From:	Tim Forcey
To:	fracking inquiry
Subject:	2nd Submission to NT Fracking Inquiry - post 2 August Darwin presentation
Date:	Friday, 11 August 2017 3:06:10 PM
Attachments:	20170806 Tim Forcey 2 Aug presentation to Inquiry.pdf 20170806 Tim Forcey 2 August Script to Inquiry.pdf
Importance:	High

To the Inquiry:

Following my presentation to the Inquiry in Darwin on 2 August, I make the following submission (including attachments).

(Attached are my presentation slides and also my prepared remarks delivered on the day.)

I would like to make the following points.

1). Eastern Australia gas supply and demand

In my presentation I recommended that the Inquiry comment on the possibility / likelihood / economics of NT gas supplying eastern Australian markets. I believe it falls within the Terms of Reference of this Inquiry to do so, as the TOR states that the Inquiry will investigate the "costs and benefits of the industry".

That said, our May 2017 report "A short-lived gas shortfall" shows that there is no need for NT gas to supply the eastern Australian market.
(Link to our May 2017 report here: http://climate-energy-college.org/short-lived-gas-shortfall)

Between March 2017 and June 2017, The Australian Energy Market Operator softened its position on potential gas supply shortfalls. Its June Energy Supply Outlook (ESO) includes a number of points similar to what we describe in our May 2017 report. https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2017/2017-Energy-Supply-Outlook.pdf

From AEMO's ESO media release: "Following the release of our Gas Statement of Opportunities in March this year, the ESO analysis suggests gas supply remains tight, however the latest industry projections of gas production are just sufficient to meet current projections of gas demand. Gas availability on the supply side, together with new initiatives to reduce peak demand via demand side management, will form a formidable combination in managing power system security during those hours on the very few extreme condition days per year," said Ms Zibelman.
https://www.aemo.com.au/Media-Centre/AEMO-Energy-Supply-Outlook

2). Methane emissions

Table 9.1 of the Interim Report:

As I discussed during my presentation on 2 August, I am having difficulty reproducing some numbers from Table 9.1 (and request further information / clarification regarding the input assumptions and calculations of that table. Using factors/inputs listed in the text explaining Table 9.1, I am able to

reproduce the “Life cycle GHG emissions per year” associated with the 200 and 1,000 TJ/d production rates. However I cannot reproduce the emissions associated with the 3,400 TJ/d production rate. I note that the emissions associated with the 3,400 TJ/d are not proportionately 3.4 times larger than the emissions associated with the 1,000 TJ/d production rate - so there seem to be other factors in play that are unclear to me and that I cannot reconstruct.

In summary, as I discussed with panel members following my presentation, I request methodology / calculations / input assumptions that allow me to reproduce / understand the figures presented in Table 9.1.

Top-down measurements can capture "super-emitters". Bottom-up scenarios do not:

As I discussed during my presentation, the top-down airborne measurement techniques described by Frankenberg et. al. (http://m.pnas.org/content/113/35/9734.full), if regularly and recurringly applied, offer an expectation that methane emissions can be measured, identified, and in some cases stopped.

I recommend that the Inquiry review and take into account state-of-the-art, top-down methane-emission quantification techniques, such as described by Frankenberg and other researchers.

Our Univ of Melbourne report into methane emissions (http://climate-energy-college.org/review-current-and-future-methane-emissions-australian-unconventional-oil-and-gas-production) highlighted several top-down studies that found high levels of methane emissions from oil and gas production in certain regions, far higher than the 2%-of-production projected by the Inquiry.

Examples:

- Bakken shale region (10%)
- Eagle Ford shale region (9%)
- Denver-Julesberg Basin (2 to 8%)
- southwestern Pennsylvania (3 to 17%);
- Uintah Basin (6 to 13%);
- north-eastern Colorado (2.3 to 7.7%).

The Inquiry refers to Scone 2017 and Littlefield 2017 as a basis for the Inquiry’s projected methane emissions level of 2%. However, those authors base their analysis on “bottom-up” measurements that have not been found to align with “top-down” measurements. (See the discussion found in our Univ of Melbourne report.)

Methane emissions at a level of 2%-of-production may be the best performance / lowest emissions that can be hoped for, but I recommend that the Inquiry apply a risk-based and precautionary approach while considering the top-down findings of U.S. research, and therefore the potential for a level of methane emissions greater than 2%. Given the study results listed above, I recommend a level of methane emissions equal to 5%-of-production is appropriate to consider / present in the Inquiry’s final report.

Total methane-emissions potential from NT shale oil and gas production is enormous

Given the enormous amount of hydrocarbons contained in NT shales, if the results of U.S. "top-down" measurements are applied, methane-emission levels can be calculated ranging into the many billions of tonnes of CO2-equivalent.

If 240 trillion cubic feet (TCF) of gas were produced from NT shales (as described here http://www.smh.com.au/business/energy/gas-entrepreneurs-bet-on-beetaloo-basin-as-australias-answer-to-us-shale-20151231-glxgwy.html), and if 5% of the methane contained is emitted to our Earth's atmosphere, that equates to additional Australian greenhouse-gas emissions of ~ 22 billion tonnes (CO2-e, 20-year GWP).

Such figures far surpass even the total global emissions that could result from the proposed Adani Carmichael Mine in Queensland, that has been the focus of significant Australian community concern. (see: https://www.theguardian.com/environment/2017/aug/02/emissions-from-nts-mcarthur-basin-would-dwarf-those-from-adani-coalmine; global emissions that may occur from producing and burning coal from the Adani Carmichael Mine have been reported to be ~ 5 billion tonnes CO2-e).

Such figures in the billions of tonnes also approach levels equivalent to Australia's entire volume of greenhouse-gas emissions that are reported today.

Australia appears to already have severe challenges in reducing greenhouse gas emissions. (See: http://www.theage.com.au/environment/climate-change/australias-carbon-pollution-soars-government-data-shows-20170804-gxpd71.html) Production of oil and gas from NT shales would make it very difficult for Australia to significantly reduce its greenhouse gas emissions - as is needed for Australia to align with the commitments of many other nations / jurisdictions as these nations / jurisdictions work toward avoiding the worst impacts of climate change.

Burning the produced gas increases global greenhouse-gas emissions by additional billions of tonnes

In addition to the potential methane emissions described above, burning the gas produced from the 240 TCF "resource" would add ~ 14 billion tonnes of CO2 to our Earth's atmosphere. {Producing or using gas from NT shales will make it difficult for the nations involved to stay within carbon budgets aimed at avoiding the worst effects of climate change.

Independently-conducted methane emission baseline studies should take place at least one year before further exploration / appraisal:

I note that the Interim Report (Section 9.6) recommends that baseline measurements should begin 12 months before production commences, in order to allow for seasonal variation. I recommend that methane-emission baseline studies should be concluded and published prior to any further exploration / appraisal activities or any further drilling. Because exploration and appraisal activities can involve extensive drilling and subsurface-disturbances, these activities, or any further drilling, should not proceed until methane-emission baseline studies are concluded and published.

Methane emission baseline studies should be conducted by organisations / individuals that are independent of, and that can be recognised as being independent of, government and industry.

3). Fracking has not made the US a net energy exporter - Interim Report Executive Summary needs

to be corrected

The Interim Report Executive Summary paragraph 3 states: “This revolution turned the US from an energy importer to an energy exporter.” This statement is not correct and is misleading.

As summarised by the US EIA, the US remains, at this time, a net energy importer. See EIA presentation here: https://www.eia.gov/outlooks/aeo/
Slide 15 presents a range of scenarios. In some scenarios the US becomes, in future, a net energy exporter. In other scenarios, the US never becomes a net energy exporter.

I am happy to engage in further discussions with the Inquiry as required.

Regards,

Tim Forcey
Energy Advisor, formerly with the University of Melbourne Energy Institute
Sandringham, Victoria
[redacted]

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Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

Tim Forcey - Energy Advisor

Darwin - 2 August 2017

"A short-lived gas shortfall",
Forcey, McConnell, May 2017.
http://climate-energy-college.org/short-lived-gas-shortfall

"A review of current and future methane emissions from Australian unconventional oil and gas production",
Lafleur, Forcey, Saddler, Sandiford, October 2016.
http://climate-energy-college.org/review-current-and-future-methane-emissions-australian-unconventional-oil-and-gas-production

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MARCH 9 2017 SAVE PRINT

Malcolm Turnbull calls energy crisis talks amid gas shortage blackout warnings

Adam Gartrell | James Massola | Nick O'Malley

SHARE TWEET MORE

Malcolm Turnbull has called urgent crisis talks with Australia's east coast gas companies after the energy market regulator warned of looming shortages that could lead to widespread blackouts as early as next year.

Describing the potential shortfall as "very concerning", the Prime Minister also called on state governments to loosen restrictions on onshore gas exploration and development in a bid to avert the energy emergency.

9 March 2017 - AEMO forecasts a gas-supply shortfall that could cause electricity black-outs.

Why has gas in eastern-Australia become expensive?

+ with LNG gas exports, the eastern-Australian gas market is now linked to overseas benchmarks

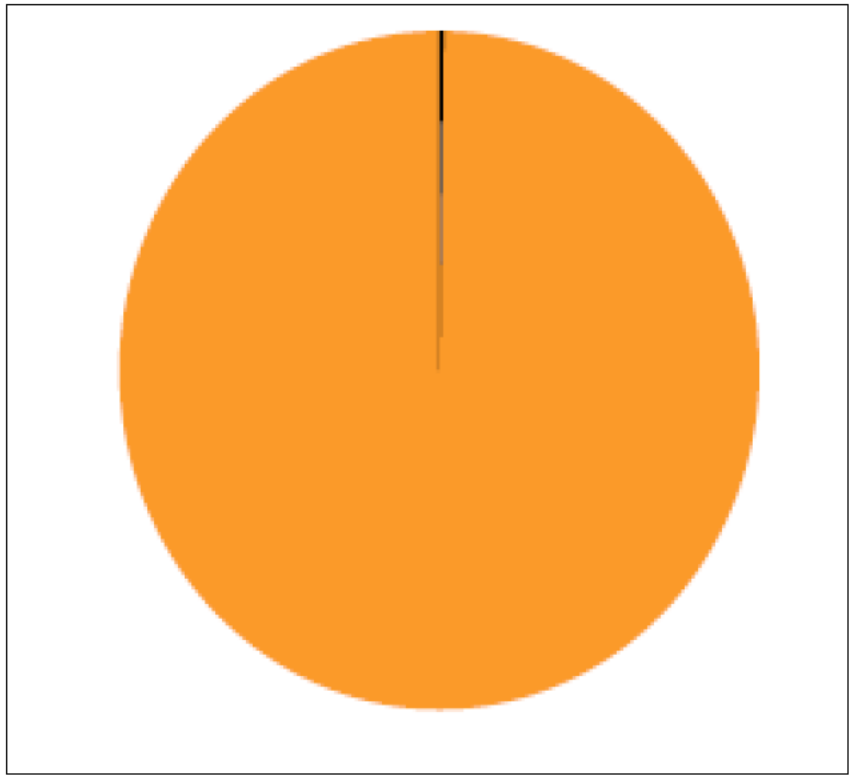
+ over-building of gas-export capacity with contractual export over-commitments

+ opaque gas market

+ opaque gas-producer behaviour

+ high costs of producing unconventional gas with some reserves now estimated to be around $7/GJ (excluding pipeline transportation costs).

"A short-lived gas shortfall", Forcey, McConnell, May 2017. (Figure 7)



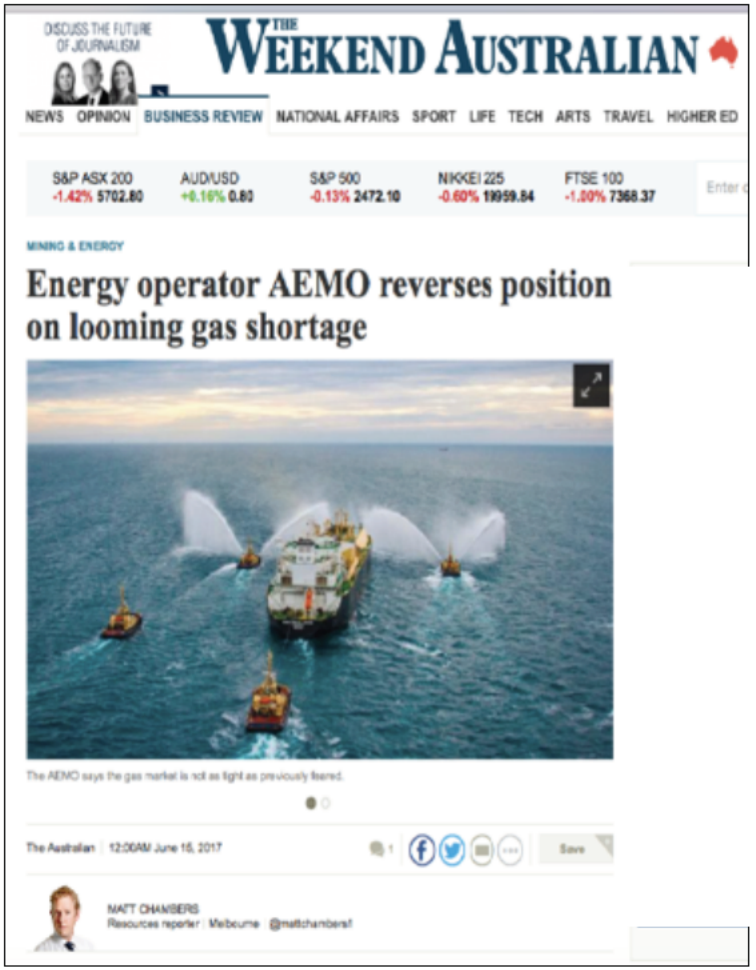
AEMO's March 2017 forecast gas-supply shortfall was no more than 0.2% of annual supply…
… shown as the black sliver.

Reasons why there won't be a gas-supply shortfall (nor consequent electricity blackouts)

+ a rapid increase in the amount of electricity generated by renewable sources - wind and solar - which is now available at lower cost than what can be produced by burning gas

+ the focus of the new AEMO CEO on electricity demand response mechanisms - where electricity demand can be reduced during critical times, with customers compensated for reducing their demand

+ gas customers "economic fuel-switching" away from gas to cheaper energy sources such as heat pumps.



DISCUSS THE FUTURE OF JOURNALISM

THE WEEKEND AUSTRALIAN

NEWS OPINION BUSINESS REVIEW NATIONAL AFFAIRS SPORT LIFE TECH ARTS TRAVEL HIGHER ED

S&P ASX 200	AUD/USD	S&P 500	NIKKEI 225	FTSE 100
-1.42% 5702.80	+0.16% 0.80	-0.13% 2472.10	-0.60% 19959.84	-1.00% 7368.37

MINING & ENERGY

Energy operator AEMO reverses position on looming gas shortage

The AEMO says the gas market is not as tight as previously feared.

The Australian | 12:00AM June 15, 2017

MATT CHAMBERS
Resources reporter | Melbourne | @mattchambers1

15 June 2017 - AEMO reverses position on gas-supply shortfall.

Eastern Australia gas demand peaked in 2012.

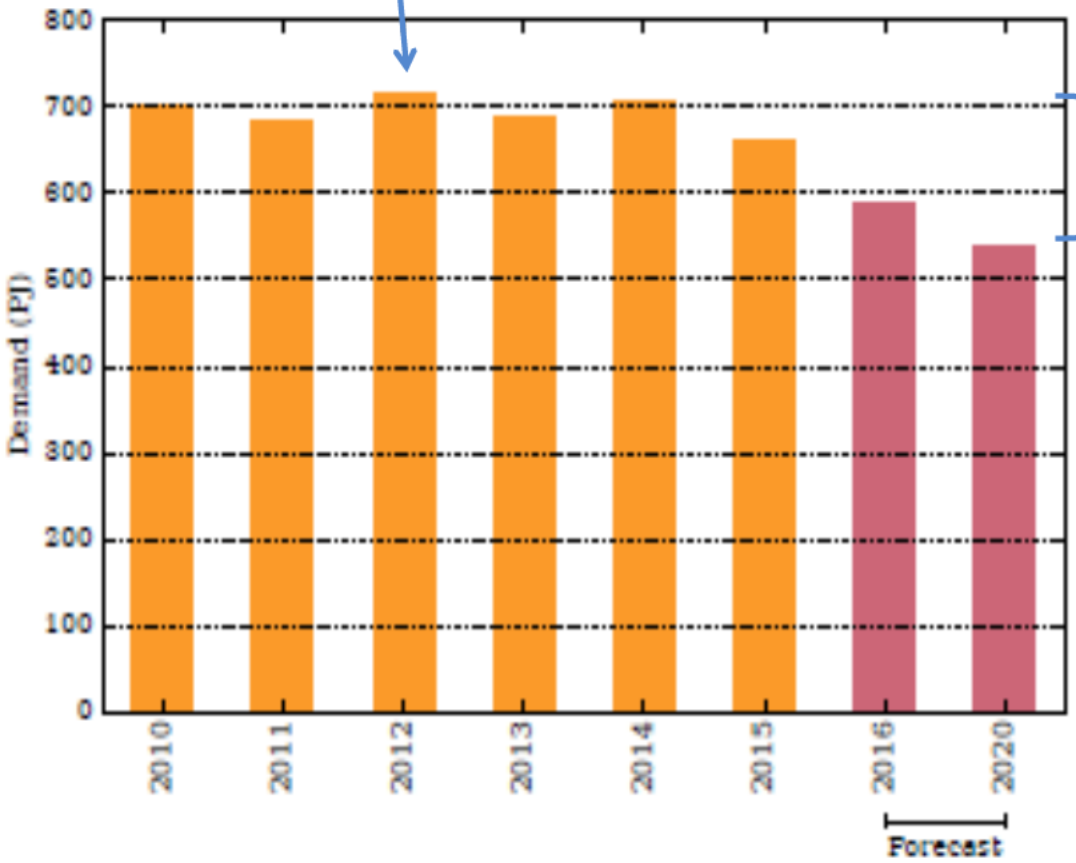


Figure 13: Actual and forecast eastern-Australian gas demand (petajoules). The forecast are taken from the 'neutral' scenario from AEMO's *2016 National Gas Forecasting Report* [source: AEMO[75]].

26% decline in
8 years, forecast.

"A short-lived gas shortfall",
Forcey, McConnell, May 2017.
(Figure 13)

Gas for electricity generation in Australia is on its way out

Australia's largest solar farm – 220MW – under construction

By Giles Parkinson on 26 July 2017

Print

The title of Australia's largest solar farm under construction will switch from Queensland to South Australia this week when Reach Solar issues a notice to proceed with the second stage of its Bungala solar farm near Port Augusta.

The company began construction and the grid connection of its first 110MW stage back in April, after reaching financial close and a obtaining a power purchase agreement from Origin Energy.

Gas-fired electricity generator

Building and running this…

…is now…

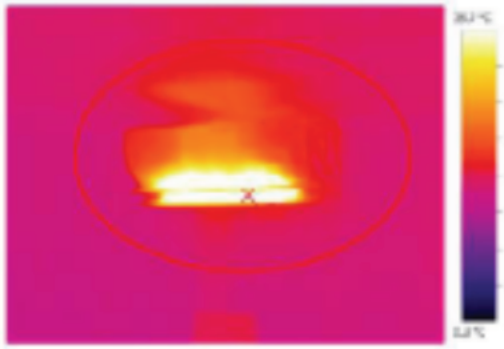
… cheaper than running this.

"A short-lived gas shortfall", Forcey, McConnell, May 2017.

A heat pump uses free renewable-ambient heat to heat your home.

"A short-lived gas shortfall", Forcey, McConnell, May 2017. (Figure 17)

Reverse-cycle air conditioner in heating mode producing temperatures of up to 50 °C



1 part of electricity produces up to 6 parts of space heating.

5 parts of renewable heat go in here.

THE AGE

AUGUST 26 2015 SAVE PRINT LICENSE ARTICLE

'Heat pump' tech could save Victorian homes up to $658 a year on gas: report

Tom Arup

Don't waste gas in your home. Heat with a heat pump!

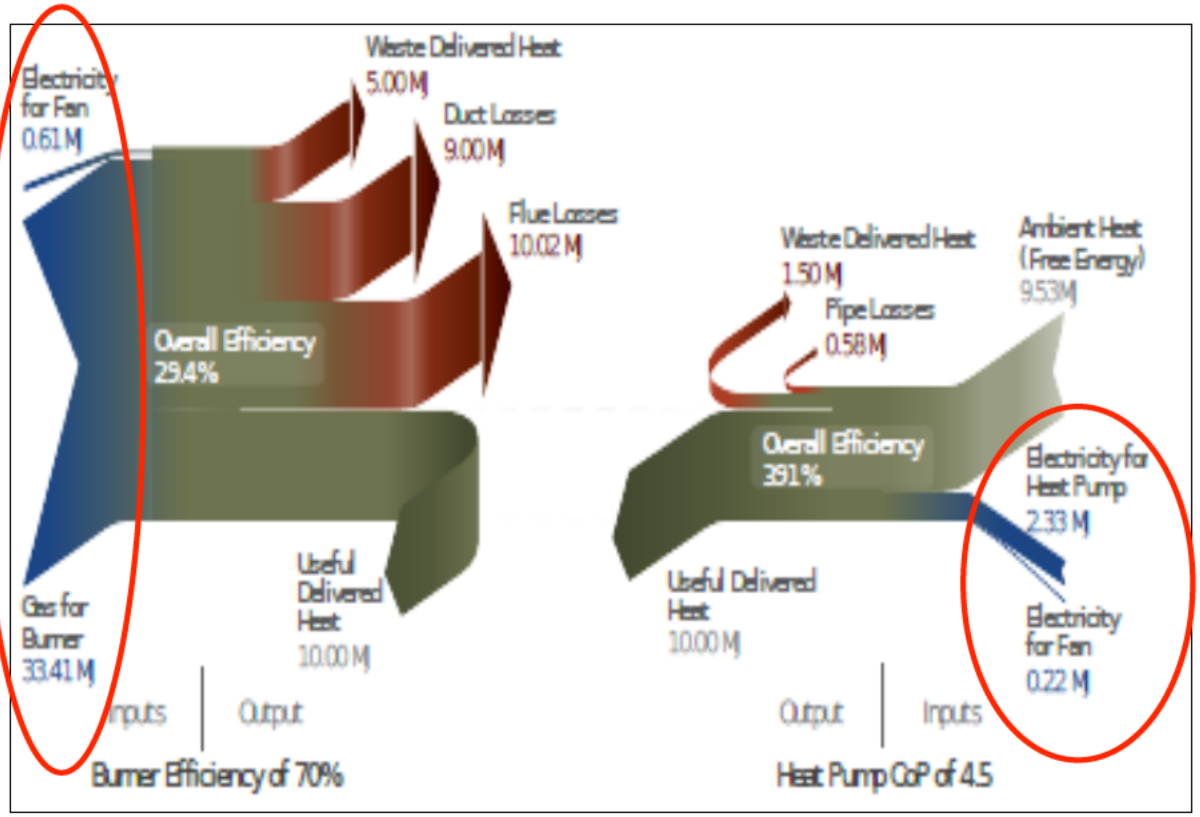
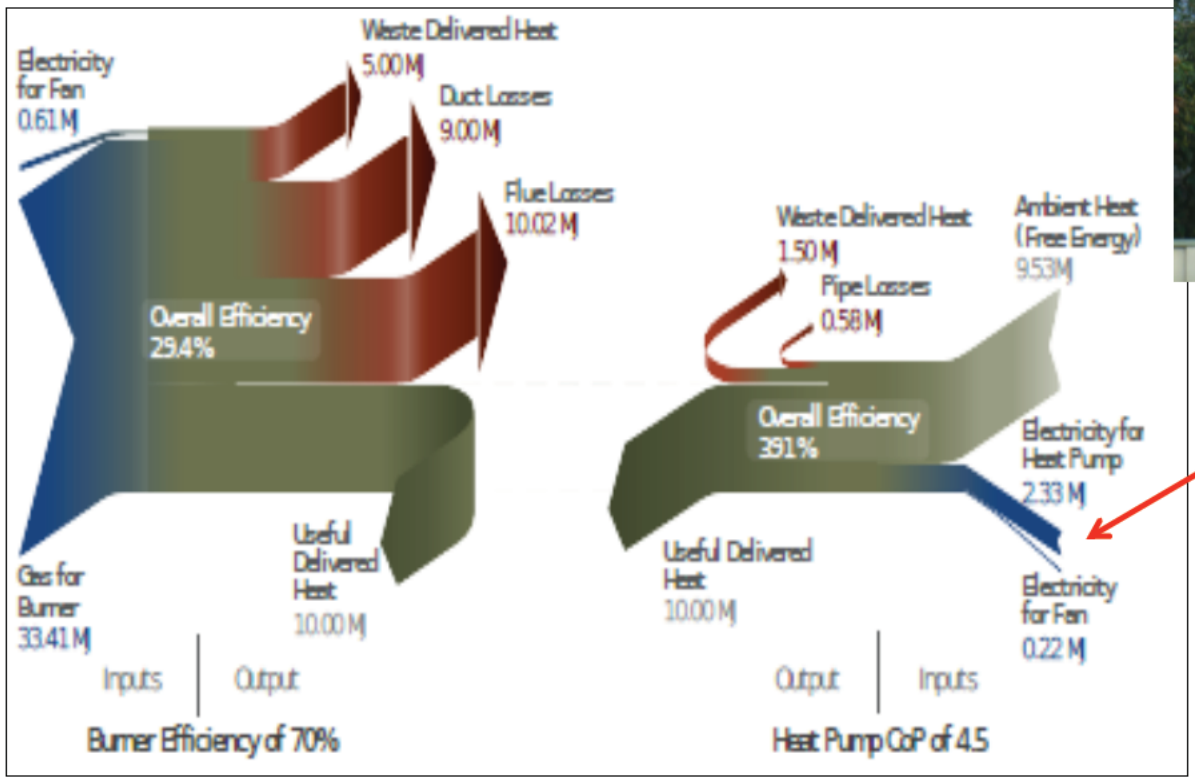


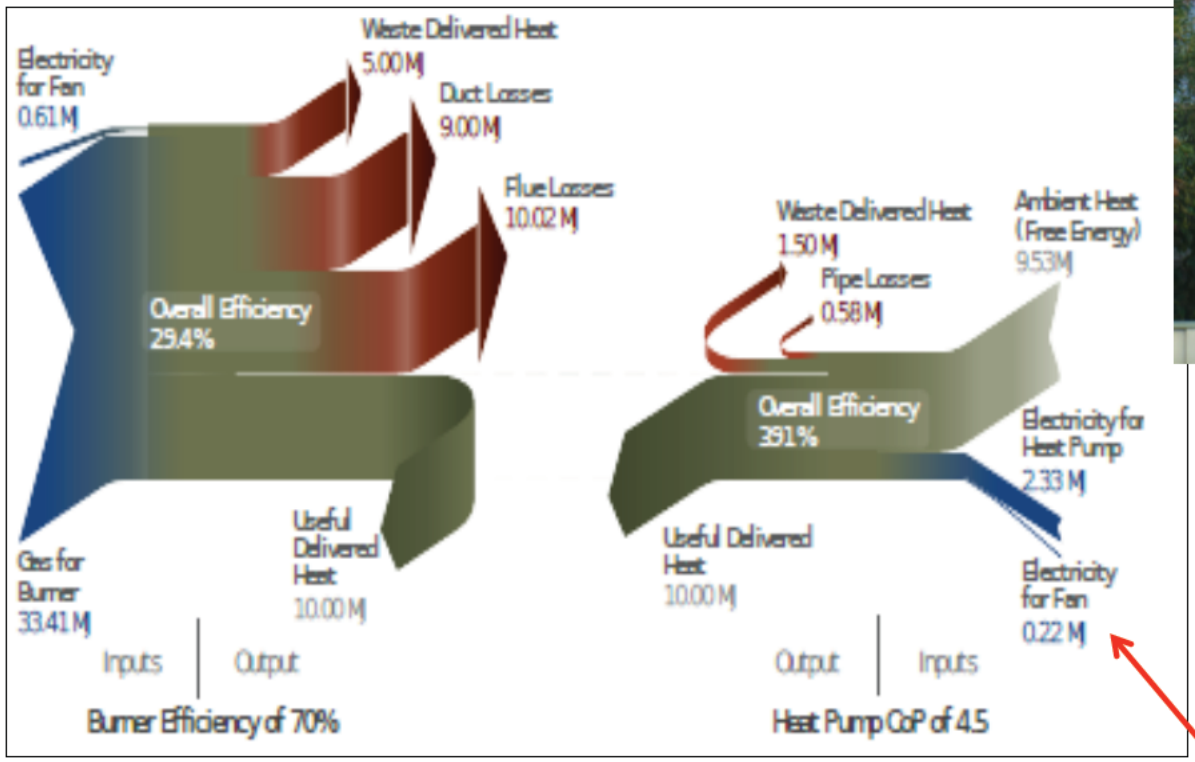
Diagram originally from "Zero Carbon Australia Buildings Plan" By Beyond Zero Emissions", 2013.

Also Figure 16 in "A short-lived gas shortfall", Forcey, McConnell, May 2017.

Gas heating system (left-hand side) requires 13 times more purchased-energy input than does a heat pump (right-hand side).



Drive your heat pump with your own solar PV electricity…


Electricity for Fan 0.61 MJ
Waste Delivered Heat 5.00 MJ
Duct Losses 9.00 MJ
Flue Losses 10.02 MJ
Overall Efficiency 29.4%
Gas for Burner 33.41 MJ
Useful Delivered Heat 10.00 MJ
Inputs
Output
Burner Efficiency of 70%
Waste Delivered Heat 1.50 MJ
Pipe Losses 0.58 MJ
Ambient Heat (Free Energy) 9.53 MJ
Overall Efficiency 391%
Electricity for Heat Pump 2.33 MJ
Useful Delivered Heat 10.00 MJ
Electricity for Fan 0.22 MJ
Output
Inputs
Heat Pump CoP of 4.5

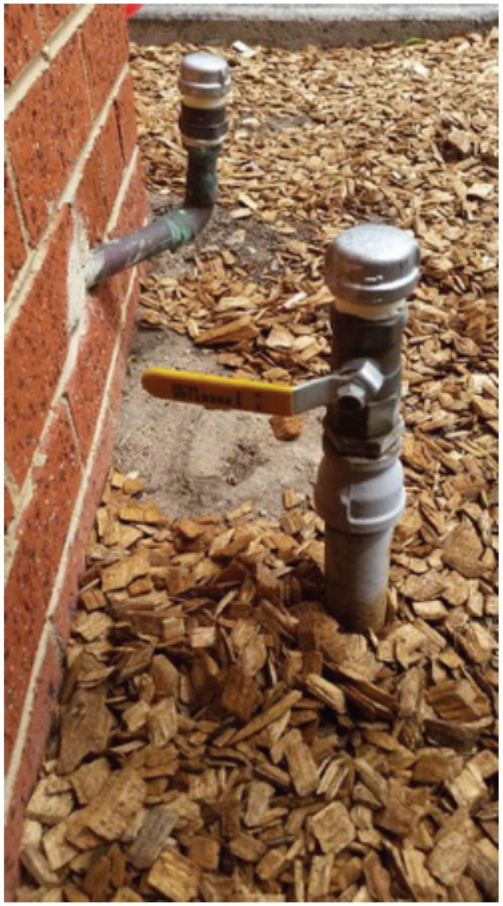
... day or night!


TESLA

Heat pump water heater:
1 part of electricity produces
4.5 parts of hot water.

How? 3.5 parts of renewable heat go in here.

In Australia, heat pump water heaters receive renewable energy certificates, just like solar PV.



My Efficient Electric Home

Tim | Home | Find Friends

My Efficient Electric Home

Public Group

Discussion

Members

Events

Videos

Joined | Notifications | Share

Write Post | Add Photo/Video | Live Video | More

Write something...

Photo/Video | Create Poll | Feeling/Activ...

PINNED POST

Richard Keech

March 9

WHO IS OFF OR IS GETTING OFF GAS?

A straw poll for the My Efficient Electric Home folk: who among you have already disconnected from mains gas in Australia? Can you respond with: yes | no intention | no, but intend; year of disconnection; postcode. I'll start: Yes; 2011; 3040.

John Mitchell, Sabrina Blom and 24 others

Like | Comment | Share

ADD MEMBERS

+ Enter name or email address...

MEMBERS 1,671 Members (69 new)

DESCRIPTION Edit

GROUP DESCRIPTION

This Australia-originated Facebook group is f...

See More

TAGS Edit

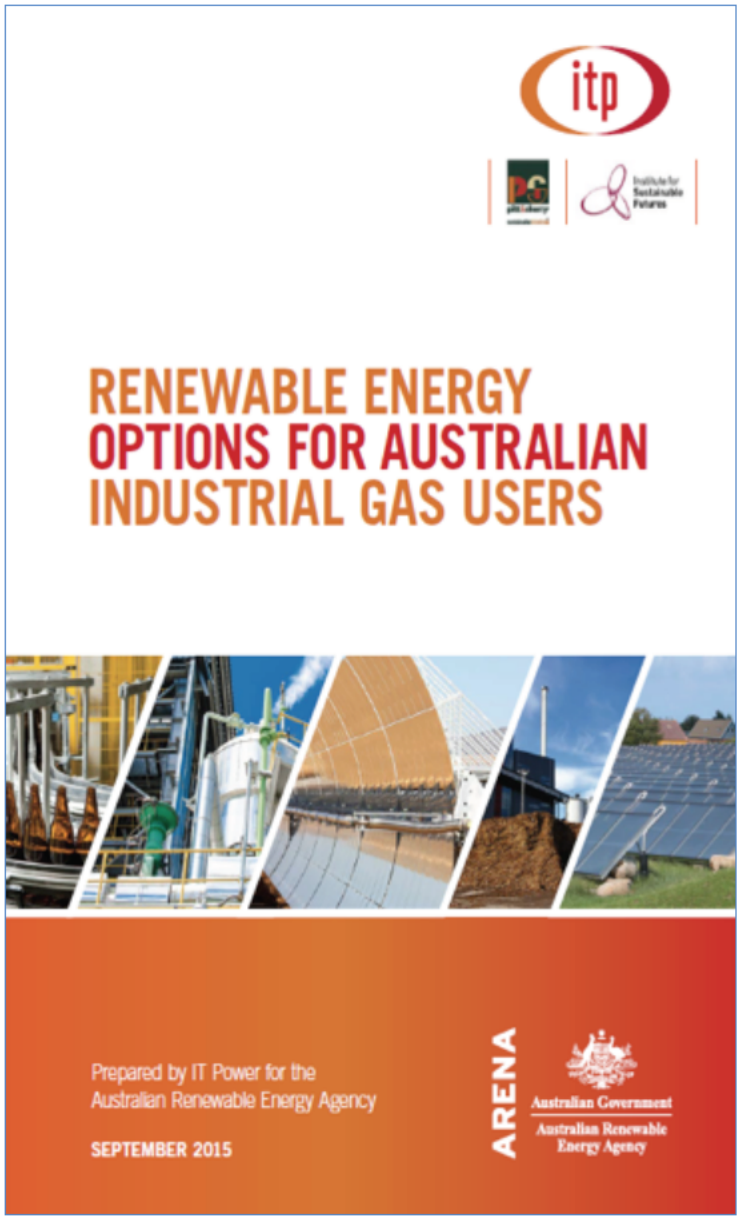
Heat pump · Renewable energy · Solar energy

LOCATIONS Edit

Facebook group:
"My Efficient Electric Home".
> 1,600 members.

Industrial-scale heat pump harvests renewable energy.

Nectar Farms on 100% renewables: "Why would you do it any other way?"



"A short-lived gas shortfall",
Forcey, McConnell, May 2017. (Figure 20)

Over the next 20 years,
~ 40,000 petajoules (PJ) of gas
will be produced in eastern Australia.

After that, there will still be another 110 years-worth of gas remaining (220,000 PJ).

(Includes proved and probable reserves, and contingent and prospective resources.)

Eastern Australian gas supply-cost curve

(Chart excludes gas expected to cost > $9/GJ to develop.

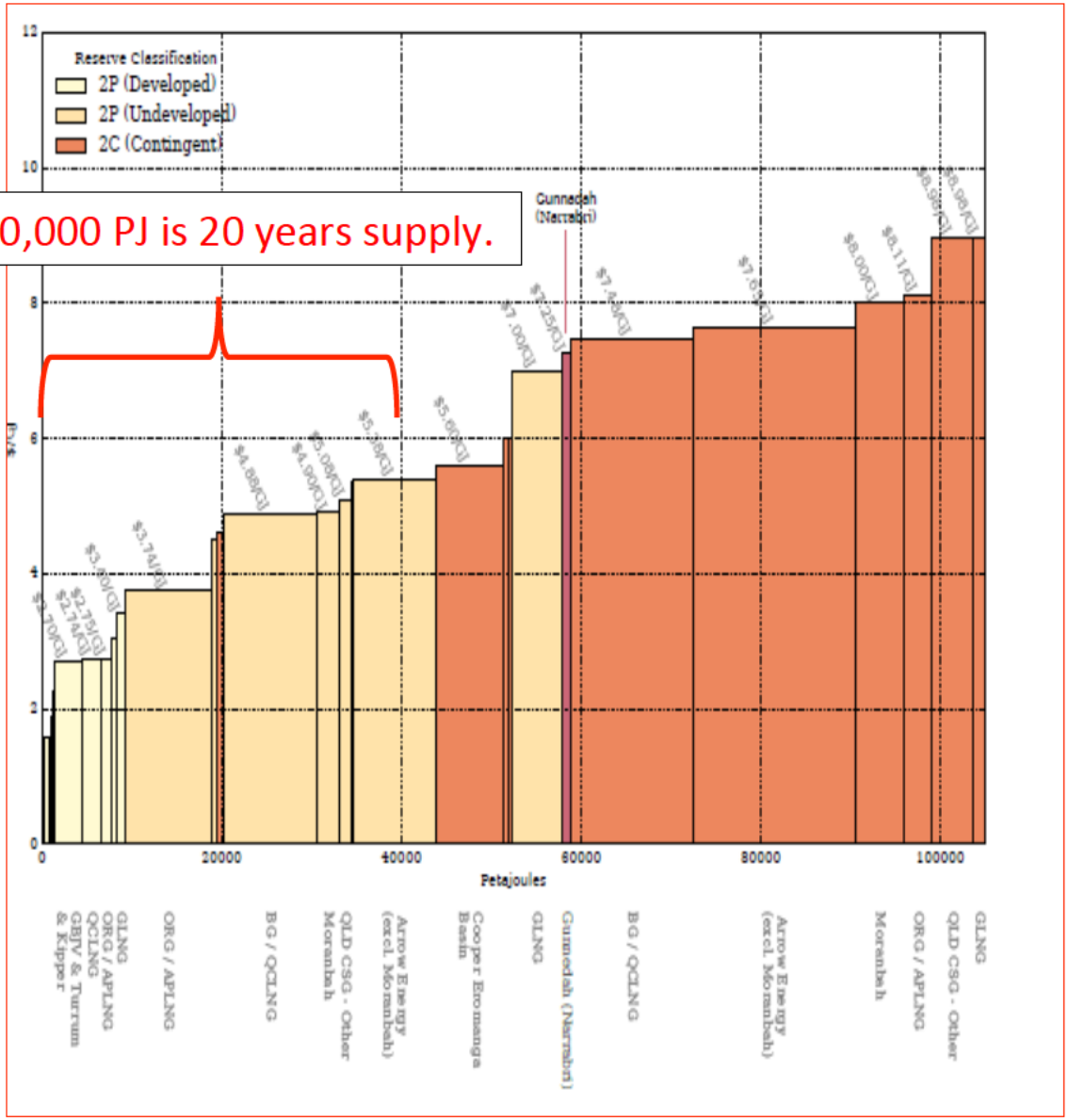
Costs quoted are development costs only and exclude transportation costs.

Gas at < $5.5/GJ can supply the next 20 years.

35 more years'-worth of gas is available at a cost in the range of $5.5 to $9/GJ.

See especially Shell/Arrow's reserves & resources.

"A short-lived gas shortfall", Forcey, McConnell, May 2017. Data from AEMO. (Figure 22)



Australian Financial Review 20 July 2017

Jul 20 2017 at 12:00 AM | Updated Jul 20 2017 at 12:00 AM

Origin Energy sizes up Beetaloo gas prize

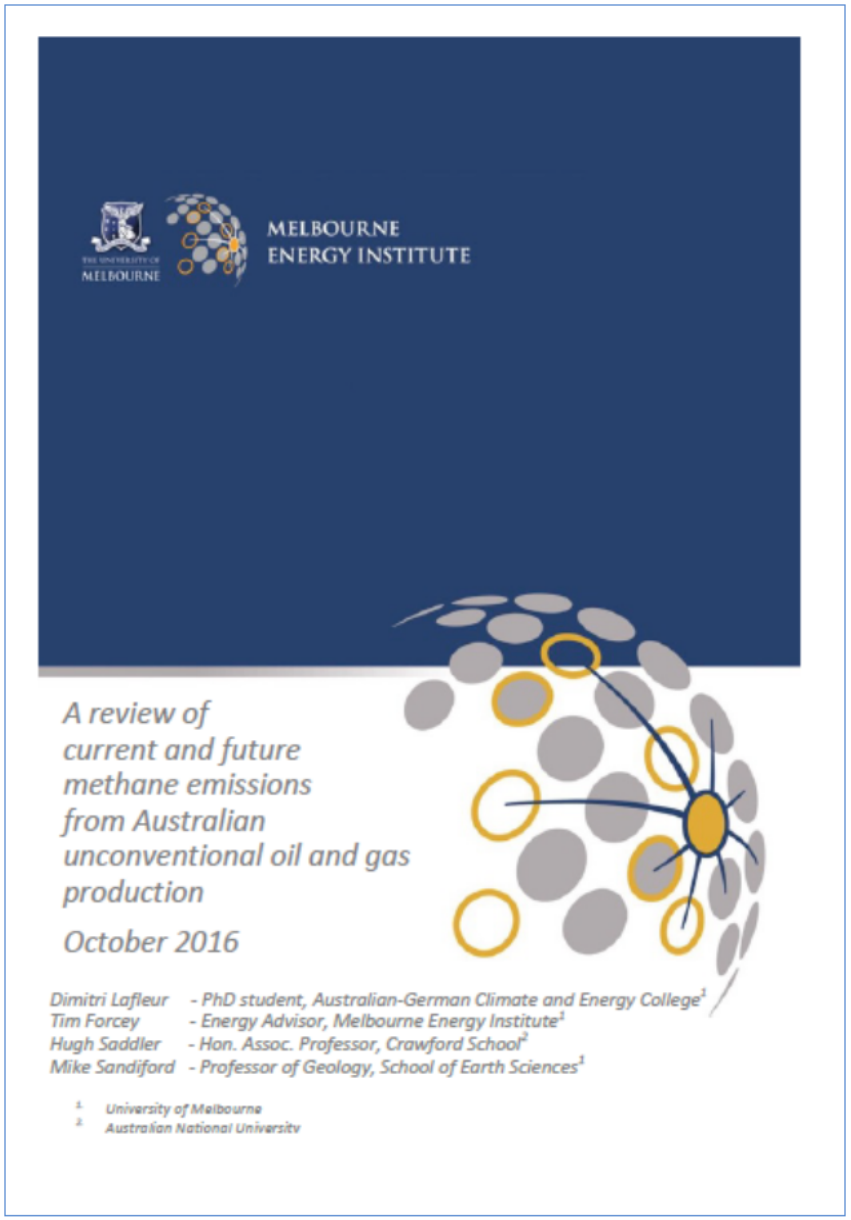
Origin chief geologist David Close is excited about the prospects for Beetaloo. Peter Eve

by Angela Macdonald-Smith

Origin Energy could be sitting on a multi-billion dollar gas resource in the Northern Territory, several times the size of the North West Shelf and with the potential to keep the energy-short eastern states market well supplied for years.

All it needs now is the green light to get gas flowing.

MONITORING AND QUANTIFYING METHANE EMISSIONS FROM OIL AND GAS PRODUCTION



"A review of current and future methane emissions from Australian unconventional oil and gas production",
Lafleur, Forcey, Saddler, Sandiford, October 2016.

University of Melbourne findings

- no baseline studies prior to start of CSG industry
- significant uncertainty about emissions reporting
- assumed emissions factors used instead of measurements
- assumed factors are outdated and lack relevance
- has been no rigorous audit of emissions
- if emissions from unconventional oil and gas production are significantly under-reported, this would have a large impact on Australia's national greenhouse accounts

3 Types of Methane Emissions from Gas Production

1). Continuous emissions from gas-industry infrastructure

2). Intermittent emissions from gas-industry infrastructure

3). Continuous methane bubbling out of the ground – away from infrastructure

1). Continuous methane emissions from infrastructure

Example: Vents on Queensland coal seam gas water lines

Infrared camera imaging report included as:
https://frackinginquiry.nt.gov.au/?a=423156

2). Intermittent methane emissions – from gas-field infrastructure

Example: Pipeline de-pressuring

Pipeline Vent, Epping, ND

Pipeline Vent, Epping, ND

3). Continuous bubbling out of the ground - “migratory methane emissions”

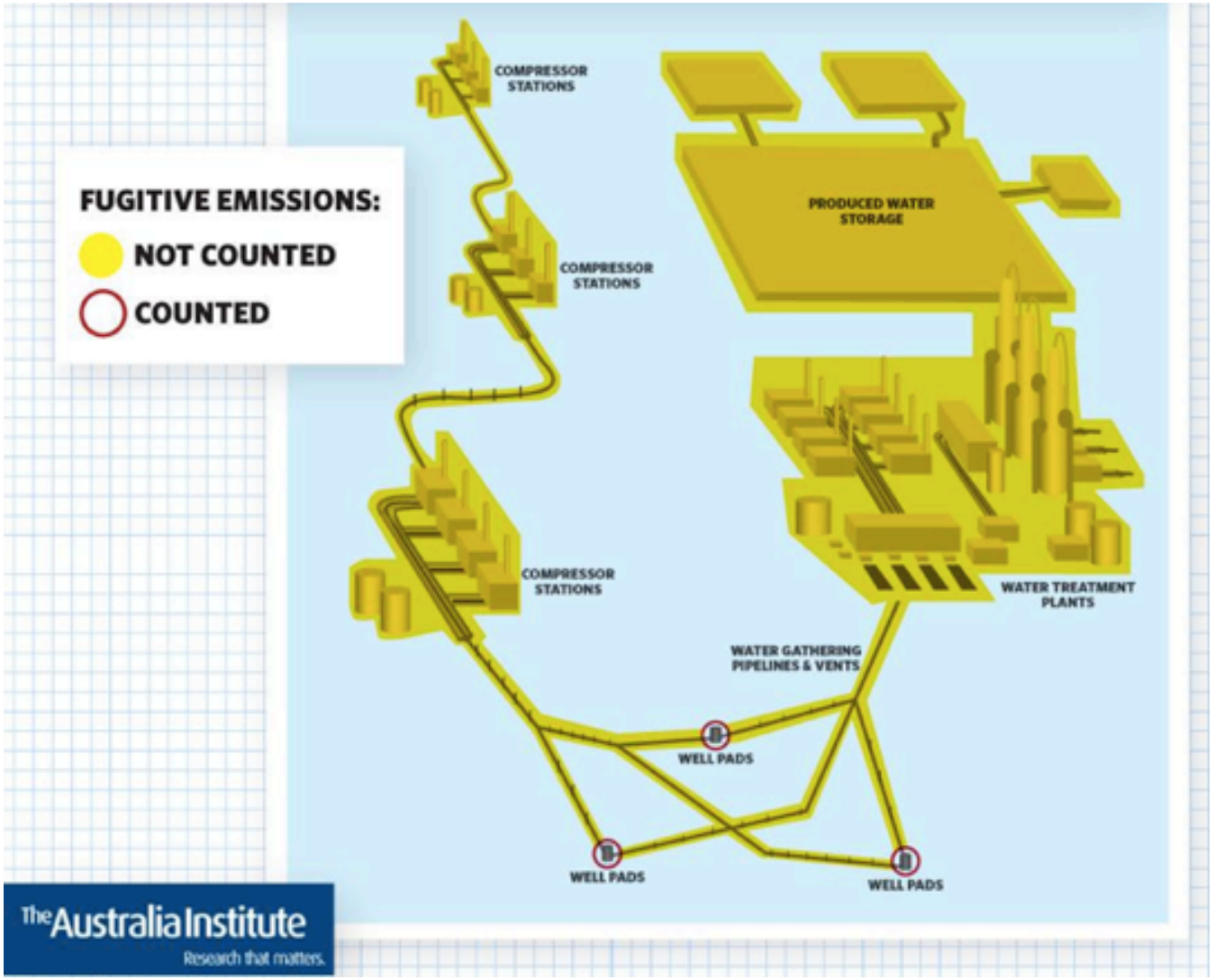
– CSG industry activity in production fields 5 to 6 km away has reduced pressure in the coal seams leading to possible up-dip flow of gas into the network of fractures and thereby into the Condamine River.

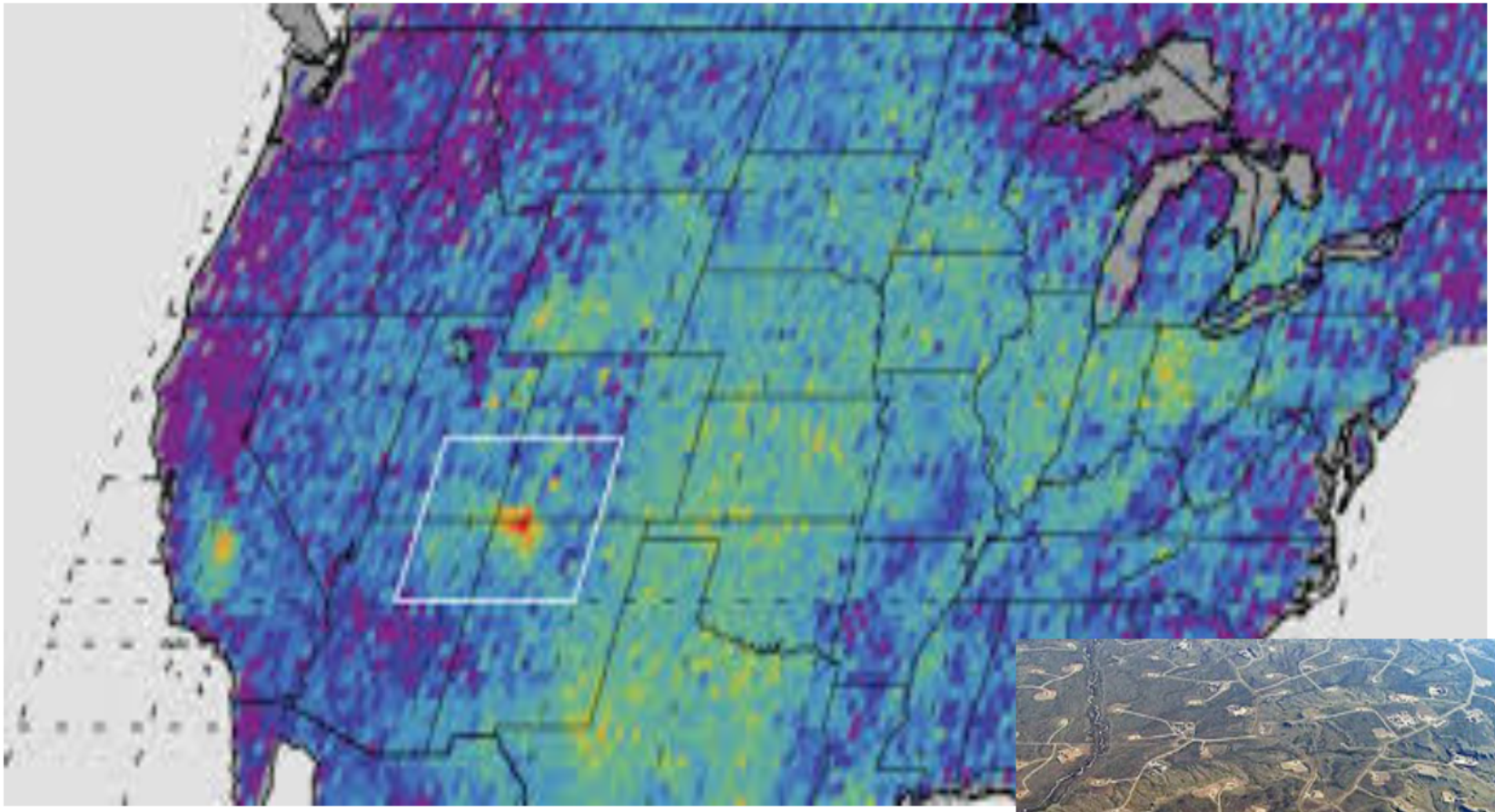
www.csiro.au

CSIRO

Methane seeps in the Condamine River

https://gisera.org.au/wp-content/uploads/2017/04/GISERA_MethaneSeepsCondamineRiver_4ppFactsheet_170310.pdf


FUGITIVE EMISSIONS:
NOT COUNTED
COUNTED
COMPRESSOR STATIONS
COMPRESSOR STATIONS
COMPRESSOR STATIONS
PRODUCED WATER STORAGE
WATER TREATMENT PLANTS
WATER GATHERING PIPELINES & VENTS
WELL PADS
WELL PADS
WELL PADS
The Australia Institute
Research that matters.



U.S. methane emissions “hot spot” seen from space

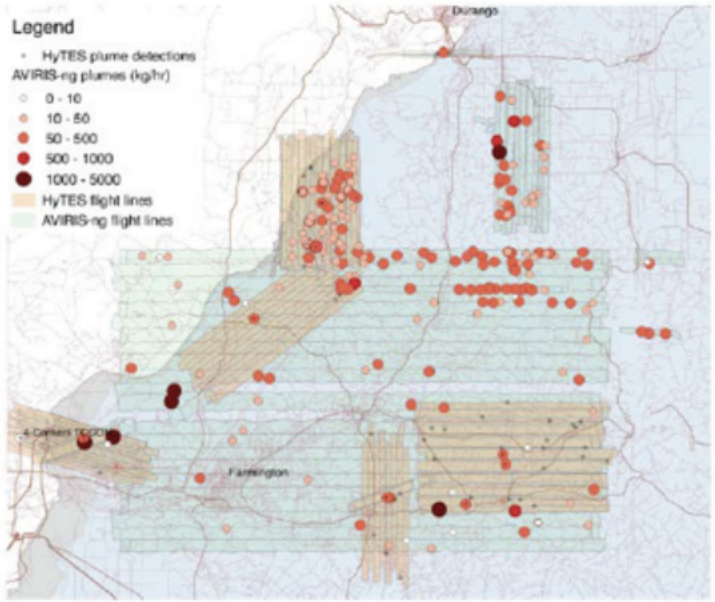
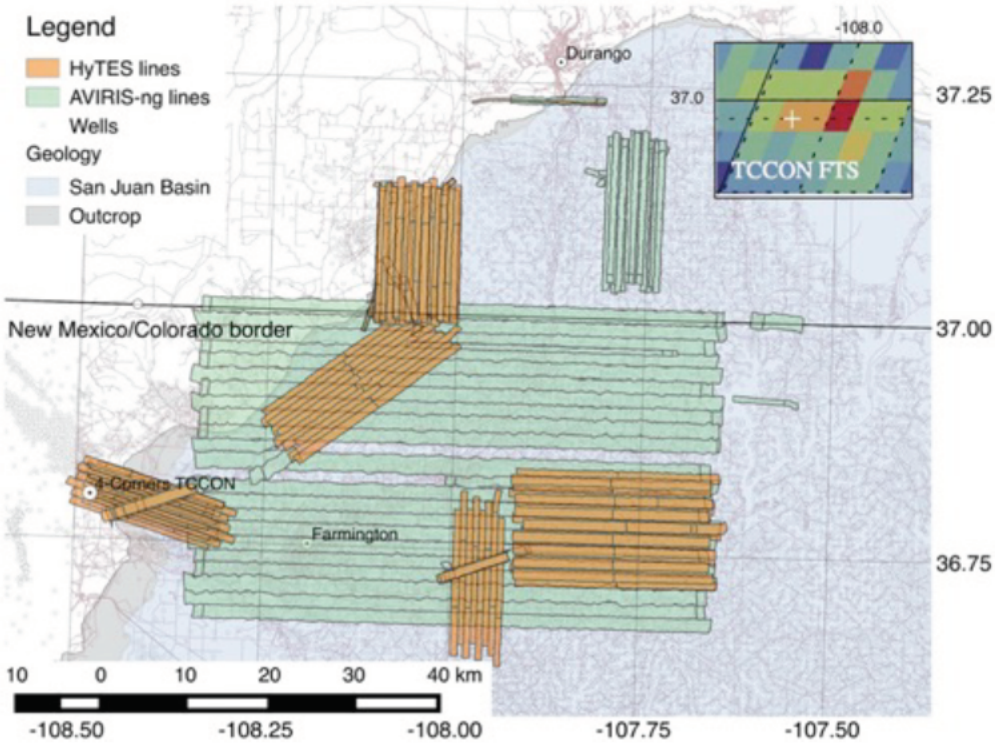
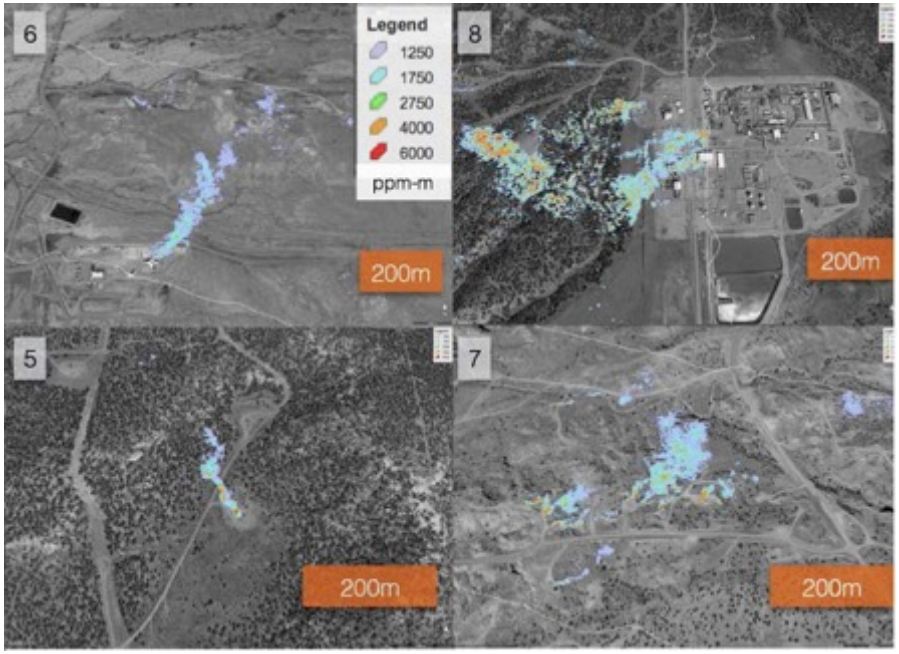


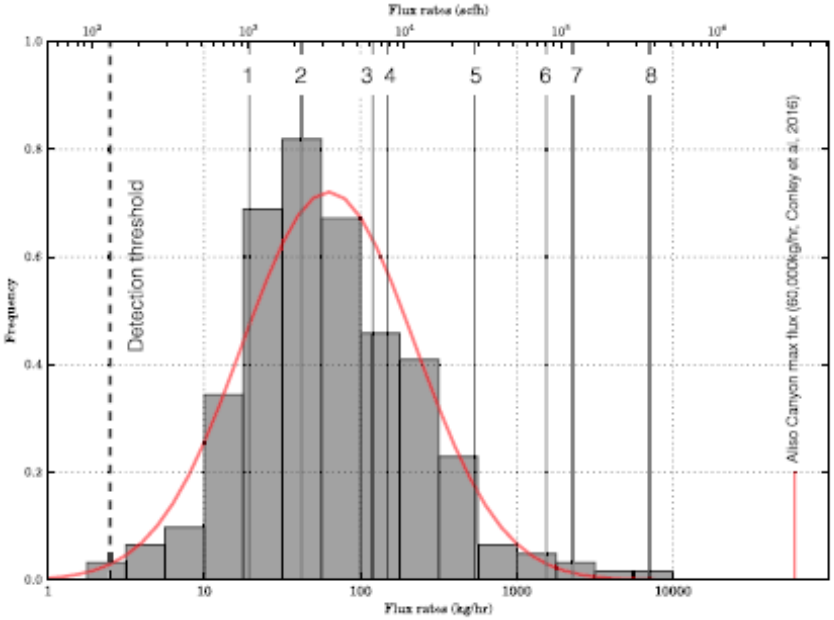
Fig. 6. Map of covered areas and detected point sources by HyTES (stars) and AVIRIS-NG (red dots with estimated flux rates color-coded).



http://m.pnas.org/content/113/35/9734.full


6
Legend
1250
1750
2750
4000
6000
ppm-m
200m
8
200m
5
200m
7
200m


2
30m


Flux rates (scfh)
Detection threshold
Frequency
Flux rates (kg/hr)
Aliso Canyon max flux (60,000kg/hr, Conley et al. 2016)

NT Fracking Inquiry

Tim Forcey - 2 August 2017

Thank you for the opportunity to present to this Inquiry.

First -- **my** background.

I trained as a Chemical Engineer - and worked for 30 years - in the petrochemical - oil - and gas industries - for companies such as ExxonMobil - BHP - and Jemena.

At those companies - I performed roles such as:

- leading engineering teams to design LNG plants
- overseeing the multi-billion dollar facilities of the Bass Strait oil and gas operations
- and – I have acted as Commercial Manager of the Queensland Gas Pipeline.

Also - from 2010 to 2012 - I worked at the Australian Energy Market Operator - - known as "AEMO" - - where I was the Gas Principal - responsible for delivering the annual Gas Statement of Opportunities.

From 2013 up to including this year - I have acted casually as an Energy Researcher with the University of Melbourne. I have authored or co-authored 7 major research reports that have covered aspects of gas, electricity, renewable energy, fuel-switching, energy efficiency, and energy storage.

Today - I will present information contained in the two most recent reports.

SLIDE 2 - TWO REPORTS

The second report shown on the right of this slide – covering methane emissions - has already been submitted to this inquiry. I shall come back to methane emissions later.

Rather – first I would like to cover the first report shown - which was published just recently – on the 18th of May. In that – we investigate gas supply-and-demand in the eastern Australian gas market.

That report is entitled *"A short-lived gas shortfall, a review of AEMO's warning of gas-supply shortfalls".* My co-author there is Dylan McConnell of the University of Melbourne.

SLIDE 3 – AEMO MIKE CLEARY

Back on the 9th of **March** this year -- AEMO published its **most** recent Gas Statement of Opportunities. In that report - AEMO cautioned that within 18 months - "shortfalls" - could occur in eastern Australia - either in the supply of gas - or in the supply of electricity generated by burning gas.

AEMO suggested solutions to these potential energy shortfalls which included the construction of new pipelines – such as from the Northern Territory – or the development of new coal seam gas fields such as Narrabri in New South Wales.

This warning of gas shortfalls was heard by the Prime Minister who – very quickly – in April - announced plans to implement the "Australian Domestic Gas Security Mechanism". This was to allow the government to impose LNG gas-export controls when there is a gas-supply shortfall in the domestic market. The Prime Minister also recognised that eastern-Australian wholesale gas prices are at historically high levels - as they are now linked to international prices.

Our report investigated AEMO's claims.

We found - that though in eastern Australia - there **is** a shortage of "cheap" gas - -a gas-supply shortfall - is unlikely to occur.

SLIDE 4 – EXPENSIVE GAS

Why is gas now expensive? We found that the former gas "buyer's market" that prevailed in eastern Australia has shifted to become a "seller's market". Where before - the wholesale gas price had been nearly the cheapest in the developed world - at $3 to 4 per gigajoule - today - it is now nearly the most expensive gas in the developed world - with offers to gas buyers at prices up to $20/GJ.

These high gas prices are a result of:

- the eastern-Australian gas market being linked to overseas benchmarks
- over-building of gas export capacity with contractual export over-commitments
- an opaque gas market and opaque gas-producer behaviour
- and - - the high costs of producing unconventional gas - now estimated to cost around $7/GJ to develop. This excludes pipeline transportation costs.

Given these factors - a return to cheap gas – in eastern Australia - is unlikely.

But what about AEMO's announcement of impending gas-supply shortfalls?

SLIDE 5 – PIE CHART

We found that the size of AEMO's forecast shortfall was very small, amounting to no more than around 0.2% of annual supply - of either gas or electricity. The scale of that is represented in this pie chart – with the potential gas supply shortfall represented by the small black sliver.

We found that even **this** - small - gas-supply shortfall is unlikely to occur for a number of reasons.

SLIDE 6 – WHY NO SHORTFALL

First - - the rapid rise in the price of both **gas** - and electricity - in eastern Australia - is reducing industrial activity. Industrial decline will reduce energy demand by an amount far larger than AEMO's forecast supply gap. Indeed, only eleven days after announcing its supply-gap concerns, AEMO essentially closed the gap when it published, on its website, updated (lower) electricity-demand forecasts.

In addition to this destruction of industrial energy demand - other reasons that gas-supply shortfalls are unlikely to occur - - include:

- a rapid increase in the amount of electricity generated by renewable sources – wind and solar – which is now available at lower cost than what can be produced by burning gas

- a new focus on market-driven - - electricity demand response mechanisms – whereby electricity demand can be reduced during critical times - with customers compensated for reducing their demand.

And lastly - - gas customers are choosing to economically fuel-switch away from gas - to using more economic energy sources - such as heat pumps.

Given the significance of our findings – it was necessary that we challenge AEMO's urgent warning of shortfalls - and that we challenge AEMO's suggested solutions - new gas pipelines –and the development of new gas fields – solutions that focus only on the gas-supply side of Australia's energy equation.

We found that AEMO sent the wrong message when focusing attention on a very small, very unlikely, and ultimately short-lived gas-supply shortfall concern. Furthermore, AEMO's suggested new pipelines and new – expensive - gas fields are false "solutions". These massive fossil-energy infrastructure investments are not needed to address a supply shortfall that is not likely to occur.

Furthermore – such investments in gas infrastructure will not reduce the wholesale price of domestic gas. New gas sources – including unconventional gas sources in the Northern Territory - are expensive to produce, and in any case, in the "seller's market" that now prevails, domestic-wholesale gas prices remain linked to international benchmarks.

AEMO may have heard our message – because…

SLIDE 7 – AEMO RETRACTS

…less than a month after we published our report - AEMO – now under the management of a new CEO – declared that revised modelling did **not** indicate a gas supply shortfall - and gas production would be **sufficient** to meet gas demand. And there was **no** threat - of gas-supply shortfalls causing electricity blackouts.

Let me summarise the domestic gas demand situation - in eastern Australia. Here I am not talking about gas that is exported – rather just the gas that is consumed right in eastern Australia.

SLIDE 8 – DECLINING DEMAND

The demand for gas in eastern Australia peaked in 2012 - - - and by 2016 had fallen by 16%. AEMO now forecast - gas demand will fall by another 9% by 2020 - to reach a level - just 74% of the 2012 peak.

The demand for gas is declining in every sector. Less gas is used in buildings for heating – hotwater – and cooking. Less gas is used in industry. And less gas is being used each year to generate electricity.

One - **very** significant finding of our research - is - that if -- electricity is what you seek…

SLIDE 9 – RENEWABLES CHEAPER THAN GAS

… it is now cheaper - to go out and build a brand **new** wind or solar PV facility – and to collect electricity from that… …that is cheaper… than feeding high-priced gas into an existing gas-fired power station.

So you might ask then – why is gas still being fed into gas-fired power stations - in places like South Australia. Well - clearly as yet – not enough wind and solar has been built. But across eastern Australia, we do see a massive construction wave of renewables – thanks to the various renewable energy targets at territory, state, and federal level – but if these high gas prices hold as I expect they will – we will continue to see more and more renewable energy deployed - until very little gas is burned to generate electricity.

So that is the National Electricity Market. What about on the home front …

SLIDE 10 – GAS HEATER

… where for example in Melbourne - many people have used gas for decades – to heat their water and living spaces – and for cooking?

Well, here is another remarkable finding – from the University of Melbourne. We found that - instead of using gas – it can be far cheaper - for many Australians - to heat their homes - using - - - - - their **air conditioners**!

SLIDE 11 – A HEAT PUMP RECOVES RENEWABLE ENERGY

At home – where I live with my wife in Sandringham Victoria - we now use our reverse cycle air conditioners to heat our house at a cost just **one-third** - of what – formerly - it cost us - to heat with gas. One-third. Our study found that an average home in Melbourne – could save over $600 per year – by heating with their air cons. We found – that were Victorians to heat - with air cons that they already own – but do not use – in winter – collectively Victorians could save a quarter of a billion dollars a year. I think this might be the biggest consumer win ever.

But most Australians remain unaware that reverse-cycle air conditioners – which are more properly known as heat pumps in other parts of the world – can be cheap to operate - because – heat pumps harvest free renewable ambient heat from the air outside your home.

This slide - shows - that if you own this particular heat pump – when you buy 1 unit of electricity – to drive the compressor, fans, and controls within this device – you get 6 units of heat coming out of it. Those 5 extra units of heat – are drawn from the "thin air" outside your house – by the magic of the refrigerant cycle contained within this heat pump.

I have made dozens of public presentations on this concept. So I know it can be hard for folks to get their head around the idea - that you can get heat out of what is basically a refrigerator running in reverse – but the idea is catching on. Certainly – even in Melbourne – there are many new homes being built that instead of having two separate heating and cooling systems - gas heaters and then evaporative cooling – it makes more economic sense for building develops to just install - air conditioners.

With this next diagram…

SLIDE 12 – SANKEY DIAGRAM

… I provide a bit more technical insight to these comparative economics. This diagram shows that over on the left side there - to produce 10 megajoules of useful heat for your home – with a ducted gas system – you might have to buy 33 MJ of gas – plus some electricity to run the blower. Whereas – using a heat pump to produce the exact same amount of heat – you may only need buy two and a half MJ of electricity.

This is a factor of 13 times less energy you have to buy. And since gas is not one-thirteenth the cost of electricity – on a per MJ basis - perhaps this drawing helps illustrate why **our** home heating bill is now one-third what it used to be.

SLIDE 13 – SANKEY WITH SOLAR PV

And let's also not forget that these days – in many homes – people are generating their own electricity – with rooftop solar PV panels … and are asking – "what can I do with all this electricity? I don't want to have to put it out on to the grid." A heat pump is a perfect fit. Generate you own electricity and heat your home – not only by day…

SLIDE 14 – SANKEY WITH SOLAR PV & BATTERY

… but even by night -- as home batteries - such as the Tesla Powerwall shown here – become more commonplace.

Heat pumps are also a good fit for heating water…

SLIDE 15 – HOT WATER HEAT PUMP

… as you see here. In Australia, in some circumstances – if you install a hotwater heat pump as **we** did at our home - earlier this year – you can earn renewable energy certificates just the same as you would were you installing a set of rooftop solar PV panels.

In the media – we often hear about homeowners - thinking - about leaving the electricity grid. But what is actually happening ...

SLIDE 16 - FACEBOOK GROUP

… as you would see at the Facebook group "My Efficient Electric Home"… … is that people are leaving the **gas** grid – disconnecting from gas - and having their gas meters taken away.

A study by the Alternative Technology Association – found - there is no longer any **economic** need - for any new home – or any new suburb – anywhere in Australia - to be connected to the gas grid.

Taking that advice, it was reported that Riverview, a suburb straddling the ACT-New South Wales border – will not be connected to the gas grid.

The prevalence now - of efficient heat pumps – means that in homes across Australia - gas is being very un-economically and very un-productively used - you could even say wasted - when this highly-valued gas - could be more productively used elsewhere.

Governments - and other stakeholders – who are interested in making gas more available – say - for industrial use - could inform people of these home economics - so that less gas is wasted in homes and other buildings.

At the University of Melbourne - our research found that if less gas were wasted in Australian buildings – over time – enough gas could be freed up to nearly supply all our future industrial demand for gas.

Around the world – in places like China, Europe, New York, and Japan – governments are subsidising building managers and home owners - to heat with heat pumps - and move away from heating with gas, oil, or coal.

In Australia - there are **no** such government incentives for space-heating with heat pumps – and in fact there have been rules in place to favour the use of **gas** - over heat pumps.

SLIDE 17 - IT POWER REPORT – NECTAR FARMS - INDUSTRIAL HEAT PUMPS

Like homes - some industries - can also - economically switch away from gas to renewable alternatives. It was recently announced - that vegetable grower Necter Farms - was looking in to energy options for its new glass-house facilities in Victoria. Necter Farms opted not only for wind and solar PV to meet their electricity needs - but also industrial-scale heat pumps to provide heat. A report by IT Power for the Australian Renewable Energy Agency – shown here - describes how gas used in industry - could be replaced by heat pumps and other sources of renewable energy.

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Now - I would like to switch from gas demand - and talk about gas reserves in eastern Australia.

Another reason - that a gas supply shortfall is unlikely - is that there is plenty of gas in the ground across eastern Australia. It's not cheap to develop – but there is plenty of it.

This chart…

SLIDE 18 - GAS RESERVES

… graphically compares Eastern Australian gas reserves and resources. First on the left-hand side - it shows the volume of gas that will be produced in eastern Australia over the next 20 years - for domestic and export LNG purposes. This is about 40,000 petajoules of gas - 20 years' worth.

That is a lot of gas - but beyond that first 40,000 PJ – there is a large yellow block shown on the chart – depicting a further 220,000 PJ of reserves and resources that have been identified in eastern Australia and reported by AEMO. 5.5 times as much as will be produced over the next 20 years. So all this gas could take us out to 130 years from now – at current rates of LNG gas export - and domestic gas use. This is the gas identified just in eastern Australia defined as QLD, NSW, VIC, TAS, and SA. So there is no Northern Territory gas included here.

Now -- there are different ways to categorise gas reserves. Gas reserves can be classed into "proved reserves", probable reserves, contingent resources, and prospective resources - with each grade indicating greater uncertainty about the existence and producibility of that gas. So - with the next chart – I'll drop off the most uncertain of these categories – the volume of gas classed as Prospective Resources.

SLIDE 19 - GAS SUPPLY CURVE

That leaves me with this chart – which is a more detailed - gas cost-supply curve. This is data from AEMO – but as far as I know – we were the first to plot it in this way – so you may not have seen this before.

This chart quantifies and ranks – on a production-cost basis - all the reserves and contingent resources for all the eastern Australian gas fields.

At the lower-cost end of the scale you can see – for example – Bass Strait gas at a production cost of $2.70/GJ.

After that – as we move across 20 years' worth of gas, that 40,000 PJ, we move up to gas that costs around $5.40/GJ to produce. Beyond that – on this chart – there is still another 35 years' worth of gas, with production costs rising to $9/GJ.

This chart shows eastern Australian gas only - no Northern Territory gas. However AEMO and their consultants - did peg Northern Territory gas at a production cost of around $6.50 per GJ. But if you wanted to send NT gas to the eastern Australian market, you would have to add on - the costs of transportation by pipeline. This would increase the costs of NT gas delivered in to the eastern Australian market by another few dollars per GJ.

The point of this chart is that eastern Australia already has stacks of gas, far more than will be produced in the next 20 years or even in the next 40 years. Yes - the production cost of some of that gas is said to be high – in the same league as the production costs of NT gas.

But it does raise the question – with all this gas already identified in eastern Australia – how can anyone possibly be talking about a supply shortfall? Just where is this gas hiding?

A place to look is at the gas identified as being under the control of Shell/Arrow. We know of the 6 LNG export trains operating at Gladstone, QLD. Shell bought two of those when they bought the company QGC. But we might forget that before this - Shell/Arrow had gas identified, plans in place, and regulatory approval - to construct another 4 LNG trains at Gladstone – to bring the total to 10. So - the Shell/Arrow gas makes up a large part of this missing gas. We don't hear too much from Shell/Arrow about this gas, although back in March and April when the subject of gas supplies was a hot topic right up to the Prime Minister, Shell did announce - they would make - some relatively small additional volumes of coal seam gas available from the Tipton, Daandine, and Ruby fields.

Why is Shell just sitting on this gas?

Shell is a global player in the gas industry - and they would have a view as to when and where they can and can't make money by developing more gas fields – either for domestic or export markets. I surmise Shell are aware of the current softness in the global gas market and are content for most of this gas to remain in the ground. Developing it would only compromise their positions elsewhere in the global LNG market. But this Shell-controlled coal seam gas is a fairly obvious competitor versus Northern Territory gas – should such a contest ever arise.

So - I have been going on for a while here about the eastern Australian gas and electricity markets. But one thing I noticed is that this Panel's interim report seems to be silent on the topic of Northern Territory gas supplying the east coast market.

I don't know why the Interim Report is silent. I don't think you **should** be silent on this topic – because it is sure - being talked about – out there.

SLIDE 20 – BEETALOO AFR EAST COAST

For example - from the Australian Financial Review - a few days ago regarding Origin and the Beetaloo Basin. I quote "Origin Energy could be sitting on a multi-billion dollar gas resource in the Northern Territory several times the size of the North West Shelf and with the potential to keep the energy-short eastern states market well supplied for years". And just yesterday – there was a headline in the Alice Springs News Online saying NT gas could bring down eastern Australian energy prices.

So – following what you have heard me say today - and what you have heard others say – I think the topic of NT gas supplying the eastern states - should be discussed in the Panel's final report.

At the University of Melbourne – we found there will **not** be gas supply shortfalls in eastern Australia. The Australian Energy Market Operator – now under the management of a new CEO – has backed away from their earlier position. But nearly everyday – I still see headlines about looming east coast energy shortages. This story is just too good to kill – so I think the words "shortage" and "shortfall" will continue to be popular in the media - despite our best efforts at shedding some light on the topic.

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SLIDE 21 – MONITORING AND QUANTIFYING METHANE EMISSIONS

This concludes my prepared remarks about the eastern Australian gas and electricity markets.

I am happy to take questions on that topic later - but now – I'll move on - to my second University of Melbourne research topic for today - monitoring and quantifying methane emissions from oil and gas production.

As I mentioned at the start – back in October 2016 – we published the report entitled…

SLIDE 22 – UoMEI REPORT

… "A review of current and future methane emissions from Australian unconventional oil and gas production".

A few months ago - I submitted this report - to this inquiry and I can see in your Interim Report that some of the points we made - have been taken on board. So I thank you for that.

SLIDE 23 - OBAMA AND TRUDEAU

Although climate action in the **US** - has recently hit a rough-spot - the importance of getting emissions of the powerful greenhouse gas - methane - under control - was emphasised a bit more than a year ago in March 2016 - by US President Obama and Canadian Prime Minister Justin Trudeau. One year before that – the Obama Administration had announced "a new goal to cut methane emissions from the oil and gas sector by 40 to 45 per cent …".

SLIDE 24 – UoMEI REPORT

I won't go through all the findings of our University of Melbourne review – because I think the panel is across those. But one key point - is that here in Australia - methane emissions from unconventional gas production are not being properly counted.

An example is from the coal seam gas fields in Queensland. In their environmental effects statements – the proponents of the CSG – LNG projects claimed - they would emit hardly any methane at all – perhaps as little as just 0.1% of production. However there were never any regulations put in place to hold the CSG-LNG industry to those claims – as we shall see.

SLIDE 25 – 3 TYPES OF EMISSIONS

Briefly - let me classify methane emissions from oil and gas production into 3 types.

First - Continuous emissions from gas industry infrastructure – such as wells, pipelines, and processing plants.

Number 2 - Intermittent emissions from infrastructure.

And lastly – methane that comes bubbling up out of the ground at some distance away - from any infrastructure.

SLIDE 26 – CONTINUOUS EMISSIONS FROM INFRASTRUCTURE

Continuous emissions from infrastructure occur - where the infrastructure has been intentionally designed to vent methane continuously. An example are vent lines - on coal seam gas water-pipelines in Queensland. In February I hired – from Singapore - a sophisticated infrared camera – valued at around $137,000 – and travelled to the coal seam gas fields – along with an ABC journalist - to get some images of these vents.

Of course a difficulty with methane is that it is a colourless and odourless chemical that is lighter than air. So you can have volumes of methane pouring from these vents and you would pass by and not even know. However with this sophisticated - military-grade camera - you can produce a visible image of this invisible gas.

In their Environmental Impact Statements – the CSG producers committed to “zero-venting” of methane. But that is not what we see. There are thousands of these vents already in Queensland and there will be thousands more. The quantity of methane emanating from these vents has never been declared by any - body.

We do know that a basis for official reporting of methane emissions from the coal seam gas industry - is to use factors and assumptions from the US conventional gas industry. These CSG water pipelines and vents – can I say – are quite “un- conventional” and so we conclude that these vent emissions – as one example - are not accounted for.

But you could say – this is coal seam gas - whereas in the Northern Territory we are talking about shale gas – so it will be different.

So perhaps the most important learning here - is not so much about methane – but rather more about what is said by project proponents in Environmental Impact Statements - and then what actually happens in the field – and the community trust that is built – or lost – when commitments made during the project approval phase - later - are not fulfilled.

SLIDE 27 – INTERMITTENT METHANE EMISSIONS

Another category of emissions are **intermittent** emissions from infrastructure.

An example would be where the gas company must – for any number of reasons – depressure a pipeline. Now since these emissions are intermittent – it can be challenging for a regulating agency to know that emissions of this invisible gas are occurring - or to quantify how **much** gas - was emitted. Locals in the Queensland CSG fields – farmers – do report very loud – high-pitched noises or roaring sounds - coming from gas-field infrastructure. Sometimes these noises occur at night. And again let me remind – that the CSG-LNG proponents – said there would be "zero" venting of methane.

The images you see here are from North Dakota – where the community has - ready access to these special infrared cameras. Here in Australia - you can imagine that if a farmer from Queensland rang me up - about a screaming pipeline blowdown event – it might take me a while to rustle up the camera from Singapore – get it clear of customs and on a plane – by which time the event would be finished. So this can make identification and quantification of these releases challenging for any independent observer in Australia.

SLIDE 28 – CONDAMINE RIVER METHANE EMISSIONS

A third type of methane emissions – you see here – is where methane starts to bubble up out of the ground kilometres away from any gas-industry infrastructure. These can be referred to as migratory emissions – because the methane gas migrates from some disturbance underground – until it finds its way to the surface and up into our atmosphere.

Since methane is a colourless and odourless chemical, a passer-by is most likely to spot these emissions coming out of a body of water such as the Condamine River you see here. Methane coming up out of dry land you would probably hardly even notice.

Recently the CSIRO – working as part of the gas-industry funded GISERA alliance – published a fact sheet that stated – amongst other things – that "CSG industry activity in production fields 5 to 6 kilometres away - has reduced pressure in the coal seams - leading to possible up-dip flow of gas into the network of fractures and thereby into the Condamine River".

In another report written by my co-author and ex-Shell Geologist Dimitri Lafleur – he notes that the aquitards – the clay layers that might seal off gas flow - are "thin or absent" in the region of the Condamine River. So clearly this region should have been a geological-no-go-zone for the CSG industry, but instead you will find thousands of gas wells there today.

SLIDE 29 - SCHEMATIC DIAGRAM OF POSSIBLE EMISSION POINTS

In the past – in Australia – and also overseas – there has been much focus on the methane emissions associated with improperly installed or failed wellbores. In the USA - this interest has been because of the potential impact on wells drilled by landholders to provide their own drinking water. And the same is true in Australia.

And also, in Queensland, around the start of the enormous CSG industry we now see – the first infrastructure out in the field - were the wells. So wells and well completions – and well-pad equipment - has had a fair bit of scrutiny. And when you look at the actual Australian-Government-reported methane emissions inventory – as my co-author Hugh Saddler did – it seems as if emissions from wells and well-pad equipment is all that is reported. But what about all of the other infrastructure and potential emission points – as illustrated by this diagram. Pipelines, water gathering lines, compressor stations, and processing plants.

If this Panel has been through our Melbourne Uni report I won't go through it again – but I encourage equal focus be put on all gas industry infrastructure - because all of it can be a source of methane emissions – and all of it can be a source of the so-called super emitters – that I will talk about next.

SLIDE 30 – FOUR CORNERS USA FROM SPACE

So I have described - some of the challenges for anyone trying to get on top of - and anyone trying to stay on top of - methane emissions from unconventional oil and gas production.

Our University of Melbourne report describes the various ways that researchers in North America are trying to develop methods. One you see in this slide. It illustrates how satellite data was used to identify a methane-emission hot spot over the so-called Four-Corners region of the United States. This is a location with coal mines, conventional oil and gas, shale oil and gas, and it is also - the largest coal seam gas - producing region in the world.

A very interesting paper that was published - after the cut-off date for our research - took a closer look at this Four Corners "methane anomaly".

SLIDE 31 – FRANKENBERG

This paper by Frankenberg et. al. – is entitled "Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners Region". The researchers describe how they were able to instrument air craft - fly over this region of interest - and with the sensing equipment onboard…

SLIDE 32 – FRANKENBERG RESULTS

… they were able to - not only identify 250 individual methane plumes – but quite amazingly in my view – to also quantify how much methane was being emitted at each of these locations. Emissions ranged from two **kilograms** per hour - to eight **tonnes** per hour. The researchers then went down - on to the ground - and were able to confirm emission sources such as equipment at a well pad, a coal mine venting shaft, a well-completion site, a gas processing plant - and so on.

One finding from this research – as reflected in the title of the paper – is that these top-down aerial surveys find a heavy-tail distribution of emission sources. In other words – a small number of emission sources - can emit a large amount of methane. These have been dubbed “super-emitters”.

Some researchers have tried bottom-up approaches - where you try to measure how much methane is emitted from individual pipe fittings or gasfield instruments.

This is a useful - if time-consuming and costly exercise – with the end result that the auditor will never know if they have failed to detect large sources of emissions - that might relate to just one particular - but rare - equipment failure such as a corroded pipeline – or one operational - or maintenance activity - that can cause a greater volume of methane to be emitted in a few hours - than might emanate from some other piece of infrastructure - over its entire lifetime.

I know this Panel is trying to work out what to report- regarding methane emission measurement - regulations and monitoring – but I would expect future best-practice will include - some sort of routine and recurring airborne monitoring – along the lines of what you see depicted here.

Making the invisible visible – is getting easier - as methane detection and leak-quantification technologies advance.

This concludes my prepared remarks.

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