottom-up estimate, namely 2.75%.
Brandt et al (2013) **Study 8**	**5.40%**	The EPA bottom-up estimate of methane leakage is 1.8%. Brandt believes this is very much underestimated. It should be 1.8 to 5.4% higher, making it 3.6 to 7.1%, average 5.4%
Caulton et al (2014) **Study 9**	**7.00%**	Top-down study. Measured atmospheric methane from an airplane over a 2800 square km area of the Marcellus shale gasfield. Their top-down measures of methane were the same as bottom -up estimates of methane. Some 22 to 67% of the methane they measured came from shale gas wells. Methane emissions were 2.8 to 17.3% of gas production, with a midpoint of 7%. This was the same as a bottom-up estimate.
Average of 9	**5.05%**	

studies		

The Empire strikes back!

From about 2000 it was thought that methane leakage from shale gas mining and burning was 1 to 2%. From that figure, it was calculated that shale gas mining and burning generates about 40% less GHGs than burning coal. The belief that shale gas was 40% 'cleaner' than coal led to a rapid transition from coal-fired power stations to gas-fired ones, from 5% gas-fired plants in 2002 to 32% in 2012.
Remember that over the period 2011 to 2014, nine studies were published (Table 2) and they showed that methane leakage from shale gas (SG) mining was not 1 to 2%, but 5%! This means that shale gas is not 40% 'cleaner' than coal. It is 35% 'dirtier'!
The SG industry greatly feared the response of the power generators to this news. Would those who had converted to gas revert to coal? Would those still with coal-fired plants decide to keep using coal?
There are 8,000 power generators in the US. That's 8,000 customers either using natural gas now or contemplating a coal-to-gas conversion. Would this new information see the the SG miners losing all of that enormously lucrative business?
The SG miners decided to do everything they could to discredit the research of Howarth and the 8 other scientists while at the same time commissioning research that created their 'untruth'.They were fighting for their survival. If they needed to resort to lies and deceit, they would. And they did!
They launched a dirty tricks campaign comprising four, carefully planned attacks.

Attack 1 was to bribe six research groups to show that shale gas produced 40% less GHGs than coal. And they delivered on the contract. In four of the six studies they calculated how much lower the lifecycle GHG emissions of shale gas were than those of coal- study 1 (44%), study 2 (39%), study 3 (42%) and study 5 (36%) (Column 3: Table 3). Interestingly, the average was 40%!
Equally interesting is how they achieved these results. Howarth et al used the EPA estimate of fugitive emissions of 3.9% (Column 1: Table 3) In each of studies 1 to 6, they stated they used EPA data. However, only one of them did, study 1 (Column 2:Table 3). The others used methane emissions much lower than the EPA estimates-study 2 (38% lower), study 3 (38% lower), study 4 (59% lower), study 5 (51% lower), study 6 (83% lower) (Column 2:Table 3). Their methane leakage was, on average, 54% lower than the EPA emissions. That's how they got lifecycle GHG emissions of natural gas to be 40% less than those of coal.
This is not science. It's cheating. It is putting into ones' model the inputs that will give the desired result!

Attack 2 was to commission a literature review by **t**he Canadian Natural Gas Initiative (CNGI). This is a partnership represented by the Canadian Association of Petroleum Producers, Canadian Gas Association, Canadian Energy Pipeline Association, Canadian Natural Gas Vehicle Alliance and the Canadian Society. The literature was sparse, comprising Howarth's experiment and the six 'dodgy' studies. CNGI's instructions were to show that Howarth had it all wrong, that the long-held belief that SG has 40% lower GHG emissions than coal had been re-affirmed. And, being an industry group, it delivered on its contract!
Shortly after attacks 1 and 2 were launched, the results of the 8 studies were published. How did the SG industry respond to this unwelcome news? It launched attacks 3 and 4!

Attack 3 was to commission another review of the literature (Brandt et al 2013), with the review to show that methane leakage was much, much lower than 5%. How could the reviewer conjure this conclusion from 8 studies averaging 5% in methane leakage? Easy! He excluded from the review four studies showing high methane leakage. And while he included another three studies with high methane leakage, he dismissed them, saying they were 'unlikely to be representative of typical SG system leakage rates'. There were only two studies the reviewer regarded as 'representative', and surprise, surprise, they were the lowest of the 8 studies (studies 6 and 7 in Table 2).

Table 3
Results of 6 'shonky' studies on methane leakage from shale gas wells

Study	Methane leakage	Lifecycle GHG emissions of shale gas compared to coal
EPA 2011	3.90%	Not calculated
Hultmann et al (2011) Study 1	3.70% Only 5% lower than EPA figure of 3.9%.	Yet 44% lower than coal A very strange result!
Skone et al (2011) Study 2	2.4%. Some 38% lower than EPA of 3.9%	39% lower than coal
Jiang et al (2011) Study 3	2.4%. Some 38% lower than EPA of 3.9%	42% lower than coal
Cathles et al (2011) Study 4	1.6%. Some 59% lower than EPA of 3.9%	Not calculated
Burnham et al (2011) Study 5	1.9%. Some 51% lower than EPA of 3.9%	36% lower than coal
Stephenson et al (2011) Study 6	0.67%. Some 83% lower than EPA of 3.9%	Significantly lower than coal, no figure given
Average of studies 2 to 6	**1.80%, 54% lower than the EPA figure**	**40.00% less than coal**

Attack 4 was to engage in some regulatory capture, the regulator being the EPA. From its sampling of many SG gas wells, the EPA produced estimates of methane leakage in the various stages of SG extraction. Researchers like Howarth used the EPA figures to calculate methane leakage in the gas wells they were studying. The SG industry convinced the EPA that their estimates of methane leakage were too high. It 'pressured' the EPA into halving them. This meant that researchers using EPA estimates in their studies would report methane leakage half of what it really was, an average of 2/3% rather than the actual figure of 5%!

Dirty tricks from Australian CSG miners

There have been no estimates of methane leakage from SG mines in Australia. But there has been one survey of coal seam gas (CSG) mines. I include it here to show you that CSG miners here are just as dishonest and deceitful as shale gas miners in the US!
When the CSG miners in Australia became aware of Howarth's work in 2012 they launched their own dirty tricks campaign.
The **first** act of deceit was a survey of CSG wells to determine the level of their methane leakage. It was conducted by the CSIRO with the backing of the CSG industry and the Federal Department of the Environment (DE). It was not so much a survey but an attempt to demonstrate that methane leakage was so low it was of no consequence. It found that methane leakage was a ridiculously low 0.02%! Remember the average was 5% in the

US. Why was it so low? The 'survey' was 'fudged' in two ways!
Fudge 1 was a strategy that Big Pharma uses, namely measuring only what will give you the desired result. There are 8 phases in CSG extraction (Table 4). The CSIRO workers measured methane leakage in only 2 of them. And these were phases in which they knew fugitive emissions are very low!

Table 4
EPA estimates of methane leakage from shale gas mining, from CSG extraction and actual estimates from the CSIRO (2012) study

Source of methane emissions	EPA (2011) estimates for shale gas (SG) mining	Assuming CSG estimates are the same as SG estimates	CSIRO (2012) estimates
Upstream - from flowback - from drill-out -from routine venting and equipment leaks at well site -from liquid unloading and gas processing	 1.3% 0.33% 0.3 to 1.9%, average 1.1% (the 0.3% reflects the best possible technology) 0.3%	 1.3% 0.33% 0.3 to 1.9%, average 1.1% (the 0.3% reflects the best possible technology) 0.3%	 Not measured Not measured 0.02% Not measured
Downstream - from transport, storage and distribution	0.9%	0.9%	Not measured
Total methane emissions	3.9%	3.9%	Not measured

Fudge 2 was to abandon the scientific practice of drawing a sample representative of the population. Instead, five CSG companies volunteered their gas wells for this study. They knew which of their gas wells had the lowest methane leakage. And guess what? These were the ones placed on the list submitted to the CSIRO workers!

But why, I hear you ask, would the CSIRO do the study knowing how fatally flawed it was. Because it was held hostage by the DE. When the DE gave it the funds to do the 'survey,' it was on the condition that much needed future funding to CSIRO would be assured only if it found that methane leakage in this 'survey' was very low!

The **second** act of deceit was the CSG miners convincing the DE, the regulator, that CSG wells need not be monitored. Its thinking was that if we aren't being monitored we can spew into the atmosphere as much methane as we like. How did they convince the DE of this? The DE is responsible for monitoring methane leakage from CSG mines. However, it is so starved of funds (intended?) it can't spend money on monitoring. It consulted with the CSG industry and between them they concocted a novel form of monitoring! No monitoring would be done at all! Instead, the DE would assume all CSG mines had a similar methane leakage. And the level of the assumed leakage wouldn't be 5% as 9 very

good US studies show. It would be 0.02%, the figure from the 'dodgy' CSIRO work!
Both players in this 'chummy' arrangement were happy. There would be no suspensions of 'dirty' CSG mines so the gas keeps flowing for the CSG miners and the rivers of gold 'runneth' for the government! Only the atmosphere and eventually humanity, suffers!

Reducing methane leakage

We know methane leakage can be reduced in CG mining, from 1.9% to 1.17%. Can the methane leakage from shale gas mining be reduced from 5% using best possible practice? No! Remember there are two types of methane leakage from shale gas and CSG wells, point emissions and diffuse emissions.
Point methane leakage comes from point sources such as flow back ponds. Flow back is rich in methane and it makes sense for the SG miners to harvest it. Howarth says that this is too expensive for SG miners to do so it isn't done.
Diffuse methane leakage comes from faulty well casings, both vertical and horizontal. It travels into overlying sediments and groundwater aquifers, then to the surface and from there into the atmosphere. Nothing can be done to reduce this considerable leakage.
There is also a non-technical reason why methane leakage from UG mines can't be reduced. Most of the UG miners are climate deniers. They don't believe that the methane they are spewing into the atmosphere is doing any harm. So why should they even try to reduce their methane leakage?

From all this, we can conclude that CG miners can lower their methane leakage from 1.9% to 1.17% and that SG miners have a methane leakage of 5% and can't or won't reduce it any further!
That's more than four times more methane leakage from UG mining than from CG extraction, 5% compared to 1.17%.

Translating methane leakage into GHG production

Few people have heard of methane leakage, let alone understand it. The fact that UG extraction has four times the methane leakage of CG doesn't mean much to them. But they are familiar with GHG production because many paid carbon tax from 2012 to 2014 on their GHG production.
So we need to convert methane leakage to GHG production. When we do, we find that because UG mines have 4+ times the methane leakage of CG mines, they produce an astounding 92% more GHGs than CG mines! Let me show you.
Say a CG well produces 100 kg of 'good' methane. When this is burnt, it generates 100 kg of CO_2. A CG well producing 100 kg of 'good' methane also releases 1.17 kg of 'bad' methane into the atmosphere. With methane having a GWP of 34, 1.17 kg is equivalent to 40 kg of CO_2. When 'good' and 'bad' methane are mixed in the atmosphere, their total GHG content is 140kg of CO_2.
Let's do the same exercise with UG. Say a UG well produces 100 kg of 'good' methane. When this is burnt it generates 100 kg of CO_2. A UG well producing 100 kg of 'good' methane also releases 5 kg of 'bad' methane into the atmosphere. With methane having a GWP of 34, 5 kg is equivalent to 170 kg of CO_2. When 'good' and 'bad' methane are mixed in the atmosphere, their total GHG content is 270 kg of CO_2.
And what is the GHG production of coal? Take 100 kg of coal. Coal is carbon-dense so when it is burnt this 100 kg produces 200 kg of CO2.
In summary, CG produces 140 kg of GHGs, coal produces 200 kg, some 42% more than CG in GHGs and UG are the 'superpolluters' spewing out 270 kg of GHGs, some 35% more than coal and a massive 92% more than CG (Figure 1).

UG		COAL		CG
270 kg		200 kg		140 kg
	35% more than coal		42% less than coal	
		92% more than UG		

Figure 1. Coal produces 42% more GHGs than CG mining and UG extraction generates 92% more GHGs than CG.

To what extent will a ban on fracking lower GHG emissions in 2030?

We know that UG mining requires fracking and that, as a result, UG extraction generates 92% more GHGs than CG extraction. It follows that a ban on fracking and extracting only CG instead of a mix of UG and CG would substantially lower GHG emissions. But to what extent?
There are four industries that use natural gas, namely power generation, the LNG industry, manufacturing and the residential industry. In the next section I will calculate, for each industry, their GHG emissions in 2005, their projected GHG emissions in 2030 and the reduction in GHG emissions in 2030 as a result of a ban on fracking.
My hypothesis is that a ban on fracking will substantially reduce GHG production in each industry.

Hypothesis 1– a ban on fracking will substantially reduce GHG emissions from power generation

What were the GHG emissions in 2005?

From data published by the Bureau of Resources and Energy Economics (BREE 2014) I determined the electricity generation in 2005. It was 229 Terawatt hours (TWh). Some 182 TWh (79%) came from coal, 40TWh (17%) from gas and 7TWh (4%) came from renewables (Table 5)
How much in GHGs were produced from this coal and gas?
Coal: every KWh of power generated from burning coal produces 0.99 kg of CO_2 (US EIA 2014) So 182TWh generated from using coal produces 180 billion kg or 180 million tonnes (mT).
Gas: every KWh of power generated from burning gas produces 0.55 kg of CO_2 (US EIA 2014.) This is the figure for CG, the only gas to be used in 2005. Little or no fracking was done in Australia in 2005. So 40 TWh generated from using gas produces 22 billion kg of GHGs or 22 million tonnes.
We also need to know how much gas is required to generate 40 TWh. It is 35mT (35mT needs 134,779 million cubic feet and this weighs 35 mT)
The renewables (hydro, wind, solar) produce no GHGs.
So the GHG emissions from electricity generation in 2005 were 202 (180+22=202) million tonnes.

What were the GHG emissions in 2030?

Let's calculate the amount of electricity generated from the use of coal, gas and renewables. Predicting power generation 13 years into the future is difficult so it is not surprising that the predictions vary greatly. Predictions were made in 3 studies (Table 5). All forecast that coal would make up 40+% of the energy mix, much less than its 79% contribution in 2005 (Table 5). It was in the mix of gas and renewable energy that the three

varied. One believed gas usage would rise to 40% (from 25% now) and renewables would rise to only 17% of the mix (Table 5). Another said that gas usage would decline to 15% while renewables would jump to 37% in 2030 (Table 5).
I have averaged the three predictions of the energy mix in 2030. It is 44% coal, 27% gas and 29% renewable energy (Table 5). And the power generation in 2030 is 292 TWh, with 126 TWh from burning coal, 79 TWh from gas and 83 TWh from wind, solar and hydro (Table 5)
To generate 79 TWh we need 269,559.190 million cubic feet of gas. This weighs 70 mT.
How much in GHG emissions was produced by generating 126 TWh from burning coal and 79 TWh from the use of gas?
Coal: every KWh of power generated from burning coal produces 0.99 kg of CO_2 (US EIA 2014) So 126 TWh generated from using coal produces 124.74 billion kg or 124.74 million tonnes.

Table 5
Contribution of coal, gas and renewables to power generation in 2005 and 2030

Study	Year	Power generated from burning coal (% in brackets)	Power generated from burning gas (% in brackets)	Power generated from renewable energy (RE) (% in brackets)	Power generated from coal, gas and RE
BREE (2014)	2005	182 TWh (79%)	40 TWh (17%)	7 TWh (4%)	229 TWh
BREE (2014)	2030	134 TWh (43%)	126 TWh (40%)	54 TWh (17%)	314 TWh
McKinsey Australia and Energy Insights (2016)	2030	131 TWh (48%)	41 TWh (15%)	101 TWh (37%)	282 TWh
Blockey in 2016	2030	114 TWh (41%)	70 TWh (25%)	95 TWh (34%)	279 TWh
Average	2030	126 TWh (44%)	79 TWh (27%)	83 TWh (29%)	292 TWh

Gas: by 2030 both UG and CG will be used. There is, however, no published information on the proportions of UG and CG that will be used in 2030. It seems reasonable to assume that the proportions used in 2030 will reflect the reserves of UG and CG available then. I have calculated the reserves in 2016 which I assume will reflect the reserves in 2030 (Table 6). Those reserves will be 63% UG and 37% CG (Table 6). We know that every KWh of power generated from burning CG produces 0.55 kg of CO_2 (US EIA 2014.) We also know from Figure I that the mining and burning of UG generates almost twice as much in GHGs, 1.93, than the extraction and burning of CG (270 divided by 140 equals 1.93). So if every KWh of power generated from using CG produces 0.55 of CO_2, then every KWh of UG produces 1.062 kg of CO_2 (1.93 by 0.55= 1.062). And how much CO_2 will a mixture of 63% UG and 37% CG produce? It will be 87.3 million tonnes (63 by 1.062 plus 37 by 0.55 divided by 100 = 87.3).
So every KWh of power generated from the use of the 63%/37% mixture of UG and CG will produce 0.873 kg of CO2.

Knowing how much GHGs are produced from burning a mix of 63% UG and 37% CG, namely 0.873 per KWh, we can calculate how much in GHGs the generation of 79 TWh produces. It is 79 by 0.873, 69 billion kg or 69 million tonnes
The total GHG production from using coal and gas to generate power in 2030 is 124.74 plus 69 million tonnes. This equals 193.74 million tonnes**.**

What reduction in GHGs would we achieve in the power industry from 2005 to 2030?
Remember that Australia has pledged to emit 27% less GHG emissions in 2030 than we did in 2005. Our GHG emissions from power generation in 2005 were 202 million tonnes. And our 2030 GHG emissions were 194 million tonnes. We reduced GHG emissions from power generation by only 4%, not by the 27% we pledged in Paris.

And the reduction in GHGs due to a ban on fracking?
Can our GHG emissions from power generation in 2030 be reduced by banning fracking? Yes. We would use only CG instead of a mix of 63% UG and CG. We would use a gas that produces 0.55 kg of CO_2 instead of a gas emitting 0.873 kg of CO_2. Instead of 79 TWh producing 69 million tonnes of CO_2 when a mix of 63% UG and 37% CG was used, this 79 TWh emit 43 million tonnes of CO_2, **a reduction of 26 million tonnes**.

Table 6
Natural gas reserves in Australia in 2016

State/territory	Basin	CG, CSG or shale gas	Reserves in petajoules
WA	Bonaparte, Browse,Carnarvon	CG	158000
Victoria	Otway, Bass , Gippsland	CG	11290
South Australia/Qld	Cooper, Eromanga, Warburton	CG	1700
Queensland	Bowen, Surat, Clarence/Morton	CSG	33760
New South Wales	Gunnedah, Gloucester, Sydney	CSG	2350
Northern Territory	Amadeus, Beetaloo, McArthur, Georgina	Shale gas	257276
		Total CG reserves (as a % of all reserves)	171,700 (37%)
		Total CSG and shale gas reserves (as a % of all reserves)	293,386 (63%)

Hypothesis 2– a ban on fracking will substantially reduce GHG emissions from LNG production

What were the GHG emissions in 2005 from mining the gas LNG was made from?
First, we need to know how much LNG was exported from Australia in 2005. It was 12 mT of LNG (BREE 2013: WA Department of Trade 2014). It all came from Western Australia. Queensland had barely started CSG extraction in 2005. Therefore, the 12 mT was all made from CG. To make 12 mT of LNG we need 16.56 billion cubic metres of CG (1 mT of LNG needs 1.38 billion cubic metre of gas). The conversion of cubic metres to tonnes is done using the equation of 1333 cubic metres of CG weighs 1 tonne. So 16.56 billion cubic metres will weigh 12.42 mT (16.56 billion divided by 1333=12.42 mT).
Note that there are 3 processes in LNG production, the mining of CG, compressing the CG into LNG, converting the LNG to CG so that the CG can be burnt. When we export the LNG for use overseas we don't burn it here, we don't produce any GHGs here from burning. The GHGs that are emitted into our skies come from mining CG.
What GHGs are produced in mining CG? Table 1 tells us it is 1.9% of the output from CG wells. The World Resources Institute has devised ways of reducing methane leakage from CG wells by 38%. But in 2005 those methods were not yet devised. The methane leakage in 2005 would have been 1.9%.
So, if CG wells were extracting 12.42 million tonnes of CG in 2005 how much methane would have escaped into the atmosphere? It would have been 0.236 million tonnes (1.9% of 12.42 = 0.236). This is equivalent to 8.02 million tonnes of CO_2 (0.236 by 34= 8.02)

What will the GHG emissions in 2030 be from mining the gas from which LNG was made?
First, how much LNG do we expect to export in 2030? We know what we exported in 2015, namely 24 million tonnes. WA contributed 15, Queensland 8 million tonnes and the NT 1 million tonnes (Table 7). BREE (2014) and the Department of Industry in the Reserve Bank (2014) predict a tripling of LNG exports from 24 MT in 2015 to 85 MT in 2019. This huge increase of 7/8% p a is expected to happen at all three hubs (Table 7).
Predicting the growth in LNG exports is as difficult as predicting power generation in 2030. One of the 2 studies (BREE 2014) says that growth from 2019 to 2030 will be 2.6% in WA, 6.7% in Qld and 4% in the NT. Another report predicts growth in LNG exports to be 2.2%, 2.7% and 3.1% in WA, Qld and NT, respectively (BREE 2013).

Table 7
Expected tonnages of LNG to be exported from WA, Qld and the NT

	LNG exports in 2015 (mT)	Expected LNG exports in 2019 (mT)	Growth in LNG exports from 2015 to 2030 (mT)	Expected LNG exports in 2030 (mT)
Western hub (WA)	15	43	2.4% p.a	55.8
Eastern hub (Qld)	8	35	4.7% p a	58
Northern hubs (NT)	1	7	3.6% p a	10.3
All 3 hubs	24	85		124

The average of both studies is 2.4% in WA, 4.7% in Qld and 3.6% in the NT (Table 7). The expected LNG exports in 2030 from WA, Qld and the NT are expected to be 55.8, 58 and 10.3 million tonnes, respectively (Table 7). These three hubs, between them are expected to produce 124 million tonnes of LNG (Tables 7 and 8).
To work out how much gas is needed to make 124 mT of LNG we multiply 124 mT of LNG by 1.38 billion cubic metre of gas. So we need 171 billion cubic metres of gas (Table 8). And to calculate the weight of this volume of gas we divide it by 1333 to get a weight of 128.5 mT (Table 8),58mT from WA, 60 mT from Queensland and 10.5 mT from NT (Table 8)
The 60 mT of gas that comes from Queensland is CSG. The methane leakage from mining CSG wells is 5% of the gas flow (Table 8). This flow of 60 mT would release 3 mT of methane which is equivalent to 102 mT of CO2 (Table 8).

Table 8
Calculating the CO2 emissions from mining gas in the three LNG export hubs

Hub	Expected LNG exports in 2030 (mT) (1)	Volume of gas to produce this LNG (billions cubic metres) (2) Multiply (1) by 1.38	Weight of this volume of gas (mT) (3) Divide (2) by 1333	Type of gas used to make LNG and its methane leakage (as a %) (4)	Methane leakage from mining the gas (in mT) (5) Multiply (4) by (3)	Methane leakage expressed in CO2 equivalents (mT) (6) Multiply (5) by the GWP of 34
WA	55.8	77	58	CG (1.17%)	0.68	23.1
Qld	58	80	60	CSG (5%)	3	102
NT	10.3	14	10.5	CG (1.17%)	0.12	4.1
All hubs	124	171	128.5			129.2 million tonnes of CO2

The 68.5 mT used to make LNG in WA and NT will be CG (58 mT from WA and 10.5 mT from NT: Table 8). CG has a methane leakage of 1.17% (Table 8). So the methane leakage from the WA and NT gas wells would be 0.68 and 0.12 million tonnes, respectively (Table 8), the equivalent of 23.1 and 4.1 million tonnes, respectively (Table 8) in CO2 emissions. Mining CG at all three hubs would generate 129.2 mT of CO2 in 2030 (Table 8).

And the reduction in GHGs due to a ban on fracking?
Can our GHG emissions from mining gas for LNG production in 2030 be reduced by banning fracking? Yes. The 128.5 million tonnes of gas, a mixture of CSG and CG, generated 129.2 million tonnes of CO2 (Table 8). Had fracking been banned no CSG would have been available. We would have access to CG only. The 128.5 mT of CG would generate 1.504 mT of methane (1.17% by 128.5= 1.504). This is equivalent to 51 mT of CO2.
So, using CG instead of CSG to make the 124 million tonnes of LNG we expect to export in 2030 would reduce GHG emissions from LNG production from 129.2 to 51.1 million

tonnes, **a drop of 78 million tonnes.**

Hypothesis 3– a ban on fracking will substantially reduce GHG emissions from gas used in manufacturing.

Natural gas has other uses other than in power generation and LNG production. Its largest use is in manufacturing a wide variety of goods. In 2005 manufacturing used 36% of the gas extracted.

What were the GHG emissions in 2005 produced from mining the gas used for manufacturing?

In 2005, 426 PJ of gas was used in manufacturing. Using a conversion factor of 1PJ equals 200,000 tonnes, 426 PJ becomes 85.2 mT.

In 2005 the gas extracted was CG. CSG mining had barely begun in Queensland then. Methane leakage then would have been 1.9%. The World Resources Institute has devised ways of reducing methane leakage from CG wells by 38%. But in 2005 those methods were not yet devised.

So, if CG wells were extracting 85.2 mT of CG in 2005 how much methane would have escaped into the atmosphere? It would have been 1.62 mT (1.9% of 85.2=1.62). This is equivalent to 55 mT of CO2 (1.62 by 34=55)

What will be the GHG emissions produced from mining the gas used for manufacturing in 2030?

There are three predictions of the growth of gas usage in manufacturing from 2005 to 2030. The first, an industry prediction (Gas Today 2008), forecasts the gas usage to grow at 8.6% p.a. This, I believe, is wildly optimistic. The second estimate is based on the population growth from 2005 to 2030. Since much of our manufacturing is devoted to producing goods for domestic consumption, I assume that gas usage in manufacturing will grow at the same rate as population growth, namely 1% p.a. The third prediction, a 0.2% p.a growth from 2005 to 2030, is based on the assumption that Australia will continue to export much of its manufacturing to China (Ibis World 2017).

I believe that the third prediction of growth in gas usage from 2005 to 2030, namely 0.2% per annum, is the most likely. At that rate, gas usage in manufacturing would have risen from 85.2 to 92.8 mT in 2030.

How much in GHGs would be produced in mining 92.8 mT? In 2030 the gas extracted will be a mixture of 63% UG and 37% CG. UG mining has a methane leakage of 5% while CG extraction has methane leakage of 1.17%. A 63%/37% mix of UG and CG will have methane leakage of 3.58% (0.63% by 5%= 3.15) plus (0.37% by 1.17%= 0.43, 3.15 + 0.43 =3.58%). The methane leakage from the 92.8 mT of the mixture will be 3.323 (92.8 by 3.58%= 3.323). This is equivalent to 113 mT of CO2 (Table 10).

And the reduction in GHGs due to a ban on fracking?

To what extent will a ban on fracking reduce CO2 emissions from manufacturing in 2030? We would use only CG, with a methane leakage of 1.17% instead of a 63/37 mixture of UG and CG, a mix that has a methane leakage of 3.58%. With 100% of gas wells having methane leakage of 1.17% their methane leakage would be 1.086 mT of methane, (92.8 by 1.17=1.086). This is the equivalent of 37 mT of CO2 (1.086 by 34= 37).

This is 76 mT of CO2 less than the 113 mT the 63/37 mixture of UG and CG generated (Table 10) (113 minus 37=76)

So a ban on fracking would reduce the CO2 emissions from manufacturing of gas **by 76 mT, from 113 to 37 mT.**

Hypothesis 4– a ban on fracking will substantially reduce GHG emissions from gas used for residential purposes

One of the the other uses of natural gas is for residential purposes (home heating and cooking). In 2005, residential uses accounted for 12% of the gas mined.

What were the GHG emissions in 2005 produced from mining the gas used for residential purposes?

In 2005, 142 PJ was used in residences. Using a conversion factor of 1PJ equals 200,000 tonnes, 142 PJ becomes 28.4 mT.
In 2005 the gas extracted was CG. CSG mining had barely begun in Queensland then. Methane leakage then would have been 1.9%. The World Resources Institute has devised ways of reducing methane leakage from CG wells by 38%. But in 2005 those methods were not yet devised.
So, if CG wells were extracting 28.4 mT of CG in 2005 how much methane would have escaped into the atmosphere? It would have been 0.54 mT (1.9% of 28.4 mT= 0.54). This is equivalent to 18.36 mT of CO2 (0.54 by 34=18.36)

What will be the GHG emissions produced from mining the gas used for residential purposes in 2030?

Gas usage for residential purposes would be expected to grow at the same rate as population increase, namely 1% p.a. This is also the likely increase in gas used for residential purposes in the report 'Energy use in the Australian residential sector 1986 to 2020'. So gas will have increased from 28.4 in 2005 to 36.4 mT in 2030.
How much in GHGs would be produced in mining 36.4 mT? In 2030 the gas extracted will be a mixture of 63% UG and 37% CG. UG mining has a methane leakage of 5% while CG extraction has methane leakage of 1.17%. A 63%/37% mix of UG and CG will have methane leakage of 3.58%(0.63% by 5%= 3.15) plus (0.37% by 1.17%= 0.43, 3.15 + 0.43 =3.58%). The methane leakage from the 36.4 mT of the mixture will be 1.304 mT (36.4 by 3.58%=1.304). This is equivalent to 44.3 mT of CO2 (1.304 by 34=44.3).(Table 10).

And the reduction in GHGs due to a ban on fracking?

To what extent will a ban on fracking reduce CO2 emissions from the gas used for residential purposes in 2030? We would use only CG, which has a methane leakage of 1.17% instead of a 63/37 mixture of UG and CG that has a methane leakage of 3.58%. With 100% of gas wells having methane leakage of 1.17% their methane leakage would be 0.426 mT of methane, (36.4 by 1.17=0.426). This is the equivalent to 14.5 million tonnes of CO2 (0.426 by 34= 14.5).
This is 29.8 mT of CO2 less than the 44.3 mT the 63/37 mixture of UG and CG generated (44.3 minus 14.5= 29.8)(Table 10).
So a ban on fracking would reduce the CO2 emissions from mining the gas to be used for residential purposes **by 29.8 mT, from 44.3 to 14.5 mT**.

A summary of the results from all four industries

In Table 10 I have summarised the results of the calculations.
If fracking is not banned by 2030 the GHGs generated in mining the natural gas the four industries use will total 355 mT in 2030. This is made up of 69 mT from power generation, 129 mT from LNG production, 157 mT from manufacturing and 44.3 mT mining gas for residential purposes (Table 10).
If fracking were banned before 2030, the GHGs generated in mining the gas for the four industries will total 145 mT in 2030. This 145mT in GHGs will be 43mT from power generation, 51mT from LNG production, 37mT from manufacturing and 14.5 mT from gas

used for residential purposes (Table 10).
The reduction in GHGs in 2030, as a result of banning fracking and not mining UG, will be 26mT in power generation, 78mT in LNG production, 76 mT in manufacturing and 30 mT in mining gas for residential purposes. Over all four industries, a ban on fracking lowered GHGs by 210 mT!

Five stories

From Table 10 come five stories.
The first tells us what an extraordinarily heavy polluter the gas mining industry is. The National Greenhouse Inventory expects our GHG emissions, Australia-wide, to be 716 mT in 2030. Look at what the gas mining industry is expected to generate in 2030. It is 355 mT (Table 10). This is 50% of all the emissions Australia will produce in 2030!
The second story concerns the 210 mT reduction in GHGs due to a ban on fracking. Not only is this the reduction in GHGs if we banned fracking, this 210 mT is also the GHGs generated from fracking and mining UG in Australia in 2030.
The third story is that the 210 mT entering the atmosphere because of fracking and mining UG, makes up 59% of the 355 mT of GHG emissions generated from all gas extraction in 2030.
The fourth story is that the 210 mT entering the atmosphere because of fracking and mining UG makes up 29% of the 716 mT of GHG emissions generated Australia-wide in 2030. Just absorb that: 29% of all GHG emissions entering the atmosphere in 2030 will come from fracking and mining UG.
The fifth story is that in Paris, Australia pledged to restrict its GHG emissions to 430mT in 2030. The National Greenhouse Inventory, however, expects our GHG emissions in 2030 to be 716 mT, 286 mT more than our 'budget'. A couple wanting to spend less from week to week would look first at the 'big ticket' item with the aim of spending less on this item. Obviously, the 'big ticket' item in gas extraction is fracking and mining UG. Were we to ban this 'big ticket' item, our GHG emissions in 2030 would be reduced by 210 mT. We would meet 210 mT of the 286 mT shortfall between what we have pledged and what is predicted.

Table 10
The reduction in GHG emissions in 2030 due to imposing a ban on fracking, by sector

Sector	Gas used in 2005 mT	GHGs generated in 2005 in mT CO_2)	Gas used in 2030 mT	GHGs generated in 2030 mT, no ban on fracking	GHGs generated in 2030, mT, a ban on fracking	Reduction in GHGs, in mT, due to ban on fracking	
Electricity generation	35	22	70	69	43	26	
LNG	12.4	8	128.5	129.2	51	78	
Manufacturing	85.2	55	92.8	113	37	76	
Residential	28.4	18.4	36.4	44.3	14.5	30	
All sectors		103		355	145	210 (59%)	

The science is clear cut. It shows that fracking and UG mining should be banned! But to make this happen, two hurdles must be overcome.

Two hurdles

The two hurdles to overcome before a ban on fracking can be imposed are fierce opposition from the UG industry and the proof that Australia has sufficient CG to meet the demands of the four industries.

Opposition from the UG industry

The UG industry will certainly huff and puff and try to blow the house down but I suspect it will not be as strong as it pretends to be. It won't be strong because it will be caught between two forces, namely public protest to fracking and market forces.

Public protest

In Australia, public protest has been very successful in forcing CSG companies to end their mining and I believe this success will continue into the future. It has taken two forms.

First

In the first form, protest is directed at a CSG company. Protests against AGL caused it to abandon CSG mining in the Sydney Basin, at Camden and St Peters in Sydney, and at Gloucester, north west of Sydney (Table 11). Public protests at Bentley, near Lismore, forced Metgasco to stop extracting CSG there (Table 11).

Table 11
A potted history of the war on CSG and shale gas mining

Gasfield	Methods successfully used to end CSG mining	Methods that might end CSG mining
Victoria	Public protest leading to a ban on fracking, state-wide and permanent	
Northern Territory	Public protest leading to a temporary ban on fracking, territory-wide	Submissions to the enquiry and public protests needed to persuade the NT government to make the ban on fracking permanent.
Surat/Bowen		Market forces likely to close down CSG mining.
Sydney Basin Camden and St Peters	Public protest forced AGL out	
Gloucester	Public protest forced AGL out	
Bentley	Public protest forced Metgasco out.	
North east region of NSW	Moratorium on fracking	
Gunnedah		Market forces will make Santos abandon the Gunnedah project.

Second

The second form of public protest aims to convince governments to ban fracking or impose a moratorium on fracking.

The ban/moratorium on fracking can be regional or state-wide, temporary or permanent.
The New South Wales government imposed a moratorium on exploration using fracking in the north east region of NSW as a result of Metgasco pulling out of Bentley.
The difference between a ban and a moratorium? The first is permanent, the second is temporary.
Victoria has in March 2017 banned fracking permanently over the whole state (Table 11). Victoria has little UG mining so little money in the form of royalties is paid by UG miners into Treasury. Little public protest was needed to convince the Victorian government to ban fracking.
The situation in the Northern Territory is very different. It has large deposits of shale gas in four gas fields, McArthur, Beetaloo, Georgina and Amadeus. The royalties from these fields when they are producing will be substantial. A very strong public protest was needed to have UG mining banned. And a strong protest there was. Lock the Gate coordinated a continuing public protest under the banner of 'Frack-free NT'. This galvanised the people to the extent that the Opposition Labor party pledged to temporarily ban fracking if it won office. This pledge was considered to be a contributor to its landslide win in the August 2016 election. And it did impose a moratorium but it may not be for long.

The message from protesters
What greatly contributed to the success of public protest was the message the activists were 'putting out there'. It was that fracking harms humans and animals. Methane leaks into the soil around the gas well and then into the groundwater. This is diffuse methane leakage. People living in gas fields tap into this groundwater contaminated with methane. They use it for drinking water, for showering and for cooking. They suffer burning of the nose, throat and eyes, headaches, dizziness, nosebleeds, vomiting, diarrhoea and rashes! Livestock also suffer from drinking well water heavily contaminated with methane. They 'wither away' and die and others abort.
These are the 'known harms'. There are many 'unknowns harms'. Like, does the milk and meat of cattle grazing pastures irrigated with methane-contaminated water contain residues of methane? Do vegetables, fruit and crops irrigated with this contaminated water contain residues of methane? If so, are these residues harmful to humans?
Then there is the 'ground level' air breathed by humans and animals. Is the methane in this 'ground level' air harmful to humans and animals?

Market forces
There is a good chance that, in the next 10 to 15 years, the CSG companies operating in Queensland and NSW will have gone bankrupt. And, of course, if they are no longer in business they can't 'huff and puff' about a ban on fracking. Let me tell you their story.
A consortium of CSG companies have thousands of gas wells in the the Surat and Bowen Basins (Figure 2). One of the consortium, Santos,plans to produce CSG from the Gunnedah Basin (Figure 2). They plan to pipe CSG from these three basins to Gladstone.
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Seven LNG plants are being constructed at Gladstone, Queensland to convert CSG into LNG. The CSG companies that are building the LNG plants were in deep financial trouble in 2016 and market forces may end their UG mining. They have invested $80 billion in building these large LNG plants. So heavy is their investment, so high are their costs of extracting CSG and so low is the price they expect to receive for their LNG, three analysts believe their LNG venture is doomed.
So high are their costs of extraction? It is 75% more expensive to extract UG than to mine CG. Low price? When they signed the contracts with Asian LNG buyers, the oil price was high, $100/barrel, and thus LNG prices were high, $12/PJ. Now the oil price has crashed to $50/barrel and LNG prices are $6/PJ. The LNG buyers want to renegotiate the gas price

to half of the contracted price.
The negotiations will have one of three outcomes. **First**, If the CSG companies refuse to renegotiate, the LNG buyers will default on the contract and buy LNG from Russia and the US. There is a large global oversupply of LNG. In this scenario, the LNG plants would cease to operate and the CSG mines supplying them would be closed down.
Second, the LNG buyers are made aware by CSG activists that CSG mining produces 92% more in GHGs than CG mining. Say they are climate change 'believers' and, as a result, want to reduce GHG emissions. They resolve to buy LNG made from the gas generating the least GHGs, namely CG. They put the following proposition to the CSG companies operating the Gladstone LNG plants: we will buy LNG from your plants, in preference to other plants, but it must be CG-based LNG, not CSG-based LNG. If the CSG miners agree to this proposal, the LNG plants keep operating but the CSG mines close down!
Third , the CSG companies don't agree to proposal 2. In this case, the LNG plants would cease to operate and the CSG mines supplying them would be closed down.

Not only are the LNG plants and the CSG wells in the Surat and Bowen Basin in financial strife, the Gunnedah CSG project is also in trouble. An IEEFA analyst, Bruce Robertson, looked closely at the economics of the Gunnedah CSG mines and predicted that market forces will make Santos abandon this project.
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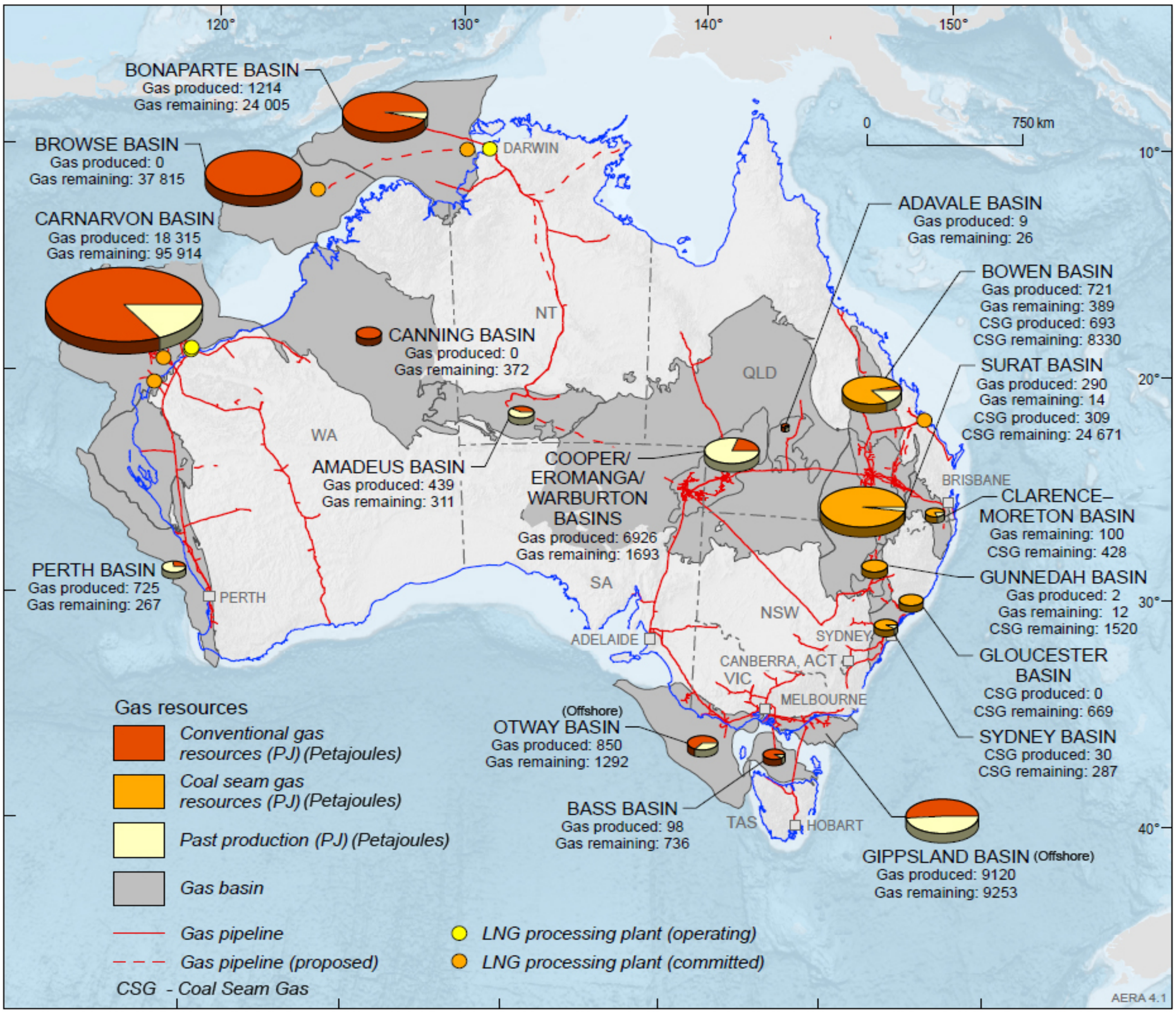
Proof that Australia has sufficient CG

Think of Australia's gas supplies as serving two markets in the future, the LNG market and the domestic market comprising power generation, manufacturing and residential use. The LNG market needs 128 mT/year of CG, the domestic market requires 200 mT/year of CG (Table 10).
The LNG market. This could be supplied from the Carnarvon Basin (see map). It has CG reserves of 96,000 PJ, enough CG for 150 years of production at the predicted 2030 usage of 128.5 mT/year (Table 10). The LNG plants at Dampier would be used to make this CG into LNG. Darwin also has an LNG plant and could source small amounts of CG, 10.5 mT/year, from the Bonaparte Basin.
No UG, including no Queensland CSG, would be needed in the future for LNG production.
The domestic market Some of the CG from the Carnarvon Basin can be piped south for power generation, manufacturing and for residential use. Most of the domestic market, of course, is in the eastern states. Where is it to source its CG?
The Cooper, Eromanga and Warburton Basins (see map) have CG reserves of 1693 PJ. And in the Otway, Bass and Gippsland Basins there are another 11,281 PJ in reserve (see map). The 12,974 PJ of reserves in the 6 basins is equivalent to 2594.8 mT of CG
From Table 10, we know that in 2030 we will need 70mT for power generation, 92.8 mT for manufacturing and 36.4 mT for residential use, a total of about 200 mT. Were we to use CG at the 2030 rate of 200 mT of CG /year, the 2594.8 mT of CG in those six basins would last only 13 years.
From where else can the domestic market in the east get its CG? From the north west of Australia! Specifically, from the Bonaparte and Browse Basins (see map). Between them they have reserves of 62,000 PJ. That is enough to supply the eastern domestic market for CG for 62 years of CG, given an annual usage of 200 mT/year.
And getting the CG from the north west to the eastern states?There are existing and proposed gas pipelines from the Browse and Bonaparte Basins to Darwin and then south to Alice Springs (see map). Another pipeline, the North Eastern Gas Interconnector (NEGI) will soon be built by Jemena. It will start at Tennant Creek running east from the Darwin – Alice Springs pipeline and go to Mt Isa in Queensland. This will then connect with existing Carpentaria Gas Pipeline going south to Wallumbilla (see map).

Enough CG? If we set aside CG from the Carnarvon Basin for LNG production (and a little from the Bonaparte Basin) we will have enough CG for 150 years of LNG exports. And if we pipe CG from the Bonaparte and Browse Basins to the domestic market to top up our dwindling local CG reserves, we will have enough CG for 75 years of power generation, manufacturing and residential use.
And through all of those years the gas miners will be exploring for new CG basins!

Yes, we have enough CG for the future. We don't need UG. We can ban fracking, we will not be penalised!

Pipelines and Major Producing areas in Eastern Australia



Convincing the states and territories

Although the federal government has signed off on Australia's pledge to restrict our 2030 GHG emissions to 430 mT, it is the states and territories who will be tasked with the job of meeting that target. They will also be tasked with the job of deciding how they will meet this target. This means that it is the individual states/territories who will decide whether or not to ban fracking.
Can the states and territories be convinced to impose a ban on fracking? I believe they can. Victoria has a permanent ban on fracking, the NT has a moratorium over the whole of

the NT and NSW has a moratorium over fracking over the north east of the state. The reason these states/territories have imposed a ban or a moratorium is that they accept that fracking and UG mining are harmful to humans and animals. They know they have a duty of care to protect the health of their citizens and their animals.
The remaining states/territories don't reject the evidence that fracking and UG mining are harmful to humans and animals. But something stops them from protecting the health of their citizens and their animals by imposing a ban on fracking. That something is royalties paid by the UG companies. Queensland, the largest fracking state, was paid $68 million in 2016 and in 2019 will receive $260 million.
Queensland, with is huge reserves of CSG (33,760 PJ) (Table 6) is steadfast in opposing a ban on fracking. It has chosen to put royalties before the health of their citizens. The other states are teetering on the edge of deciding to put the health of their citizens before royalties. They are leaning toward imposing a ban on fracking. They just need a little push. That push could come from the task the Feds have foisted on them, namely to restrict Australia's GHG emissions to 430 mT in 2030. They know that the National Greenhouse Inventory predicts that our GHG emissions in 2030 will be 716 mT, 286 mT more than our pledge. They know that, collectively, they have no chance of meeting that shortfall of 286 mT.
If, however, they were to ban fracking, something that would lower our 2030 GHG emissions by 210 mT, they would fall just short of meeting this shortfall of 286 mT.
Put yourself in the shoes of the states/territories. They are strongly leaning toward banning UG mining because it harms the health of their citizens. However, it yields royalties so they impose no bans. They are tasked with restricting Australia's GHG emissions in 2030 to an impossibly low 430 mT, 286 mT lower than what is predicted. They are told that a ban on fracking will lower our 2030 GHG emissions by 210 mT.
Imposing a ban on fracking, they realise, solves their two problems. First, it ends UG mining, greatly reducing methane leakage from gas extraction, the methane that is harmful to humans and their animals. Second, banning fracking and ending UG extraction would lower GHG emissions in 2030 by 210 mT. This reduces the shortfall of 286 mT by 210 mT.
That's the argument I believe we should present to the states and territories!

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