Narrabri gas would be a major GHG (greenhouse gas) emitter and is not 'clean' gas

KEY POINTS:

- **The carbon dioxide (CO_2) content of the gas is considerably higher than Santos assumes in the EIS. Based on analysis of available well results, the Narrabri coal seam gas average CO_2 content is 25% - 30%. That is about three times what Santos "assumes" in its EIS and six times its new "5% CO2" claim. The available exploration data clearly shows high CO_2, which is not reflected in the EIS.**

- **There is no available data which supports a 5% CO2 average across the NGP area, and Santos should be required to provide any data and independent analysis which contradicts the thousands of sample from 40 wells at the NGP locations**

- **The high inerts (CO_2 and Nitrogen [N_2]) content of gas in wells in PPLA13/14/15/16 will add materially to the cost of the proposed Narrabri CSG project**

- **Fugitive methane emissions are underestimated in the Santos EIS. The addition of reasonable estimates of fugitive methane emissions would increase the CO_2e emissions from the proposed project to over two (2) million tonnes CO_2e per year**

- **The use of the actual CO_2 content of the gas in the coal seams at Narrabri, and of internationally accepted factors for fugitive methane emissions for gas production, mean that total GHG emissions from the use Narrabri gas would approach those of coal, and lower emissions gas from other sources would be a better 'transition fuel' than Narrabri gas**

- **The emissions figures for CO2 alone, based on the 25% CO2 content are 1.7 million tonnes for "own fuel use" and this would increase to 2.1 million tonnes p.a. for the case where the project uses NSW coal-based electricity to remove the CO2. It is misleading to not count the emissions from power used to process the gas.**

HIGH CARBON DIOXIDE GAS CONTENT IN NARRABRI GAS WELLS

- Narrabri CSG is very high in CO_2 which means there would be significant greenhouse gas (GHG) emissions arising from removing this CO_2 to obtain saleable gas. It means Narrabri CSG cannot be classed as a clean (low carbon) fuel.

- The "in-ground" CO_2 content of Narrabri gas which will be produced under the Narrabri Gas Project is estimated at 25%-305% using DIGS (NSW Geoscience)[1] open file data. This is contrary to Santos' representations in its EIS, where Santos assumes an average of only 10% CO_2 in produced gas. This appears to be a material understatement of the carbon dioxide content of the gas.

- Santos has not provided useful summary material to allow the NSW EPA or other stakeholders (including its own shareholders) the ability to understand the high CO_2 content of the gas at Narrabri or the impacts of this high CO2 on emissions and costs associated with the proposed project.

- The Narrabri gas project would need to extract and vent this 25%-30% CO_2 in order to meet user and NSW pipeline requirements. Based on 70 PJ of clean gas per year, this results in a calculated CO_2 volume vented (emitted to the atmosphere) by the Narrabri CSG project of around a million tonnes of CO_2 per year.

- It is likely that the high CO_2 (and nitrogen) components in the Narrabri gas will significantly increase the cost of developing and supplying gas from the high CO_2 coal seams around Narrabri to well over $7/GJ[2]

- When the high CO_2, which must be removed from the produced gas and which Santos intends to vent to the atmosphere, is accounted for, the Narrabri gas has a very high CO_2 emissions factor associated with its use for power generation or other gas industry usage. The figures for this are presented in this analysis.

The distribution of CO_2 content in the main coals seams in the Pilliga is shown in Figure 1 and Figure 2 below, and in the wider Gunnedah Basin in Figure 3.

[1] https://search.geoscience.nsw.gov.au/

[2] Santos has claimed that Narrabri gas will cost $6/GJ to bring to market (ABC Business Insider, February 2020), Independent costing of the Narrabri Project indicates it is in excess of $7/GJ, before the high CO_2 and N_2 content is taken into account

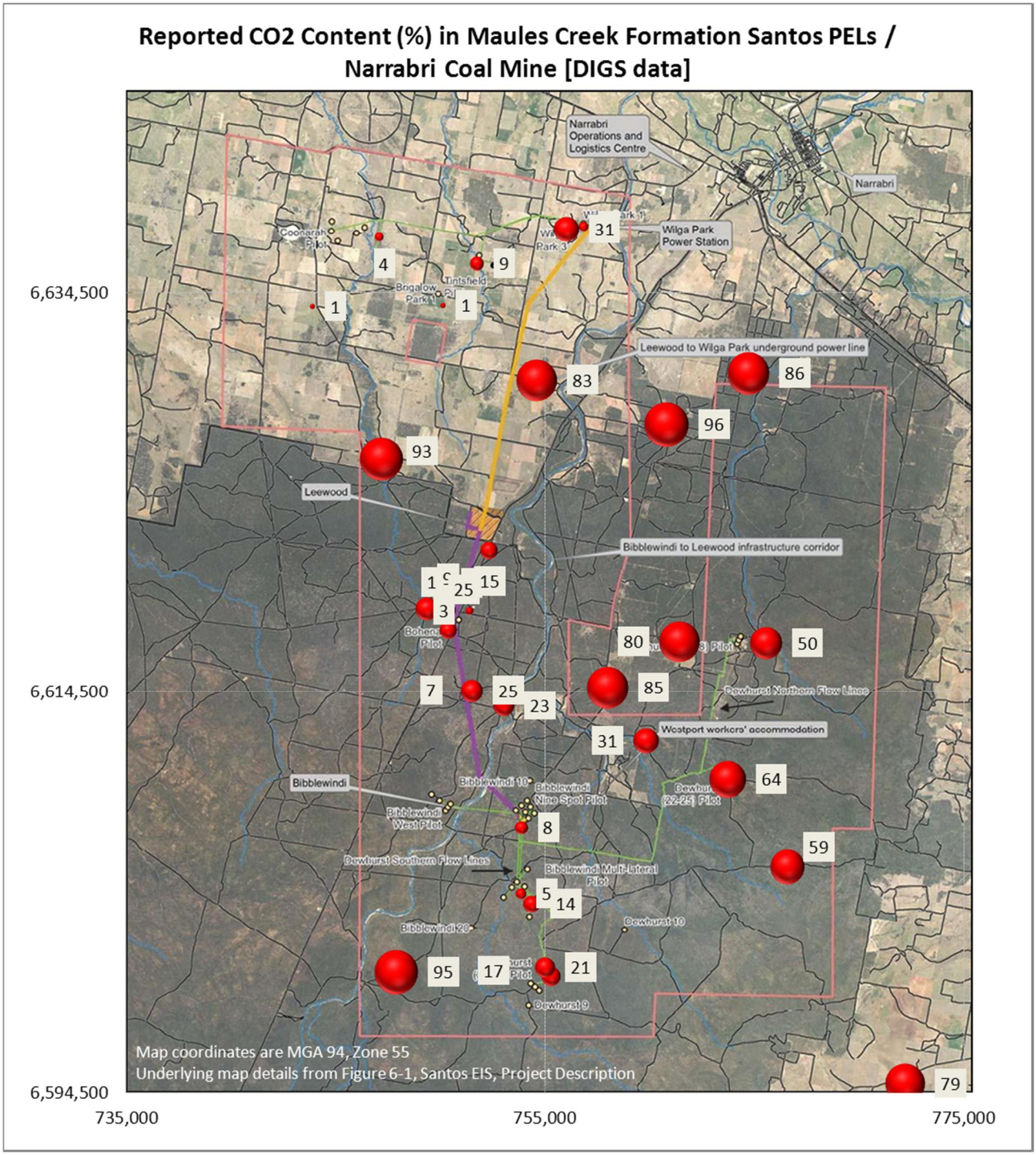


Figure 1 : Reported CO2 percentages in Maules Creek Formation PEL 238 (PPLA 13/PPLA14/ PPLA15/PPLA16)

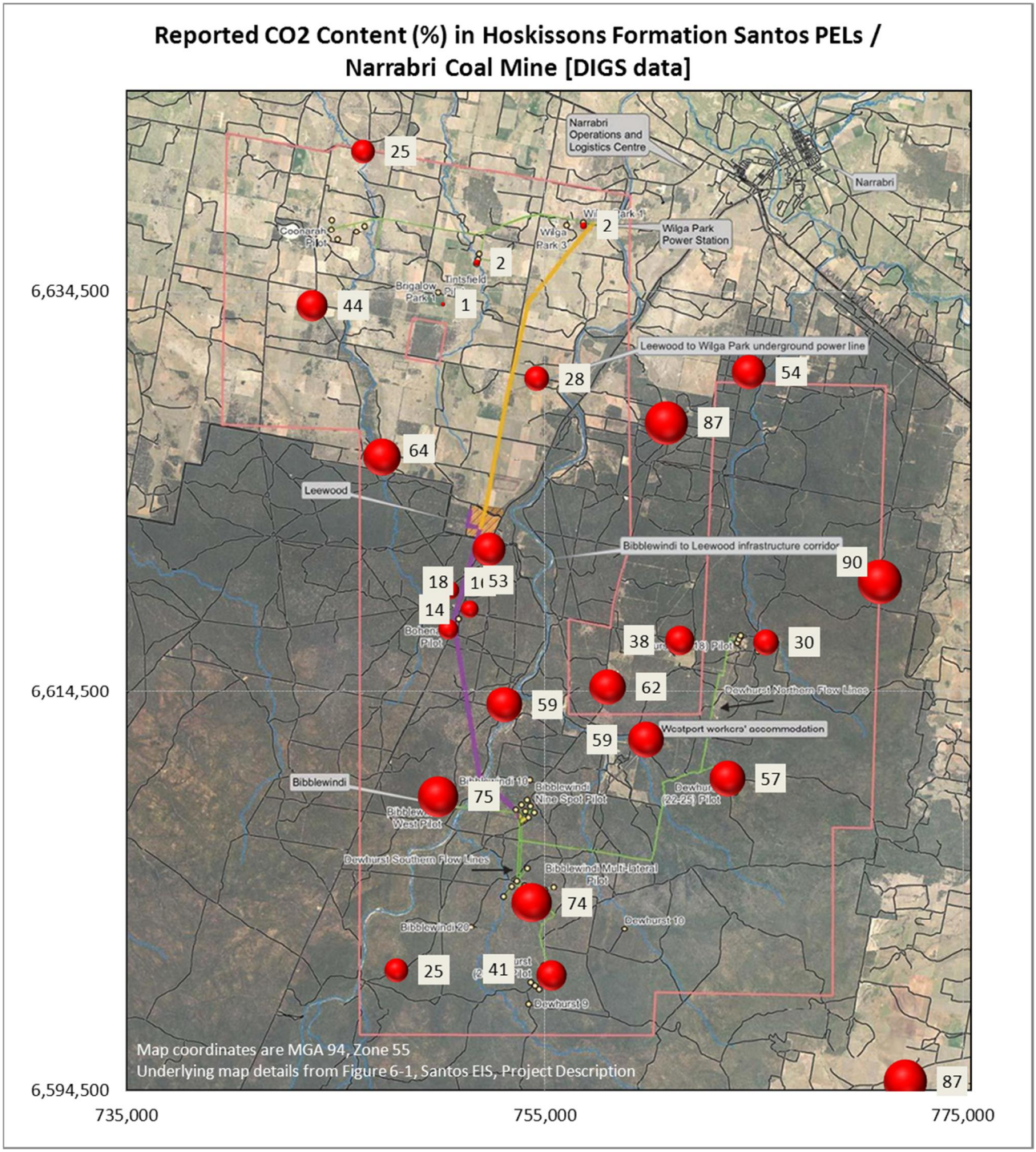


Figure 2 : Reported CO2 percentages in Hoskissons Formation PEL 238 (PPLA 13/PPLA14/ PPLA15/PPLA16)

(Note: A table with the relevant DIGS well data is presented at the end of this document.)

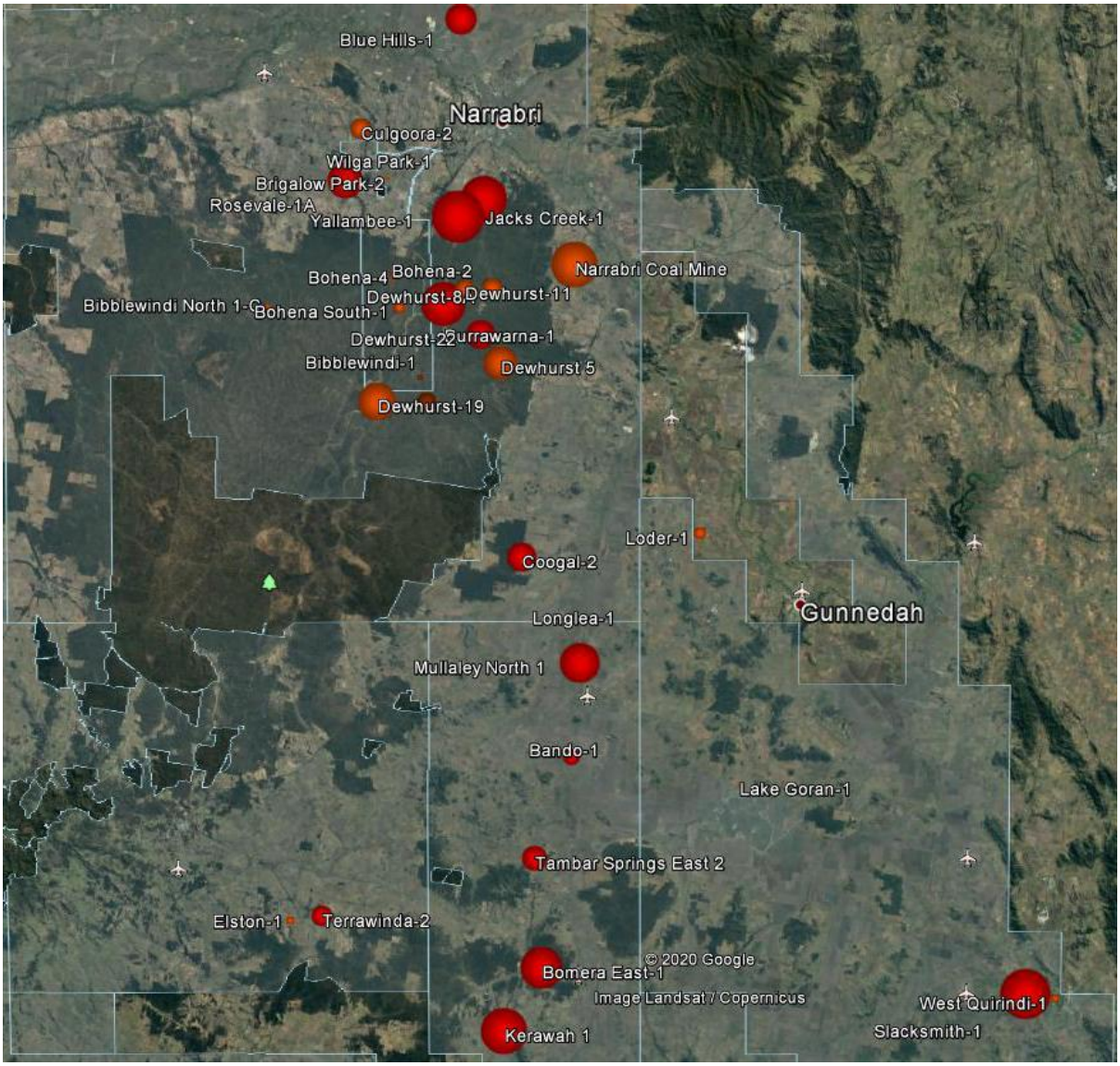


Figure 3 : Reported CO2 percentages in main coal seams Santos PELs 1, 12 and 238 and Whitehaven Coal's Narrabri Underground Coal Mine.

Wells with composition data available in PEL 238, PEL 12 and PEL 1 (Gunnedah Basin).
Largest red bubble is 99.8% CO_2, bubble radius is proportional to CO_2 content.
(Note: A table with the relevant DIGS well data is presented at the end of this document.)

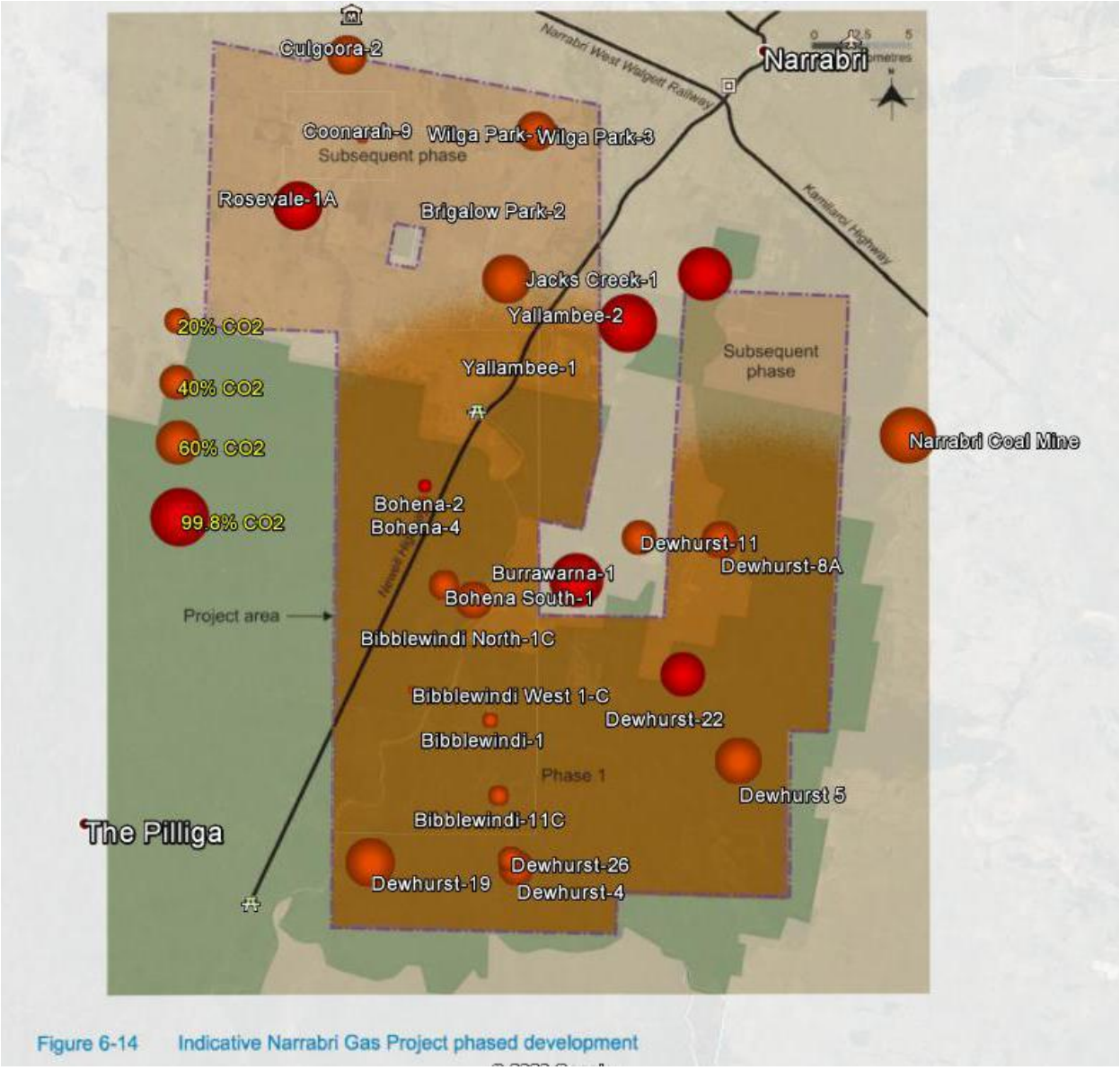
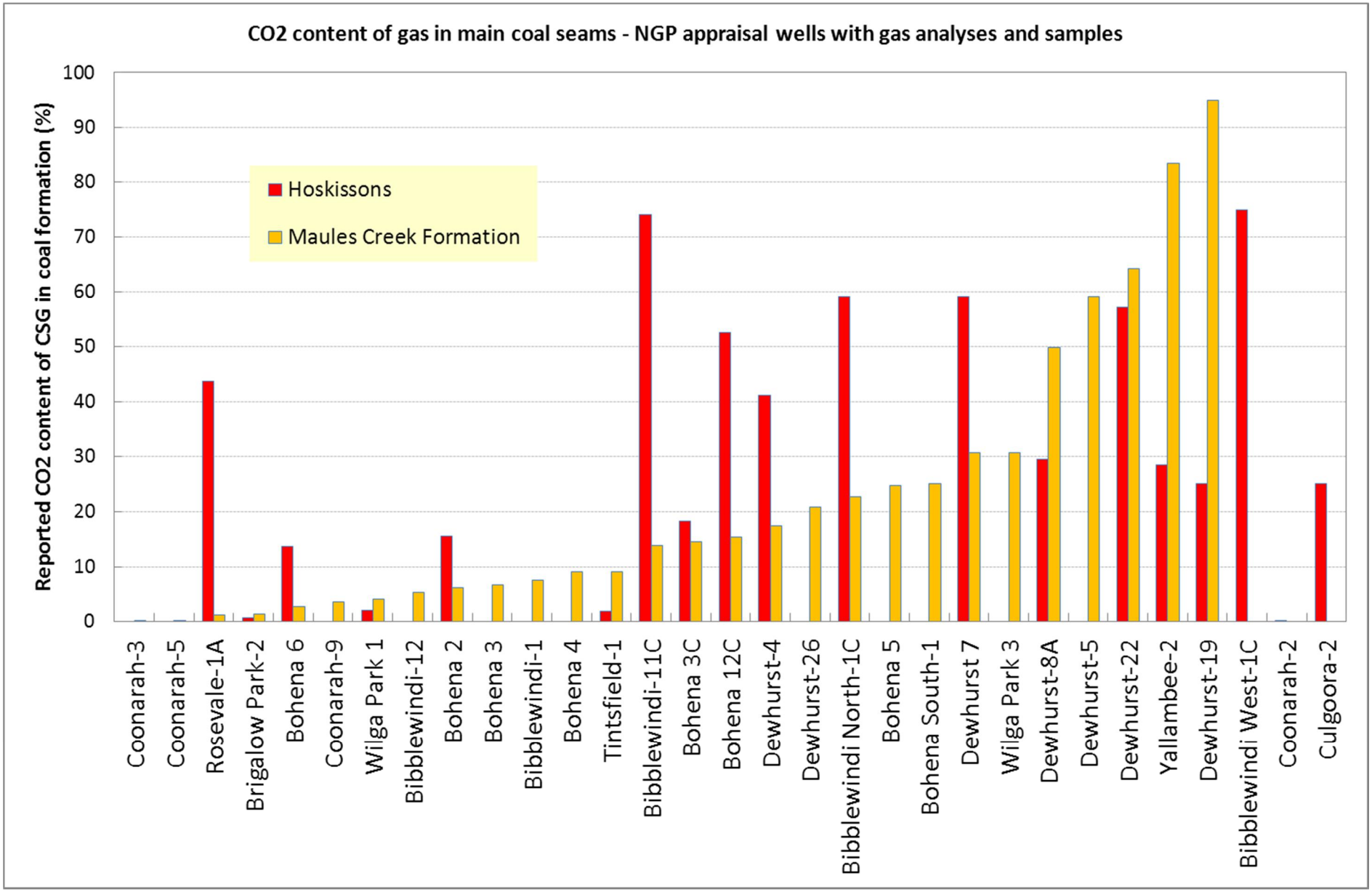


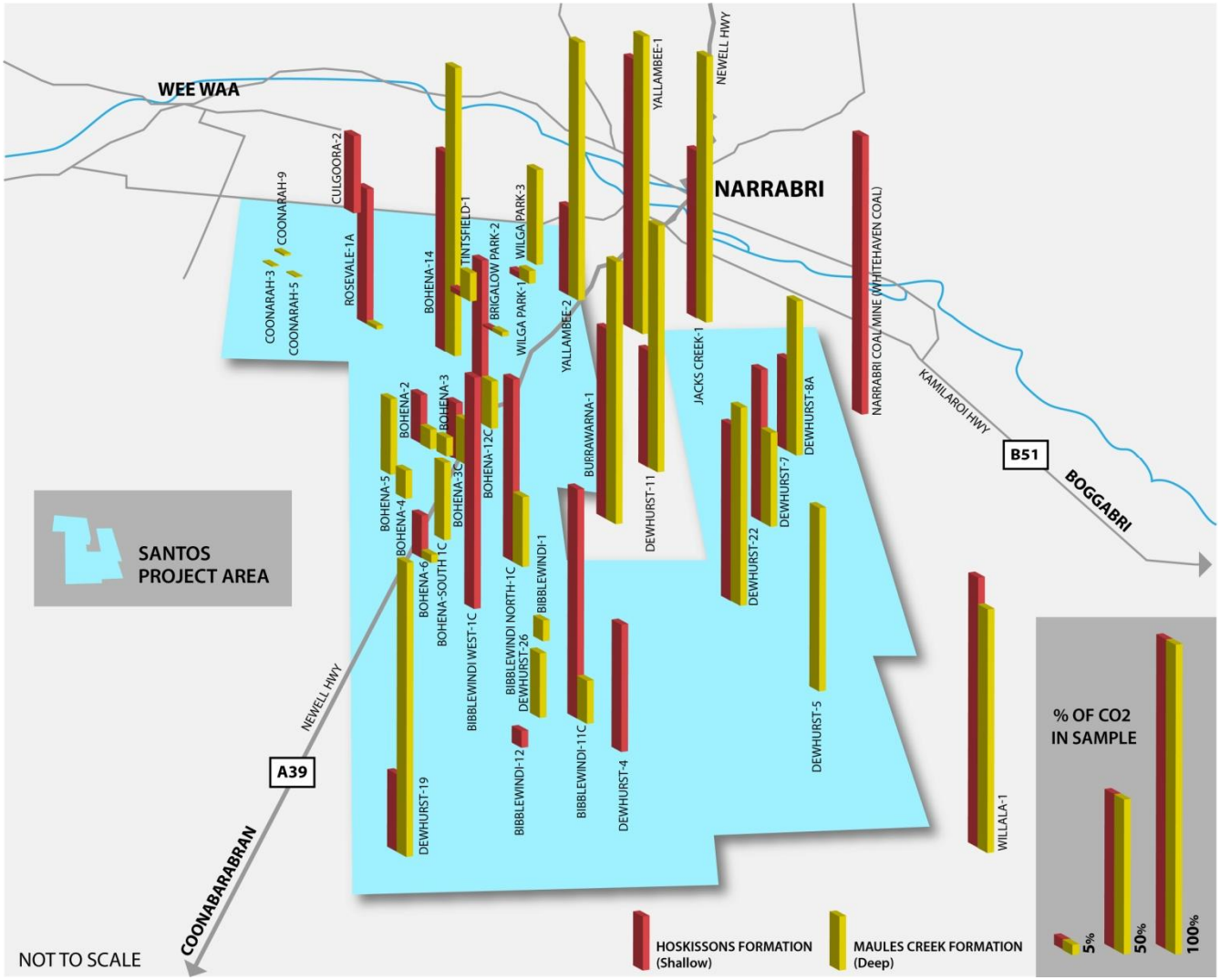
Figure 4: Reported concentrations of CSG CO2 (in red) applied to Narrabri Gas Project area (in brown) showing that 60% CO2 is not unusual or unexpected

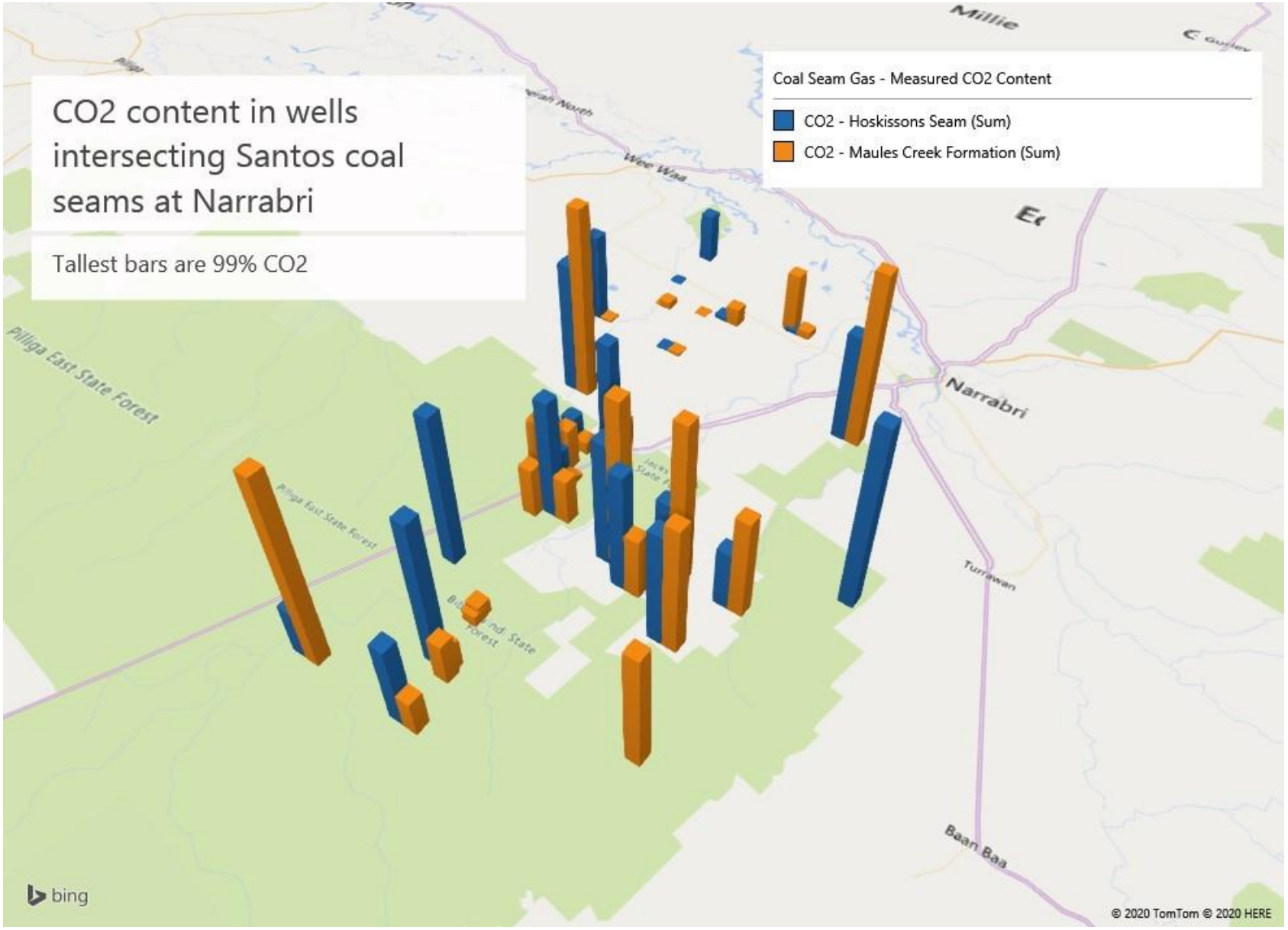
Santos EIS Development Plan (Chapter 06 Project Description) indicative well phasing of the planned 850 wells, with well results from DIGS overlain, and showing most of the initial Phase 1 area to be developed has high CO2 concentrations in the gas, in some cases exceeding 60%


CO2 content of gas in main coal seams - NGP appraisal wells with gas analyses and samples
Reported CO2 content of CSG in coal formation (%)
100
90
80
70
60
50
40
30
20
10
0
Hoskissons
Maules Creek Formation
Coonarah-3
Coonarah-5
Rosevale-1A
Brigalow Park-2
Bohena 6
Coonarah-9
Wilga Park 1
Bibblewindi-12
Bohena 2
Bohena 3
Bibblewindi-1
Bohena 4
Tintsfield-1
Bibblewindi-11C
Bohena 3C
Bohena 12C
Dewhurst-4
Dewhurst-26
Bibblewindi North-1C
Bohena 5
Bohena South-1
Dewhurst 7
Wilga Park 3
Dewhurst-8A
Dewhurst-5
Dewhurst-22
Yallambee-2
Dewhurst-19
Bibblewindi West-1C
Coonarah-2
Culgoora-2

CO_2 CONTENT ACROSS THE SANTOS NARRABRI PROJECT AREA

Well data spread across the project area, showing very high CO2 in both **Hoskissons Formation** and the deeper **Maules Creek Formation** coal seams targetted by Santos for the project.




CO2 content in wells intersecting Santos coal seams at Narrabri
Tallest bars are 99% CO2
Coal Seam Gas - Measured CO2 Content
CO2 - Hoskissons Seam (Sum)
CO2 - Maules Creek Formation (Sum)
Millie
Wee Waa
Narrabri
Pilliga East State Forest
Turrawan
Baan Baa
bing
© 2020 TomTom © 2020 HERE

FUGITIVE METHANE EMISSIONS FACTORS

- "Emissions factors" used to estimate the average fugitive emission rates of GHGs from a given source in kilograms per tonne can vary considerably, and there is a large difference between Australian allowed factors and international accepted factors (such as the EPA in the USA).

- Santos uses an "allowed" factor in its EIS of 0.0058% of methane[3] fugitive emissions, according to the Australian Government National Greenhouse and Energy Reporting (Measurement) Determination 2008, clause 3.72.

    - This factor is recognised as unrealistically low, as it is not based on objective and unbiased areal sampling in a CSG (Coal Seam Gas) operation, but on an undocumented and curated selection of wells nominated by CSG (Coal Seam Gas) producers for CSIRO well-only measurements. The researchers from CSIRO who measured the methane leaks from "selected" wells were under a Federal Energy Department directive to NOT measure any high fugitive emissions sources (pipelines and gathering facilities) outside of or in between well pads, but had to confine themselves to well pad measurements[4].

- The use of more realistic NGGI (National Greenhouse Gas Inventory) factors for fugitive methane emissions materially increases the calculated carbon footprint of the gas predicted to be produced at Narrabri.

    - The average fugitive emission factor for the Australian O&G Industry in Australia in 2015 is reported as 0.5% in the NGGI submitted to the United Nations[4].

    - The U.S. EPA estimates of fugitive methane emissions in the oil and gas sector was increased to 1.4% of produced methane in February 2016[4].

- When the more realistic Australian industry average of 0.5%[5] or the USA EPA figure of 1.4% are used the total fugitive emissions from the Narrabri project increase from 2,000 tonnes of CO2e (Carbon Dioxide equivalent) per year (for 70 PJ of sales gas) to 192,000 (at 0.5% fugitive emissions) or 540,000 tonnes CO2e per year (at 1.4% fugitive emissions).

- There are numerous documented cases in Australia of CSG wells leaking high amounts of methane[6], and also of gathering facilities leaking methane[7]. In some cases researchers were actively prevented from measuring these leaks (pages 47 and 48[4]).

- Santos EIS numbers for fugitive emissions and estimates, using more appropriate factors such as the U.S. EPA, are presented at the end of this document.

[3] Santos EIS "Greenhouse Gas Assessment"
[4] "A review of current and future methane emission from Australian unconventional oil and gas production", October 2016, Melbourne Energy Institute (MEI)
[5] See video evidence such as YouTube clip below
[6] "Tony Smith from Warren, NSW, comments on a noisy, leaky CSG well. Apr 22, 2018" (https://www.youtube.com/watch?v=AYulwI111vs)
[7] "Leaking, bubbling coal seam gas well - Pilliga State Forest - 21 July 2011"(https://www.youtube.com/watch?v=qf5Rj3vfQPc)

IMPACT OF HIGH CO2 AND FUGITIVE EMISSIONS ON PROJECT GHG EMISSIONS

- The Table below summarise the CO_2 and CO_2e emissions from methane from the Narrabri CSM proposed project. Using realistic factors for CO_2 content and methane emissions, these CO_2e emissions range from 1 million tonnes per year to 2 million tonnes per year (Scope 1 emissions from the project). Santos figures for power use, flaring and venting are taken from or derived from Table 5.3 in Appendix R of the Santos Narrabri Gas Project EIS.

- Shifting the power generation for the proposed Project from "own use" to the coal dominated NSW grid will increase associated GHG emissions even further, and is not presented below as it is an even higher emissions case (the NSW average grid emission factor is 0.82 tonnes CO_2/MWh). **In effect, Santos would be using coal-fired power generation to remove CO_2 from Narrabri gas and also vent additional CO_2 into the atmosphere.**

Background Evidence concerning Narrabri Gas Project GHG claims

	Carbon Dioxide from Produced Gas and Power for CO2 removal with 70 PJ p.a. of sales gas				
	Imported LNG#	Narrabri CSG - Santos EIS CO2 content (Table 5-3)	Narrabri CSG - Santos EIS CO2 content (Table 5-3)	Using average well CO2 content from DGIS data	Using average well CO2 content from DGIS data plus external NSW power emissions
CO2 fraction of produced gas	0.0%	10.8%	10.8%	24.50%	24.50%
Million tonnes CO2e fuel (own use)	0.050	0.470	0.470	0.605	0.215
Million tonnes CO2e fuel (grid power fron NSW)	-	-	-	-	0.720
Million tonnes CO2e vented	-	0.493	0.493	1.120	1.120
Million tonnes CO2 flared	-	0.005	0.005	0.011	0.011
Million Tonnes CO2e (operations, excluding fugitive methane) (a)	0.050	0.968	0.968	1.736	2.066

	Fugitive (Methane) Venting Emissions Estimation (CO2e) - 70 PJ				
	NGER Factors	Santos EIS (uses contested NGER "Factors" for wells only)*	Australian 2014 National Inventory Report - Gas Industry Average (NGGI)	USA EPA February 2013 Gas Industry Average (NGGI)**	USA EPA 2016 Gas Industry Average (NGGI)**
Applied Leakage Factor	0.0058%	0.0058%	0.50%	1.20%	1.40%
Tonnes fugitive methane	80	80	6,854	16,451	19,193
Methane Global Warming Potential relative to CO2***	28	25	28	28	28
Million Tonnes CO2e (Fugitive Methane) (b)	0.002	0.002	0.192	0.461	0.537

	Total Project Associated Emissions Estimation (CO2e) - 70 PJ				
	NGER Factors	Santos EIS (uses contested NGER "Factors" for wells only)*	Australian 2014 National Inventory Report - Gas Industry Average (NGGI)	USA EPA February 2016 Gas Industry Average (NGGI)**	USA EPA 2013 Gas Industry Average (NGGI)**
CO2 Emissions (production activities) (tonnes p.a.) [(a)+(b)]	**51,930**	**969,631**	**1,159,568**	**2,196,700**	2,603,470
CO2 Emissions from 70PJ of generation (tonnes p.a.) [Sales Gas]	3,770,000	3,770,000	3,770,000	3,770,000	3,770,000
Electricity assumed generated from 70 PJ of gas (MWh)	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000
Power generation from gas - emissions intensity (tonnes CO2e/MWh)	0.55	0.68	0.70	0.85	0.91

NGGI : National Greenhouse Gas Inventory

#GHG estimate taken from Scenario C, Import Terminal EIS for 140 PJ p.a. supply from low CO2 content LNG producer

** this factor lacks validity as it ignores (a) high emission wells (b) any leakage in in-field gathering lines and infrastructure (see MEI report, p6)*

*** Table 4, MEI 2016 Report*

**** Santos uses a legacy GWP of 25. UNFCCC Fifth Assessment Report recommends a value of 28*

Figure 4. Impact of CO_2 and fugitive methane on Total Emissions from Narrabri Gas

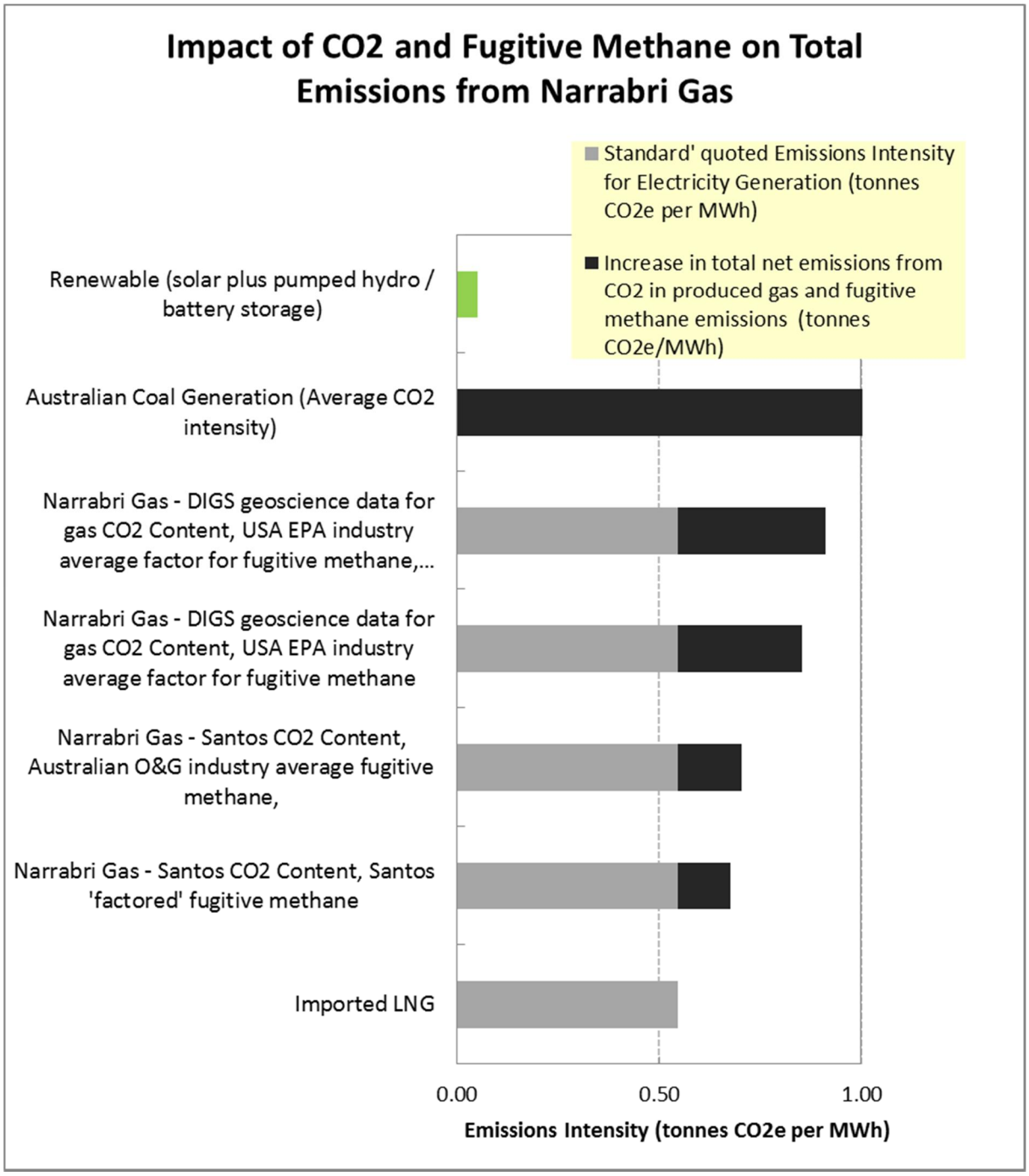
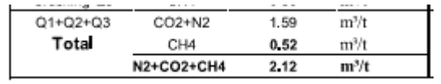


Table 3. Data from https://search.geoscience.nsw.gov.au (DIGS) used to calculate average CO_2 content in Pilliga licences for Narrabri CSG (Coal Seam Gas)
Note - *well names have direct link to data (also see DropBox). These wells are* ***inside or near the borders of PPLA 13 / PPLA 14 /PPLA 15/ PPLA 16.***
This Table has the data for all gas samples that are publicly available (i.e. low CO2 and high CO2)

		MGA Zone 55					Composition of MCF				Composition of Hoskissons				
Well	**Date drilled**	**Easting**	**Northing**	**CO2 Value used - MCF**	**CO2 Value used - HS**	**Source of Composition Data**	**Seam**	**N2**	**CO2**	**CH4**	**Seam**	**N2**	**CO2**	**CH4**	**Comments**
Bibblewindi North-1C	11-05-07	753011.0	6613832.8	22.6	59.1	Bibblewindi_North_1C_Gas_Composition (thickness weighted average of seams)	MCF		22.6				59.1		
Bibblewindi West-1C	07-01-08	749880.1	6609246.3	No data	75.0	Use HS sample data ES0067 on in gas desorption report. [GS2010_0481.RE0000272.Bibblewindi West 1C Gas (Composition).pdf Sample is described as wellhead gas in March 2009 but no record of sampling can be found and well is recorded as P&A in 2007, so impossible to have taken a sample in 2009? Note - BW-1C Desorption report consistently indicates significantly high [CO2+N2], but only Hoskissons seam analyses are presented	Thin		No data		HS		75.0		
Bibblewindi-1	01-04-00	753855.4	6607734.7	7.6	No Data	Appendix_5b_gas_and_water_analysis.pdf [Sample 238/0007]	Tight	5.03	7.6	87.03	Tight, No data		No Data		Separator Gas
Bibblewindi-11C	24-11-07	754342.8	6603932.2	13.9	74.0	Bibblewindi_11C_Gas_Composition.pdf [BBW11C-GG14]	MCF	0.25	13.91	85.83	HS		74.0		Black Jack Formation : 47% CO2; Hoskissons 74%
Bibblewindi-12	08-01-09	753818.6	6604437.0	5.4	No Data	Bibblewindi_12_Gas_Composition.pdf (looks to be from wellhead sample 23/4/2009. Hoskissons seam cemented off)	MCF	2.69	5.42	91.82	No data		No Data		
Bohena 2	02-04-98	750432.7	6619591.0	6.3	15.6	Appendix_2_Gas_composition_analyses.pdf [BHN2391905980020A]	MCF	1.75	6.26	91.83	HS		15.63		
Bohena 3	29-06-98	750352.8	6617645.6	6.7	No Data	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF	3.63	6.71	89.40	No data		No Data		
Bohena 3C	03-02-99	750352.8	6617645.6	14.6	18.3	Appendix_II_gas_comp_sample_timing_tabulations_plots_ gas_comp_analyses	MCF	22.45	14.55	62.00	HS		18.30		
Bohena 4	11-06-98	750377.9	6618623.1	9.1	No Data	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF	0.57	9.10	90.22	No data		No Data		
Bohena 5	12-07-98	749349.0	6618693.6	24.7	No Data	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF	4.60	24.66	66.84	No data		No Data		
Bohena 6	04-08-98	751373.9	6618618.3	2.6	13.7	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF	6.78	2.62	77.40	HS		13.65		Use HS data from 6H, B-6 N2 is too high to be real data
Bohena 12C	23-07-07	752301.8	6621619.8	15.3	52.6	Bohena_12C_Gas_Composition.pdf [Hoskissons 45% / Maules Creek Formation 15%]	MCF	6.50	15.32	76.00			52.61		
Bohena 14	14-04-10	747170.1	6626227.0			Bohena_14_Gas_Composition.pdf [Hoskissons formation 64% CO2, MCF 93% CO2]	MCF		93.19				64.39		
Bohena South-1	02-07-04	751483.1	6614583.6	25.0	No Data	Well_completion_report_on_Bohena_South_1.pdf (Producing gas sample data) Desorption reports referred to in WCR are missing from DIGS	MCF	5.00	25.00	65.00	No data		No Data		https://search.geoscience.nsw.gov.au/report/R00079264
Brigalow Park-2	15-11-10	750105.7	6633893.1	1.4	0.7	Brigalow_Park_2_Gas_Composition.pdf [BPK002_0010211102330A1_1] HS : BPK002_009; MCF : BPK002_014	MCF	0.00	1.36	99.06	HS		0.69		
Burrawarna-1	05-05-00	757961.1	6614737.7			Appendix_8_desorbtion_report (Composition).pdf MCF : BWA1ED170206001609B ; HS : BWA1ED081505001101A	MCF	3.58	85.13	11.00	HS		61.73		
Coonarah-2	21-08-95	646830.7	6637863.6	No data	0.0	Appendix_3_gas_analysis_(240kb_pdf).pdf	Not drilled		No data		HS	7.00	0.01	92.67	https://search.geoscience.nsw.gov.au/report/R00031946
Coonarah-3	14-12-01			0.1	No data	Text_Coonarah-3_well_completion_report.pdf DST #1 tested the Maules Creek Formation	MCF	12.45	0.08	86.70	No data		No data		
Coonarah-5	10-11-01			0.1	No data	Appendix_3_gas_analysis_report_pdf_79KB.pdf, DST#2 [MCF]	MCF	12.77	0.14	86.55	No data		No data		
Coonarah-9	13-07-09	747066.0	6637315.0	3.6	No data	Coonarah_9_Gas_Composition.pdf [CNH009ED071905091537A1]		2.31	3.57	94.08	No data		No data		

		MGA Zone 55					Composition of MCF				Composition of Hoskissons				
Well	**Date drilled**	**Easting**	**Northing**	**CO2 Value used - MCF**	**CO2 Value used - HS**	**Source of Composition Data**	**Seam**	**N2**	**CO2**	**CH4**	**Seam**	**N2**	**CO2**	**CH4**	**Comments**
	20-01-11	746284.2	6641556.5	No data	25.0	Culgoora_2_Gas_Composition.pdf (Mostly Black Jack Group, only 2 m of MCF in well)	Very thin		No data		HS		25.00	50.00	https://search.geoscience.nsw.gov.au/report/RE0001453
Dewhurst-2	21-04-08	758390.9	6606255.8	No data	No data	Cannot find any composition data in WCR or Appendices	No data		No data		No data		No data		
Dewhurst-4	03-07-08	755289.1	6600283.6	17.5	41.1	Dewhurst_4_Gas_Composition.pdf	MCF		17.48	60.00	HS		41.13		https://search.geoscience.nsw.gov.au/report/RE0000254
Dewhurst-5	08-10-08	766562.7	6605802.4	59.2	No data	Dewhurst_5_Gas_Composition.pdf (Average of MCF; GC06 sample - 68% CO2)	MCF		59.22	35.00	No data		No data		https://search.geoscience.nsw.gov.au/report/RE0000255
Dewhurst 7	10-09-08	759818.4	6612077.3	30.6	59.2	Dewhurst_7_Gas_Composition.pdf	MCF	6.00	30.61	62.00	HS		59.18		
Dewhurst-8A	20-11-13	765546.0	6616987.0	49.9	29.5	Appendix_13-Gas_Desorption_Report [DWH8A_021D MCF] note - all formations > 40%	MCF	5.00	49.85	55.00	HS		29.51		https://search.geoscience.nsw.gov.au/report/RE0005996
Dewhurst-11	10-11-09	761419.8	6617066.8			Dewhurst_11_Gas_Desorption_Analysis [DWH11ED230911091302B, MCF - 80%; DWH11ED081710091900A Hoskissons, 38%]	MCF	5.00	80.00	60.00	HS		38.00		https://search.geoscience.nsw.gov.au/report/RE0000617
Dewhurst-19	15-May-11	747878.1	6600510.2	95.0	25.0	Dewhurst_19_Gas_Composition.pdf [DWH019_0030805111017A1 Black Jack 70%; DWH019_0080805111036A1 Hoskissons 75%; DWH019_0101105110714A1 Maules Creek Formation 94%]	MCF	5.00	95.02	25.00	HS		62.17		https://search.geoscience.nsw.gov.au/report/RE0001664
Dewhurst-22	10-12-13	763704.0	6610149.0	64.3	57.2	Appendix_12-_Gas_Desorprtion_Report (Composition).pdf [DEW022_001DGASB]	MCF	0.28	64.27	35.00	HS		57.16		All seams high CO2. 594 - Hoskissons 923 Bohena (MCF), 60% average in both
Dewhurst-26	03-03-14	754984.3	6600730.2	20.8	No data	Appendix_9_-_Gas_Desorption_Report (Compositions).pdf [DEW026_006D (E)]	MCF	0.00	20.80	78.50	No data		No data		Bohena Coal Seam (base of MCF)
Jacks Creek-1	29-07-00	764715.4	6630498.4			Appendix_6_core_description_test_results_(Composition).pdf [JAC1ED401408001550B]	MCF	12.93	86.03	1.04	HS		54.00		WCR "the well appeared to be highly CO2-prone"
Mullaley North-1	14-02-02	777405.0	6560650.0			Text_main_report (Composition).pdf [E109 considered representative]	MCF	0.00	75.60	24.50	HS		85.20		Desorbed has composition, no test flow
Narrabri Coal Mine	13-04-15	771000.0	6620000.0			NAR- Stage 2 EA Specialist-Part 8 - Greenhouse Gas Assessment.pdf (P8-15]	No data				HS		90.00	10.00	Underground mining of up to 8 Mtpa of ROM coal from the Hoskissons Seam.
Rosevale-1A	17-Feb-10	743852.3	6633826.7	1.2	43.6	Rosevale_1A_Gas_Composition.pdf HS : RVL001AED123101100700A ; MCF : RVL001AED161002101800A1	MCF	0.00	1.20	30.27	HS		43.64		BJG - 60%, Hoskissons - 35%, MCF 1% - big variability between seams
Tintsfield-1	09-Oct-09	751732.3	6635979.9	9.1	1.8	Tintsfield_1_Gas_Composition.pdf HS : TFD1ED121711091157C1 ; MCF : TFD1ED251711091413C1	MCF	0.00	9.10	90.00	HS		1.82		
Wilga Park 1	13-03-98	756830.7	6637863.6	4.1	2.0	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF		4.08		HS		1.95		
Wilga Park 3	09-12-98	755995.6	6637719.9	30.7	No data	WCR280.R00031547.Bohena 2 Gas Composition.jpg	MCF		30.65		No data		No data		
Willala-1	07-Feb-11	772194.2	6594958.5			Willala_1_Gas_Composition.pdf HS : WIL001_0023001110822B1_2 ; MCF : WIL001_0080202112156A1_2	MCF	0.00	78.69	8.76	HS		87.13		
Yallambee-1	26-Aug-09	760783.0	6627968.0			Yallambee_1_Gas_Desorption_Analysis.pdf (Outside permit) HS : YLB1ED06 ; MCF : YLB1ED19	MCF	0.00	96.26	0.00	HS		87.39		
Yallambee-2	21-Apr-11	754579.8	6630169.1	83.4	28.5	Yallambee_2_Gas_Composition.pdf HS : YLB002_001; MCF : YLB002_007	HS?	0.00	83.37	28.45			58.82		Can't match sample numbers to seams unambiguously; min CO2 58%, some >84%
Average				*22.3%*	*32.7%*	*<- average CO2 with wells outside PPLAs (13,14,15,16) excluded*		**4.3**	**34.8**	**59.8**		**7.0**	**46.6**	**50.9**	
	Assumed reserves contribution to 70 PJ annual			70%	30%										
	Average CO2			*25.4%*											

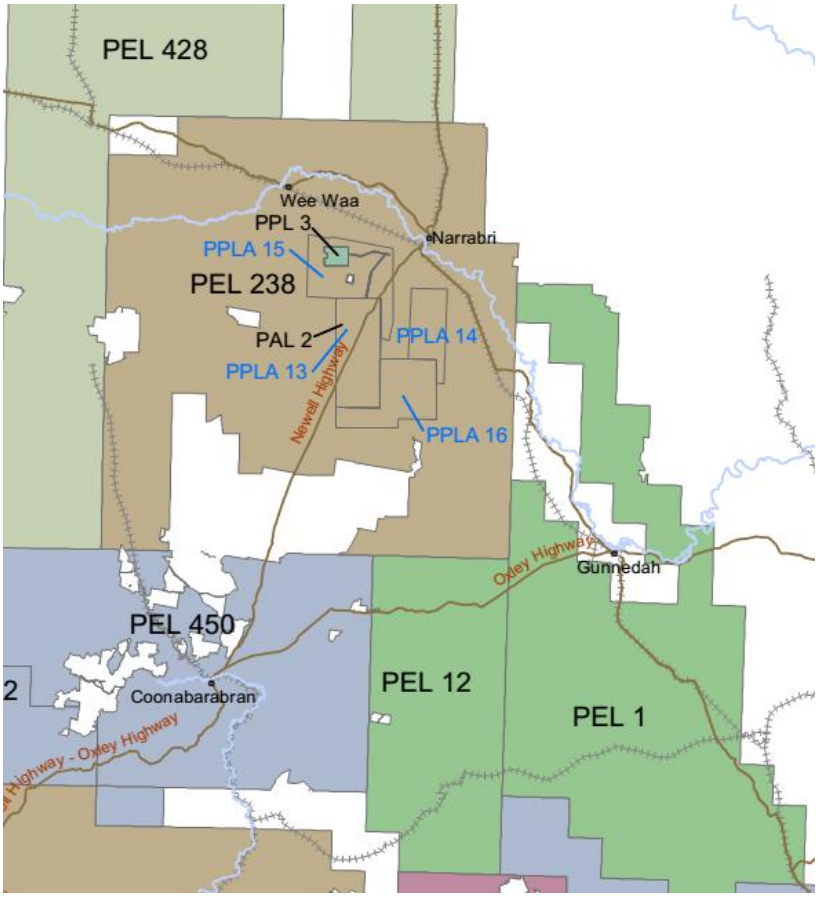


Figure 5 : *Location of PELs and PPLAs from "PETROLEUM APPLICATIONS AND TITLES", NSW Department of Industry, Resources and Energy, 7/12/2016*

METHODOLOGY

Detailed quantification of CO_2 and Methane (Fugitive) emissions

Tables 1 and 2 (above) summarise the CO_2 and CO_2e emissions from the Narrabri CSM (Coal Seam Gas) proposed project. Using realistic factors for CO_2 content and methane emissions, these CO_2e emissions range from 1 million tonnes per year to 2 million tonnes per year (Scope 1 emissions from the project). Santos figures for power use, flaring and venting are taken from or derived from Table 5.3 in Appendix R of the Santos Narrabri Project EIS. Shifting Project power generation from own use to the coal dominated NSW grid will increase emissions even further, as the average grid emissions intensity for NSW is 0.82 tonnes CO2/MWh.[8] Essentially, the Project would be burning coal to produce gas.

Notes on methodology:

Appropriate averages of the CO_2 in wells for which gas composition data was available for the Gunnedah Basin form the basis for this analysis. Wells have been analysed, tabled and mapped according to which PEL they are related to. As exploration wells seemed (logically) to be relatively evenly spread across the relevant areas, an average of the CO2 in widely dispersed wells was considered as good an approach to determining the average CO_2 content in the PPLA areas as could be developed. With area-weighted averaging of the CO_2 in the wells with a GIS system, it is considered quite likely that the calculated average CO_2 content of the gas would increase.

The well coordinates and gas composition data are available for anyone to peer review and determine, if they wish, if there should be a different area-weighted averaged CO_2 fraction of the coal seam gas across the PPLAs and across the Gunnedah basin.

The basis for Santos' emissions factors are described in detail in Santos Appendix R Greenhouse Gas Assessment and the validity or applicability of those factors for fugitive methane are explored in detail in the MEI report cited above.

SOURCE DATA

Readers can refer to the DropBox drive link below which contains all relevant data.

CO2 Emissions Gunnedah Basin

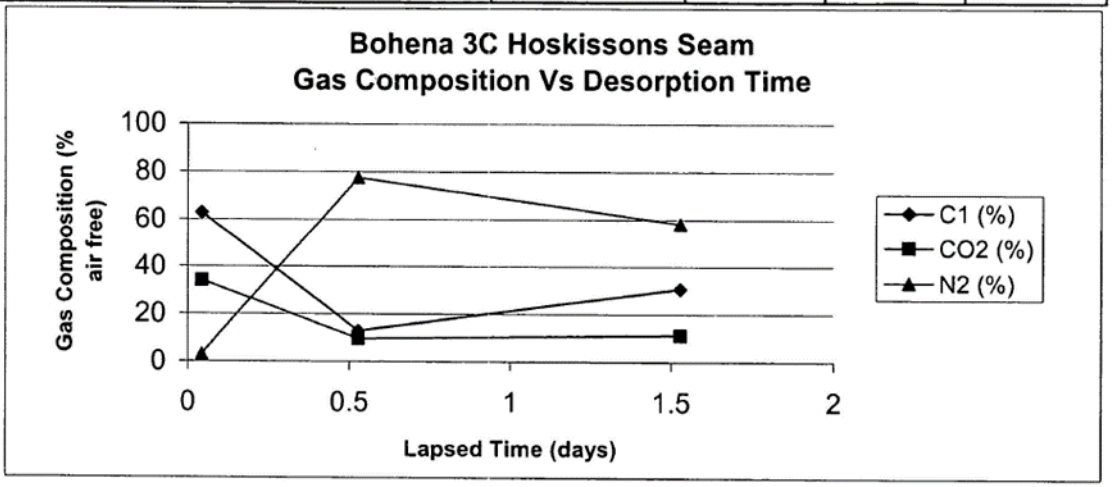
[8] Based on Generation sources in Table O2 of https://www.energy.gov.au/sites/default/files/aes-table-o-2016-17_2017.pdf

DESORPTION RATES

The data available on DIGS indicates that the high CO_2 and N_2 contents of the gas are produced (desorbed from the coal) at the same time as methane (CH_4) production. An example is shown below from Bohena 3C. In addition to the high CO_2 desorption (release from the coal) the increasing N_2 production over time is likely to also impact cost and reserves for the project.

Figure 6 : Bohena 3C gas composition variation over time

Well	Sample/Seam	Lapsed Days	C1 (%)	CO_2 (%)	N_2 (%)
Bohena 3C	B3CED35 - Hoskissons	0.0418	62.79	34.09	3.02
Bohena 3C	B3CED35 - Hoskissons	0.0592	Not Analysed		
Bohena 3C	B3CED35 - Hoskissons	0.1946	Not Analysed		
Bohena 3C	B3CED35 - Hoskissons	0.5279	12.88	9.61	77.51
Bohena 3C	B3CED35 - Hoskissons	1.5279	30.62	11.24	58.11



Source : Bohena 3C - Appendix II Gas Composition Sample Timing Tabulations and Plots, Gas Compositional Analysis (13 pp), https://search.geoscience.nsw.gov.au/report/R00030074)