Economic significance of Coal Seam Gas in Queensland

Final Report

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ACIL Tasman

Economics Policy Strategy

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Key Findings

Queensland Coal Seam Gas (CSG) has become an important and integral component of Eastern Australia's natural gas supply. Continuing growth of CSG production in Queensland has the potential to support a new large scale export industry based on liquefied natural gas (LNG) as well as supply to domestic users in Queensland and southern states. Such developments have the potential to deliver very large economic benefits to the state and to the nation.

This study presents an assessment of the economic benefits arising from three Queensland CSG growth scenarios:

- A **Base Case** under which the industry grows to support six LNG export trains (nominal production capacity 24 million tonnes per year of LNG) with additional production available to supply domestic customers.
- An **8-train Expansion Case** under which the industry grows to support eight LNG export trains (nominal production capacity 32 million tonnes per year of LNG) with additional production available to supply domestic customers.
- A **10-train Expansion Case** under which the industry grows to support ten LNG export trains (nominal production capacity 40 million tonnes per year of LNG) with additional production available to supply domestic customers.

In order to assess the resulting economic benefits, each of these scenarios is compared with a Reference Scenario (counterfactual) in which no further development of Queensland or New South Wales CSG occurs beyond current levels. Such a scenario would see no export LNG developments, declining production of Queensland CSG over time and heavy reliance on conventional gas reserves and discovery of new conventional gas and tight gas resources in areas such as Bass Strait and the Cooper Basin.

Summary of results

Table ES 1 summarises key performance parameters in relation to the gas industry, electricity industry and the general economy, for Queensland and Australia as a whole, for each of the CSG development cases compared to the Reference Scenario.

Table ES 1 **Key economic performance parameters: Base, 8-train Expansion and 10-train Expansion Scenarios compared to the Reference Scenario**

Parameter	Unit	Base Case		8-train		10-train	
		QLD	AUST	QLD	AUST	QLD	AUST
Gas consumption increment EA including LNG (2035)	PJ/a	1,998	2,474	2,400	2,654	2,743	2,975
Wholesale gas price% change relative to Reference Case (Brisbane avg 2015–35)	% change	–14%	na	–2%	na	9%	na
Powergen CO2 emissions at 2035	Mtpa	70.7	192.1	70.9	184.1	70.9	183.5
Queensland wholesale electricity price % change on Reference Case (2015–35)	% change	–23%	–20%	–15%	–13%	–10%	–10%
GSP/GDP change from Reference Case – aggregate to 2035	$ billion	363	368	427	450	497	515
GSP/GDP change from Reference Case – NPV(7%) to 2035	$ billion	146	152	173	183	197	207
Real income (gross) to 2035, change from Reference Case	$ billion	231	351	286	438	342	515
Real income NPV (7%) to 2035, change from Reference Case	$ billion	90	142	110	173	131	200
Employment (Annual avg FTE), change from Reference Case	FTE jobs	14,242	14,031	17,125	17,016	20,210	19,420
Queensland Government royalties, payroll tax & QLD-sourced GST – gross, to 2035	$ billion	21.6	n.a.	26.7	n.a.	32.0	n.a.
Queensland Government royalties, payroll tax & QLD-sourced GST – NPV (7%) to 2035	$ billion	8.9	n.a.	10.9	n.a.	12.9	n.a.
All Australian government taxes (excluding transfer taxes and greenhouse gas penalties) – gross to 2035	$ billion	n.a.	162	n.a.	228	n.a.	275
All Australian government taxes (excluding transfer taxes and greenhouse gas penalties) – NPV (7%) to 2035	$ billion	n.a	66	n.a	90	n.a	107

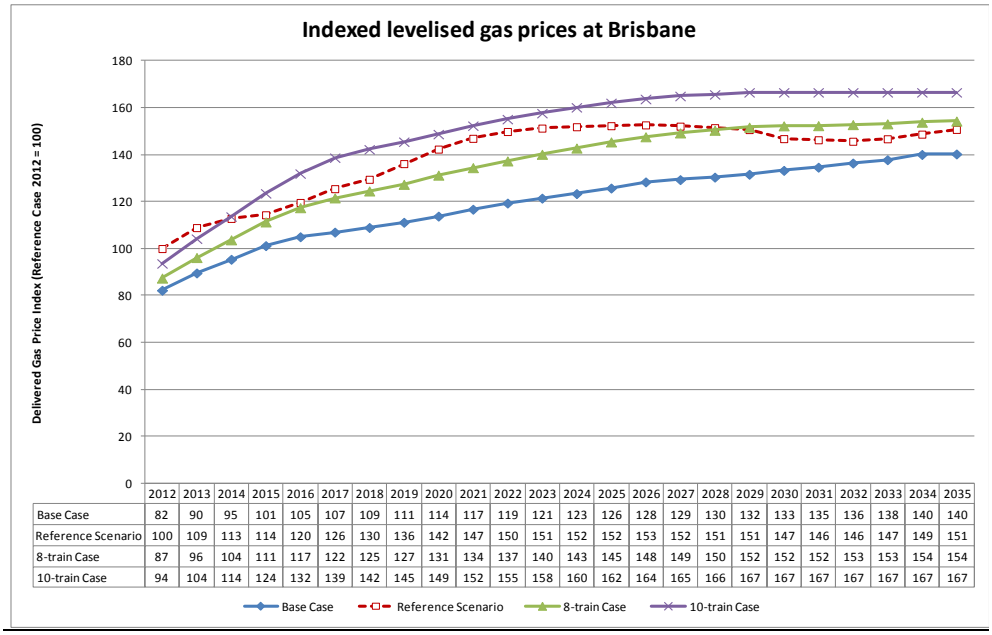
Data source: ACIL Tasman modelling

Wholesale gas prices on a delivered Brisbane basis will be 14% lower on average over the period 2015 to 2035 under the Base Case (CSG expansion with 6 LNG trains). For the 8-train Case the average Brisbane gas prices over the same period are 2% lower. For the 10-train LNG Case average Brisbane gas prices will be 9% higher than for the Reference Case as a result of the heavy call on CSG resources to support the larger scale of LNG production. This is illustrated in Figure ES 1, which compares indexed gas prices[1] on a

[1] Index based on Reference Case modeled price in 2012 = 100

levelised (rolling 10-year contract) basis for the three CSG cases with the Reference Scenario.

Figure ES 1 **CSG industry impacts on gas prices**

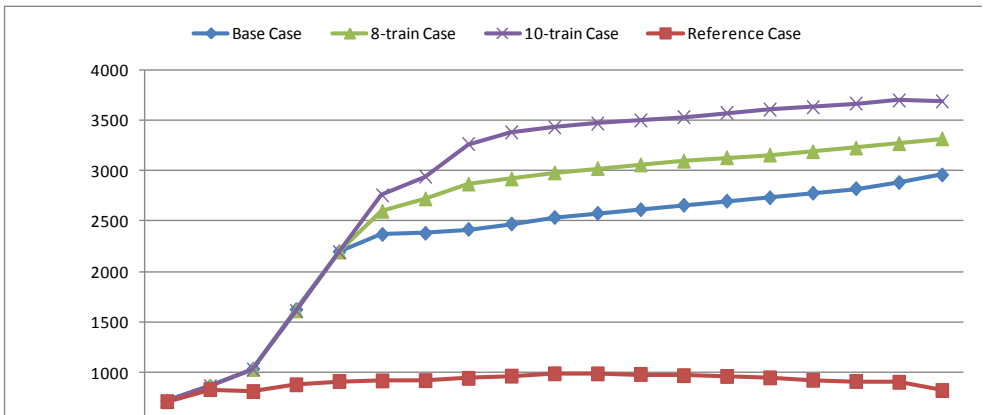


	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Base Case	82	90	95	101	105	107	109	111	114	117	119	121	123	126	128	129	130	132	133	135	136	138	140	140
Reference Scenario	100	109	113	114	120	126	130	136	142	147	150	151	152	152	153	152	151	151	147	146	146	147	149	151
8-train Case	87	96	104	111	117	122	125	127	131	134	137	140	143	145	148	149	150	152	152	152	153	153	154	154
10-train Case	94	104	114	124	132	139	142	145	149	152	155	158	160	162	164	165	166	167	167	167	167	167	167	167

Source: ACIL Tasman *GMG Australia* modelling

Eastern Australia total gas consumption levels (domestic use plus LNG exports) for the various cases are compared in Figure ES2.

Figure ES 2 **CSG industry impacts on Eastern Australia gas consumption**

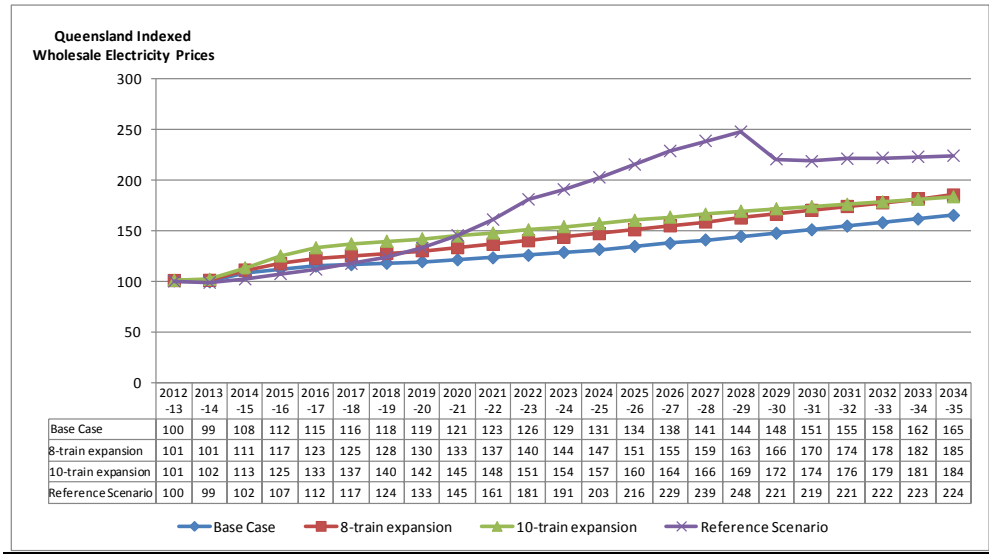


	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Base Case	716	863	1033	1622	2197	2368	2379	2418	2472	2536	2577	2614	2657	2698	2732	2777	2822	2883	2958
8-train Case	715	863	1030	1610	2194	2598	2721	2868	2918	2979	3022	3057	3095	3129	3156	3189	3225	3268	3317
10-train Case	715	863	1029	1608	2191	2756	2941	3265	3381	3430	3467	3499	3531	3573	3606	3629	3666	3696	3688
Reference Case	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820

Source: ACIL Tasman *GMG Australia* modelling

Figure ES 3 compares modelled wholesale electricity price indices (Queensland Regional Reference Price) for the three CSG cases and the Reference Scenario.

Figure ES 3 **CSG industry impacts on wholesale electricity prices**



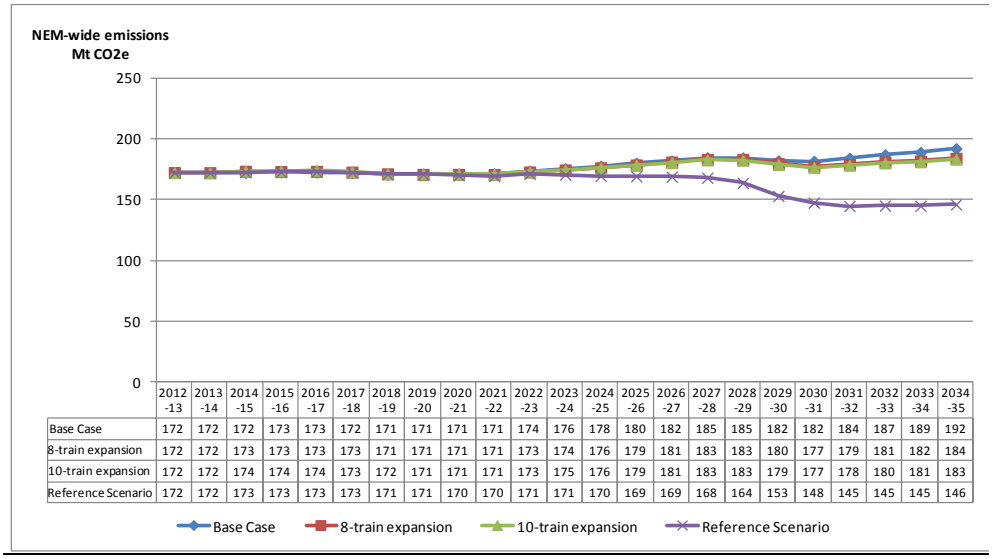
	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Base Case	100	99	108	112	115	116	118	119	121	123	126	129	131	134	138	141	144	148	151	155	158	162	165
8-train expansion	101	101	111	117	123	125	128	130	133	137	140	144	147	151	155	159	163	166	170	174	178	182	185
10-train expansion	101	102	113	125	133	137	140	142	145	148	151	154	157	160	164	166	169	172	174	176	179	181	184
Reference Scenario	100	99	102	107	112	117	124	133	145	161	181	191	203	216	229	239	248	221	219	221	222	223	224

Source: ACIL Tasman *PowerMark LT* modelling

Note: Index based on Reference Scenario 2012 = 100.

Figure ES 4 compares the levels of CO_2 emissions across the whole of the National Electricity Market (NEM) for the three CSG cases and the Reference Scenario.

Figure ES 4 **CSG industry impacts on whole of NEM CO_2 emissions**

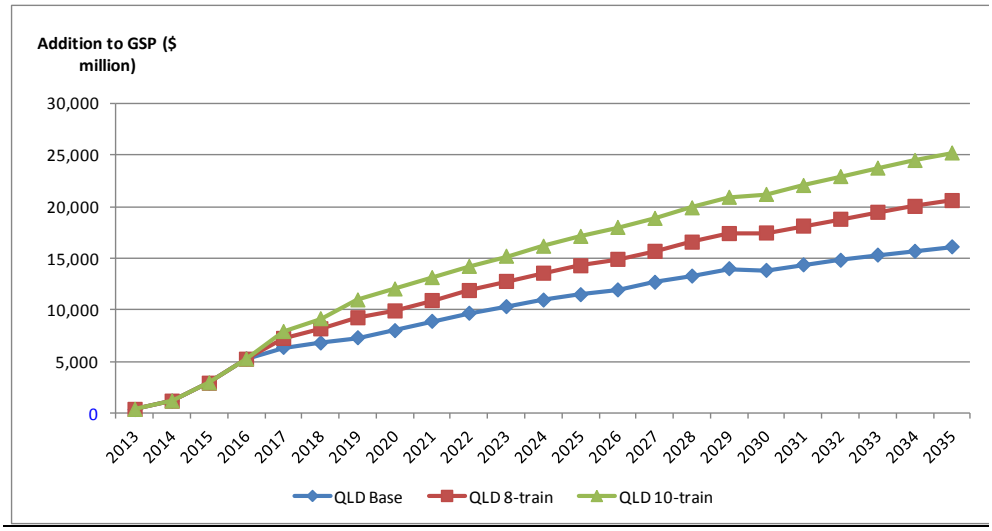


	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Base Case	172	172	172	173	173	172	171	171	171	171	174	176	178	180	182	185	185	182	182	184	187	189	192
8-train expansion	172	172	173	173	173	173	171	171	171	171	173	174	176	179	181	183	183	180	177	179	181	182	184
10-train expansion	172	172	174	174	174	173	172	171	171	171	173	175	176	179	181	183	183	179	177	178	180	181	183
Reference Scenario	172	172	173	173	173	173	171	171	170	170	171	171	170	169	169	168	164	153	148	145	145	145	146

Source: ACIL Tasman *PowerMark LT* modelling

Figure ES 5 shows the impacts of the three CSG growth scenarios on Queensland Gross State Product (GSP). By 2035 the CSG development scenarios add between $15 billion and $25 billion annually to Queensland GSP.

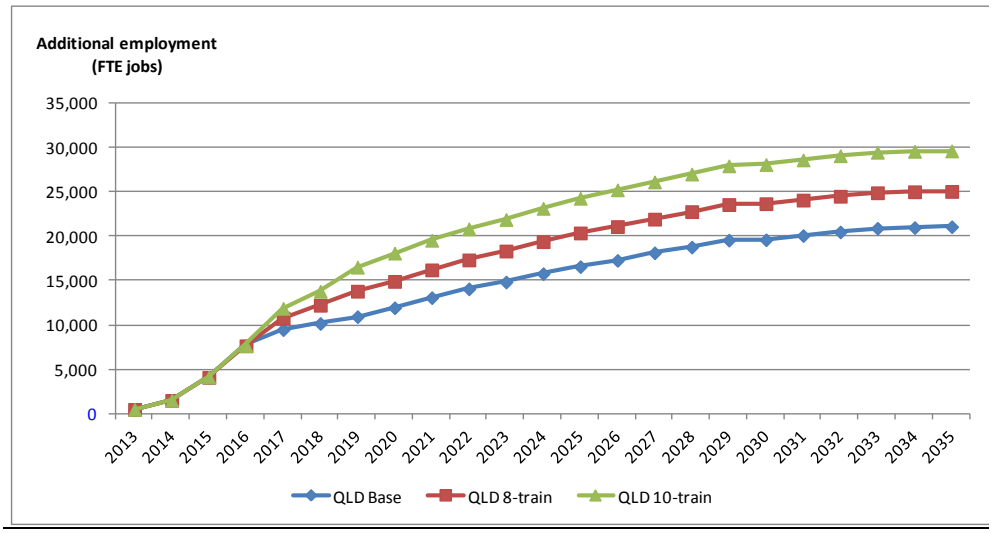
Figure ES 5 **CSG industry impacts on Queensland Gross State Product relative to Reference Scenario**



Source: Tasman Global modelling

Figure ES 6 shows the impacts of the three CSG growth scenarios on employment numbers in Queensland (full-time equivalent employment basis). By 2035 the CSG development scenarios add between 20,000 and 30,000 full-time equivalent jobs annually in Queensland.

Figure ES 6 **CSG industry impacts on Queensland jobs**



Source: ACIL Tasman modelling

Summary Results—Base Case

Base Case

The study finds that the **Base Case** would result in:

Gas market impacts

- An increase in overall gas consumption in Eastern Australia compared to the Reference Scenario, with the difference widening over time to some 2,474 PJ/ per annum (PJ/a) by 2035. Gas consumption in Queensland would be almost 2,000 PJ/a higher over the same period. In terms of gas supply for local markets (that is, excluding LNG exports) consumption would be up to 1,028 PJ/a higher by 2035.
- Wholesale gas prices would be 14% lower on average in Queensland[2] over the period 2015 to 2035 when compared to the Reference Scenario. Wholesale gas prices would also be lower by 12% on average in NSW over the same period. In Victoria, South Australia and Tasmania average gas prices over the period 2015 to 2035 would be lower by 22%, 14% and 3 % respectively, as a result of reduced demand for exports from the Bass Strait region.

Electricity market impacts

- Total electricity generation in the NEM (that is, excluding non-scheduled generators) would reach 340,000 GWh by 2034-35, 11% higher than under the Reference Scenario.
- In Queensland, total electricity generated under the Base Case assumptions reaches 127,000 GWh by 2034-35. This is 18,500 GWh or 17% higher than under the Reference Scenario.
- Total gas-for-power generation consumption in the NEM is projected to grow dramatically, from 310 PJ in 2012-13 to 1,250 PJ in 2034-35. The largest increases in gas consumption for electricity generation occur in Queensland and Victoria.
- The changing fuel mix under the Base Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.56 tCO_2e/MWh (sent out) by 2034-35.
- Compared to the Reference Scenario, average electricity prices[3] in the NEM under the Base Case over the period 2014-15 to 2034-35 will be 20% lower.

---

2 Calculated on the basis of wholesale delivered prices at Brisbane City Gate.

3 Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

General economic impacts

- Around $32.8 billion cumulative direct capital investment in upstream CSG development and a gain of around $26 billion of associated recurrent operating expenditure in Queensland over the period to 2035
  - While these gain will be at least partly offset by reduced investment and expenditure on gas production elsewhere in the country, the net result sees an increase in real Queensland Gross State Product of $363 billion in total over the period to 2034-35
  - This equates in net present value terms (7% discount rate) to a $146 billion increase in real value-added, equal to approximately 55 per cent of the total value of GSP in Queensland for the 2010-11 financial year.
- Queensland real income $231 billion higher in total over the period to 2035 ($90 billion higher in net present value terms, which based on current population represents approximately $19,600 per Queensland resident)
- Total employment in Queensland 14,242 higher per year on average (FTE basis).

Queensland Government Revenue

- Queensland Government receipts from CSG royalties, payroll tax and Queensland-sourced GST over the period to 2035 increased by $21.6 billion in aggregate, or $8.9 billion in NPV terms (7% discount rate).

All Government Revenue

- Nationally, Australian government receipts over the period to 2035 increase by $162.2 billion in aggregate or $65.9 billion in NPV terms (7% discount rate).

Summary Results—8-train Expansion Scenario

The **"8-train Expansion" Scenario** would result in:

Gas market impacts

- An increase in overall gas consumption in Eastern Australia compared to the Reference Scenario, with the difference widening over time to more than 2,650 PJ/ per annum (PJ/a) by 2035. Gas consumption in Queensland would be up to 2,400 PJ/a higher over the same period. In terms of gas supply for local markets (that is, excluding LNG exports) consumption would be up to 725 PJ/a higher by 2035.
- Wholesale gas prices would be 2% lower on average in Queensland[4] over the period 2015 to 2035 when compared to the Reference Scenario.

[4] Calculated on the basis of wholesale delivered price index for Brisbane City Gate, with index based on Reference Case 2012 = 100.

Wholesale gas prices in New South Wales would also be lower by 10% on average over the same period. In Victoria, South Australia and Tasmania average gas prices over the period 2015 to 2035 would be lower by 20%, 12% and 1 % respectively, as a result of reduced demand for exports from the Bass Strait region.

Electricity market impacts

- Total electricity generation in the NEM (that is, excluding non-scheduled generators) would reach 340,000 GWh by 2034-35, 11% higher than under the Reference Scenario.
- In Queensland, total electricity generated under the 8-train Expansion Case assumptions reaches 127,000 GWh by 2034-35. This is 18,500 GWh or 17% higher than for the Reference Scenario.
- Total gas-for-power generation consumption in the NEM is projected to grow dramatically, from 156 PJ in 2010-11 to 947 PJ in 2034-35. The largest increases in gas consumption for electricity generation occur in Queensland, New South Wales and Victoria.
- The changing fuel mix under the 8-train Expansion Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.54 tCO_2e/MWh (sent out) by 2034-35.
- Compared to the Reference Scenario, average electricity prices[5] in the NEM under the 8-train Expansion Case over the period 2014-15 to 2034-35 will be 13% lower.

General economic impacts

- Around $37.1 billion cumulative direct capital investment in upstream CSG development and a gain of around $30.7 billion of associated recurrent operating expenditure in Queensland over the period to 2035
  - While these gain will be at least partly offset by reduced investment and expenditure on gas production elsewhere in the country, the net result sees an increase in real Queensland Gross State Product of $427 billion in total over the period to 2034-35
  - This equates in net present value terms (7% discount rate) to a $173 billion increase in real value-added, equal to approximately 65 per cent of the total value of GSP in Queensland for the 2010-11 financial year.
- Queensland real income $286 billion higher in total over the period to 2035 ($110 billion higher in net present value terms, which based on current population represents approximately $23,900 per Queensland resident).

[5] Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

- Total employment in Queensland 17,125 higher per year on average (FTE basis).

Queensland Government Revenue

- Queensland Government receipts from CSG royalties, payroll tax and Queensland-sourced GST over the period to 2035 increased by $26.7 billion in aggregate, or $10.9 billion in NPV terms (7% discount rate).

All Government Revenue

- Nationally, Australian government receipts over the period to 2035 increase by $228.3 billion in aggregate or $90.1 billion in NPV terms (7% discount rate).

Summary Results—10-train Expansion Scenario

The **"10-train Expansion" Scenario** would result in:

Gas market impacts

- An increase in overall gas consumption in Eastern Australia compared to the Reference Scenario, with the difference widening over time to some 2,975 PJ/ per annum (PJ/a) by 2035. Gas consumption in Queensland would be up to 2,743 PJ/a higher over the same period. In terms of gas supply for local markets (that is, excluding LNG exports) consumption would be up to 702 PJ/a higher by 2035.
- Wholesale gas prices would be 9% higher on average in Queensland[6] over the period 2015 to 2035 when compared to the Reference Scenario. This is a result of the large volume of CSG required for LNG exports, which pushes up the marginal cost of CSG production. Wholesale gas prices in New South Wales would also be slightly higher (by 1% on average) over the same period. In Victoria and South Australia average gas prices over the period 2015 to 2035 would be lower by 17% and 9 % respectively, as a result of lower demand for exports from the Bass Strait region, while in Tasmania average gas prices would be around 2% higher on average over the period.

Electricity market impacts

- Total electricity generation in the NEM (that is, excluding non-scheduled generators) would reach 340,000 GWh by 2034-35, 11% higher than under the Reference Scenario.

[6] Calculated on the basis of wholesale delivered price index for Brisbane City Gate, with index based on Reference Case 2012 = 100.

- In Queensland, total electricity generated under the 10-train Expansion Case assumptions reaches 127,000 GWh by 2034-35. This is 18,500 GWh or 17% higher than for the Reference Scenario.
- Total gas-for-power generation consumption in the NEM is projected to grow very strongly, from 156 PJ in 2010-11 to 936 PJ/a in 2034-35. The largest increases in gas consumption for electricity generation occur in Queensland, New South Wales and Victoria.
- The changing fuel mix under the 10-train Expansion Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.54 tCO_2e/MWh (sent out) by 2034-35.
- Compared to the Reference Scenario, average electricity prices[7] in the NEM under the 10-train Expansion Case over the period 2014-15 to 2034-35 will be 10% lower.

General economic impacts

- Around $43.4 billion cumulative direct capital investment in upstream CSG development and a gain of around $35.5 billion of associated recurrent operating expenditure in Queensland over the period to 2035
  - While these gain will be at least partly offset by reduced investment and expenditure on gas production elsewhere in the country, the net result sees an increase in real Queensland Gross State Product of $497 billion in total over the period to 2034-35
  - This equates in net present value terms (7% discount rate) to a $197 billion increase in real value-added, equal to approximately 74 per cent of the total value of GSP in Queensland for the 2010-11 financial year.
- Queensland real income $342 billion higher in total over the period to 2035 ($131 billion higher in net present value, which based on current population represents approximately $28,300 per Queensland resident).
- Total employment in Queensland 20,210 higher per year on average (FTE basis).

Queensland Government Revenue

- Queensland Government receipts from CSG royalties, payroll tax and Queensland-sourced GST over the period to 2035 increased by $32.0 billion in aggregate, or $12.9 billion in NPV terms (7% discount rate).

[7] Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

All Government Revenue

- Nationally, Australian government receipts over the period to 2035 increase by $274.9 billion in aggregate or $106.7 billion in NPV terms (7% discount rate).

1 Introduction

A large-scale coal seam gas (CSG) industry is now emerging in Queensland, with production having risen over the past decade from less than 20 PJ/a to more than 200 PJ/a. Queensland CSG now accounts for around 30% of natural gas production in eastern Australia. Further developments now under way will see the construction of liquefied natural gas (LNG) production facilities and associated infrastructure in Central Queensland capable of producing more than 20 million tonnes of LNG annually from CSG feed. These developments will transform the eastern Australian gas sector—until now entirely focussed on domestic supply—by establishing a major export industry worth more than $10 billion per year.

While CSG exploration and development activity in New South Wales has not yet achieved the success of the industry in Queensland, it has clearly established that there are very large *in situ* resources of CSG in New South Wales and that these resources have the potential to support a large-scale production industry supplying local gas consumers and export markets.

Over the past year or so, public opposition to CSG developments in Queensland and NSW has been gaining momentum. Opponents of CSG development have called on governments in both states to stop, or at least to defer, CSG developments pending further investigations into their potential impacts. These calls have gained some political traction particularly in New South Wales where the government during 2011 imposed a 60-day moratorium on grant of new exploration permits for coal, CSG and petroleum as well as an extended moratorium on the use of hydro-fracturing ("fraccing") technology during CSG drilling.

1.1 About this Report

The Australian Petroleum Production & Exploration Association Limited (APPEA) engaged ACIL Tasman Pty Ltd ("ACIL Tasman") to analyse and to report on the economic impacts likely to arise from the growth of a major CSG industry in Queensland.

Specifically, ACIL Tasman was asked to undertake a study addressing the following questions:

1. What economic benefits could be expected as a result of continued growth of the Queensland CSG industry to the levels required to support six LNG export trains (nominal 24 million tonnes of LNG per year) as well as production for local domestic markets?

2. How would the estimated economic benefits change if the Queensland CSG industry were to expand to the levels required to support eight LNG export trains (nominal 32 million tonnes of LNG per year) as well as production for local domestic markets?
3. How would the estimated economic benefits change if the Queensland CSG industry were to expand even further, to the levels required to support ten LNG export trains (nominal 40 million tonnes of LNG per year) as well as production for local domestic markets?

1.2 Methodology

1.2.1 Gas demand, supply and price projections

Gas demand, supply and price projections in this report have been prepared using *GMG (GasMark® Global) Australia,* ACIL Tasman's proprietary model of the eastern Australian gas market. The *GMG Australia* model is a long range (20 to 30 year) economic model that attempts to match supply and demand in each of the regional markets in Eastern Australia with the dual objective functions of:

- minimising the cost of gas to consumers; and
- maximising field netbacks to producers (delivered price less transport costs).

The model takes into account assumptions about gas supply (reserves, production rates, minimum selling prices), gas demand at individual customer or customer group level (annual quantity, price tolerance) as well as existing and possible future transmission pipelines (current capacity, future expansions, tariffs).

Further details on *GMG Australia* are provided in Appendix A.

For the purposes of this report four cases have been modelled:

1. The **Base Case** generally represents ACIL Tasman's current default assumption set for gas modelling purposes. It assumes that the Queensland CSG industry grows to support six LNG export trains (nominal production capacity 24 million tonnes per year of LNG) with additional production available to supply domestic customers. However in order to be able to accommodate the Expansion Cases (see below) it was necessary to modify our default assumptions regarding the Queensland CSG supply cost curve (that is, the amount of developable CSG production capacity available at different break-even gas production costs) to ensure that the resource base and production capability would be adequate to supply up to ten LNG trains (40 million tonnes of LNG per year). The same Queensland CSG production cost curve assumptions were then used for all four scenarios.

2. An **8-train Expansion Case** which adopts the same assumptions as the Base Case except that the CSG LNG industry grows to support eight LNG export trains (nominal production capacity 32 million tonnes per year of LNG) with additional production available to supply domestic customers.
3. A **10-train Expansion Case** which adopts the same assumptions as the Base Case except that the CSG LNG industry grows to support ten LNG export trains (nominal production capacity 40 million tonnes per year of LNG) with additional production available to supply domestic customers.
4. The **Reference Scenario** which is a hypothetical scenario that effectively establishes, as a comparative benchmark, what the economy would look like *in the absence of the CSG industry*.

1.2.2 Electricity market projections

ACIL Tasman's long term model of the National Electricity Market (NEM)—*PowerMark LT*—has been used to assess the impacts of CSG development policy on electricity generation, wholesale prices and CO_2 emissions from the electricity generation sector. *PowerMark LT* is a dynamic least cost model that optimises existing generation operations and new investments over the period 2010 to 2050, given a range of input assumptions regarding demand growth, generation technology costs, interconnectors, new development costs and government policy settings (CEF, expanded RET etc.). *PowerMark LT* utilises a large scale commercial LP solver. *PowerMark LT* solves by providing the efficient least cost solution for a single long term scenario (technology costs, policy settings etc.). Further details on *PowerMark LT* are provided in Appendix B.

The four modelling scenarios have been set up in *PowerMark LT* by using the wholesale gas price projections generated by the gas model, *GMG Australia* for the corresponding gas model scenarios. The wholesale gas prices are used to specify fuel prices for each of the existing and new-entrant gas-fired generators in *PowerMark LT*. Changing the fuel price relativities between gas-fired generators and other generating plant (coal-fired, liquid-fuelled, hydro and other renewables) will result in changes in plant merit order and therefore in the dispatch levels for different generating units. This in turn affects the levels of gas consumption for electricity generation as well as the wholesale electricity prices determined by *PowerMark LT*. All other assumptions in *PowerMark LT* (for example other fuel prices, carbon prices, electricity demand and the capital and operating costs for existing and new entrant plant) are held the same in all scenarios *with one exception:* under the Reference Scenario the assumptions regarding electricity demand have been adjusted downward reflecting lower electricity demand as a result of substantially higher electricity prices.

1.2.3 Estimation of broader economic effects

The economic impacts of a policy, project or other activity can be estimated using a variety of economic analysis tools, with the most often utilised generally being input-output (I-O) multiplier analysis and computable general equilibrium (CGE) modelling. The selection of the right tool is critical to the accuracy of the estimated impacts and depends upon the characteristics of the project/industry. Sometimes a range of tools are required.

Fundamentally, although various aspects of a policy or project—such as the number of jobs or the size of the investment expenditure—are of relevance to certain stakeholders, the key aggregate measure of the impact of a project is the extent to which the total wealth of the economy has changed as a result of the policy or project[8]. Typically this is measured by real gross national disposable income (RGNDI), although real gross domestic product (GDP) and consumer surplus (among others) can also be important aggregate measures depending on the nature of the policy or project being analysed.

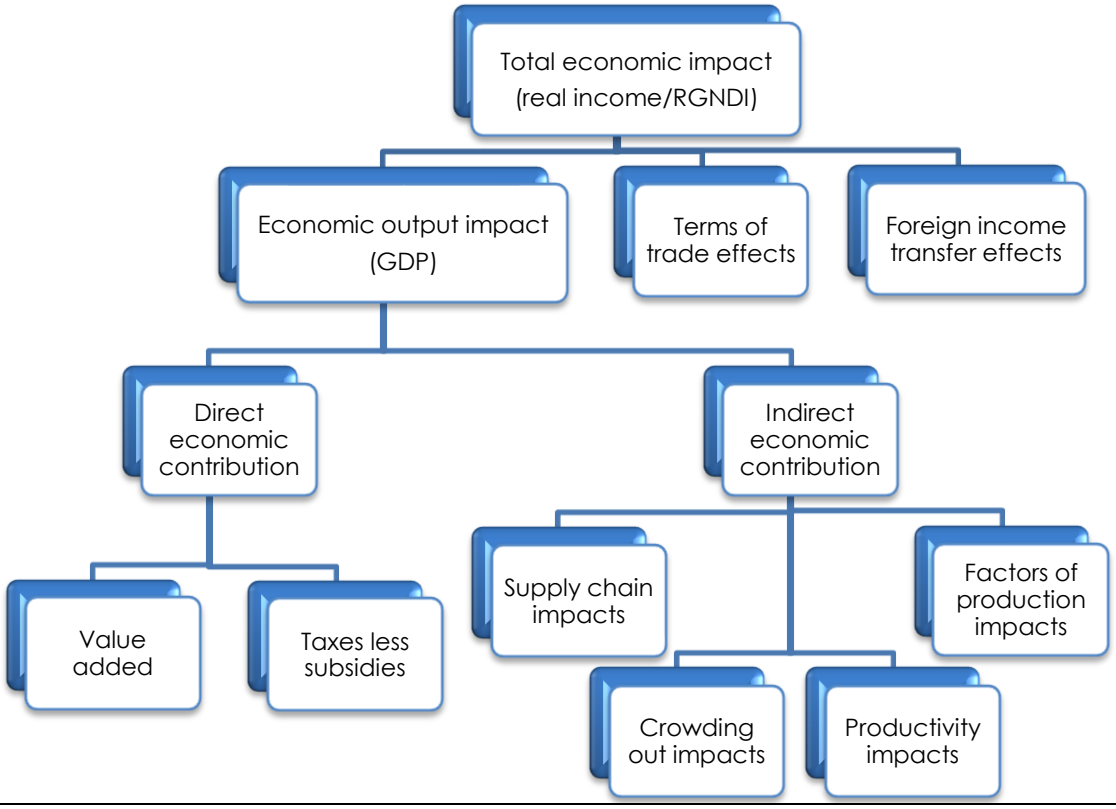
The main factors that need to be considered when analysing the economic impacts of a project or policy include:

- the direct and indirect contribution to the economy as a result of the activities associated with the project
- any 'crowding out' implications, which is where the use of scarce resources in one project means that resources are diverted from other productive activities, potentially 'crowding out' those activities by delaying or preventing them from occurring
- any productivity effects generated as a direct result of the policy or project activities – particularly any enduring productivity changes or productivity spillovers to other activities not directly associated with the project or policy
- any changes to the factors of production in the economy
- any welfare implications associated with changes in terms of trade or foreign income transfers
- whether there is a dynamic element to the size of any of the above effects (due to different phases of the project for example).

[8] Analysis of any non-market impacts (such as the loss of biodiversity, changes in air quality, social justice implications, etc.) may also be relevant in assessing the full implications of a project or policy.

Figure 1 shows these components graphically. Some of these effects may have negligible impact while others may be very significant and an understanding of the relative size of these effects helps determine the most appropriate tool(s) for the analysis.

Figure 1 **Estimating the economic impact of a project or policy**



Source: ACIL Tasman

For many projects, static estimates of the direct economic contribution and supply chain implications can be obtained through the use of I-O multipliers. Estimating the size of other components using multiplier techniques is either not possible or very complex, as is estimating the economic impacts through time. In contrast, most CGE models are able to estimate all of the components shown in Figure 1 with dynamic CGE models able to estimate the impacts through time. The greater complexity of CGE models generally increases the cost of undertaking analysis compared to using I-O multipliers, but it enables a much broader range of economic impacts to be considered within a single framework.

Ongoing development of the CSG industry in Queensland will have significant economic impacts at the national, state and regional level. The direct benefits will come through:

- investment expenditures in upstream exploration, drilling, production and processing activity – which provides benefits through the flow-on to domestic business activity and employment
- investment expenditures in gas transmission pipelines used to transport the processed CSG to end user customers, including export LNG facilities and local consumers
- investment expenditures in downstream facilities such as power stations and industrial facilities that use the CSG
- ongoing operation and maintenance expenditures during the operation of facilities across the entire supply chain.

These injections and flow-on effects will result in increased consumption and welfare for the people of Queensland and for Australians generally. Owing to the nature of the impacts, CGE modelling (rather than I-O multiplier analysis) has been chosen as the preferred tool to undertake the economic impacts assessment in this report.

The Tasman Global CGE Model

For this analysis, ACIL Tasman's CGE model known as *Tasman Global* has been used to estimate the impacts of the construction and operation activities associated with the development of the Queensland CSG industry. *Tasman Global* is a large scale, dynamic, computable general equilibrium model of the world economy that has been developed in-house by ACIL Tasman. *Tasman Global* is a powerful tool for undertaking economic analysis at the regional, state, national and global levels. More detail of the *Tasman Global* model is provided in Appendix C. CGE models mimic the workings of the economy through a system of interdependent behavioural and accounting equations which are linked to an input-output database. These models provide a representation of the whole economy, set in a national and international trading context, starting with individual markets, producers and consumers and building up the system via demands and production from each component. When an economic shock or change, such as the expansion of the Queensland CSG industry, is applied to a model, each of the markets adjusts according to the set of behavioural parameters which are underpinned by economic theory.

This theory and the use of the models are generally well understood and respected by decision makers from various Australian Governments. CGE can be a powerful tool for understanding the implications of a project to affected regions, the state and nationally as the models recognise not only the direct and second round impacts but the third and fourth round etc. impacts of a project.

2 The Queensland CSG Scenarios

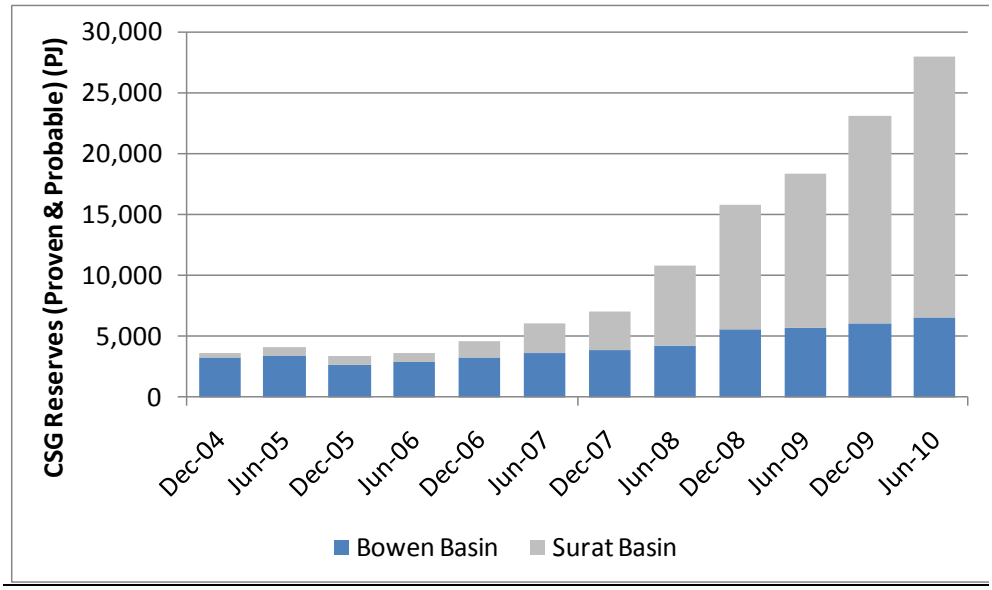
2.1 Introduction

Natural gas supply to the major population centres of South East Queensland commenced in 1969, based on conventional gas production in the Surat Basin (Roma district). Further conventional gas supply sources were subsequently discovered in the Bowen Basin (Dension Trough) region and in the Cooper Basin (South West Queensland), and the market for natural gas was expanded with the construction of transmission pipelines that enabled delivery of gas to Central Queensland and to North West Queensland. In recent years, however, conventional gas production in Queensland has declined as reserves in the Surat, Bowen and Cooper Basins have been largely depleted. Declining conventional production has, however, been more than offset by a rapid increase in CSG production over the past decade.

Both reserves and production of CSG in Queensland have increased dramatically over the past five years, as illustrated in Figure 2 and Figure 3.

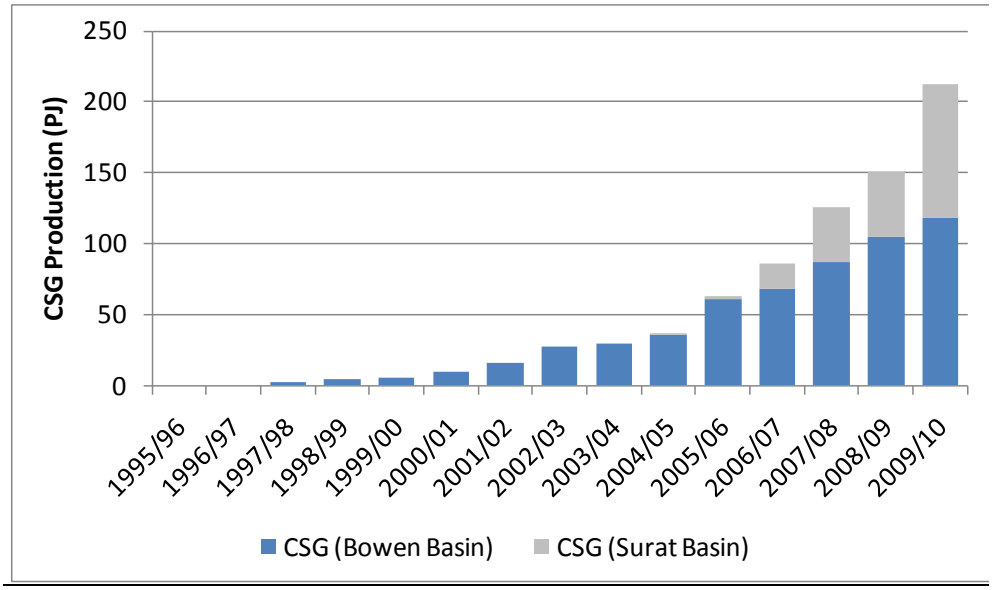
Levels of independently certified reserves of CSG in Queensland continue to grow rapidly, and by mid 2011 had reached around 35,000 PJ of proven and probable (2P) reserves. Possible (P3) reserves and contingent resources are much larger than the currently established 2P reserves base, which will therefore continue to grow as further drilling provides more information on gas content and well performance. Queensland production of CSG exceeded 100 PJ for the first time in 2007-08, and by 2009-10 had risen to 212 PJ from some 1,048 producing wells, accounting for almost 30% of total gas supply in Eastern Australia. Production continues to rise with a number of projects on ramp up to meet contractual commitments for LNG exports as well as local supply.

Figure 2 **CSG reserves growth in Queensland**



Data source: Queensland Department of Mines & Energy data file

Figure 3 **Historical production of CSG in Queensland**



Data source: Queensland Department of Mines & Energy data file

2.1.1 CSG to LNG Industry

Until 2007, Eastern Australia had not been considered a prospective location for large scale LNG manufacture, principally because uncommitted conventional gas resources in the region were inadequate to support a world-scale LNG facility. However, surging international energy prices together with the identification of large resources of CSG in southern and central Queensland changed the prospects for Eastern Australian LNG. Since early

2007, at least eight LNG proposals based on CSG feed from the Bowen and Surat Basins have been announced, and there is now a proposal for a mid-scale LNG plant at Newcastle, New South Wales. The proposed developments have had LNG liquefaction train sizes ranging from 0.5 to 4.5 million tonnes per year, with potential in each case for installation of multiple liquefaction trains. If all of the proposed projects were to be developed to the ultimate capacities announced by their respective proponents, the total installed liquefaction capacity would be well in excess of 60 million tonnes of LNG per year.

To put this prospect into perspective, 60 million tonnes of LNG is equivalent to about 3,300 PJ of gas. Allowing for additional gas used in production, transportation and processing, gross CSG production required to support this level of LNG development would be around 3,800 PJ/a. The entire Eastern Australian domestic gas market (Queensland, New South Wales including the Australian Capital Territory, Victoria, South Australia and Tasmania) currently consumes around 750 PJ/a.

It is unlikely that all of the proposed LNG projects will proceed. However four large scale projects in Queensland are now well advanced:

- **Queensland Curtis LNG project—QCLNG** (BG Group/QGC). Up to 12 Mtpa.
- **Gladstone LNG project—GLNG** (Santos/Petronas/Total/KOGAS). Up to 10 Mtpa.
- **Australia Pacific LNG project—APLNG** (Origin Energy/ ConocoPhillips). Up to 18 Mtpa.
- **Arrow Energy LNG Project** (Shell/PetroChina). Up to 16 Mtpa.

All of these projects are proposed to be located on Curtis Island, on the eastern side of Gladstone Harbour in Central Queensland. A fifth project—Fisherman's Landing LNG—is proposing to build a mid-scale (1.5 to 3 Mtpa) LNG facility on the mainland adjacent to Curtis Island.

While it is possible that there will be some consolidation of these projects over time, at present each is being pursued independently. The following provides a brief summary of the current status of the projects:

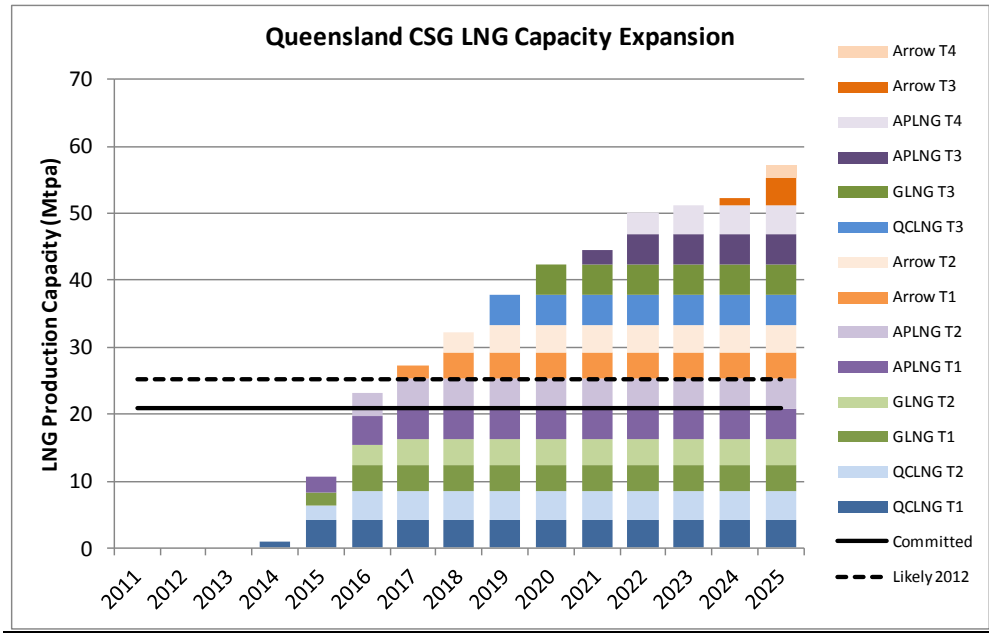
- In October 2010 BG/QGC made a final investment decision on a two-train, 8.5 Mtpa development of the **QCLNG** project. Contracts have been let for some long lead items; the large diameter export pipeline has been fabricated in China and delivered to Gladstone; and the project is now well into construction. First LNG shipments are scheduled for late 2014. There is scope for QCLNG to add a third liquefaction train subject to further reserves definition within the BG/QGC areas or introduction of third-party gas reserves.

- The Santos/Petronas/Total/KOGAS consortium reached a final investment decision in relation to the first two trains of the **GLNG** project in January 2011. The development approval triggered major works on upstream field development, pipelines and construction of a 7.8 Mtpa two-train LNG facility at Gladstone. First LNG shipments are scheduled in 2015. There is potential for addition of a third train to the GLNG project, subject to identification of sufficient CSG reserves and securing customers for the additional LNG volumes.
- In November 2010 Origin Energy and ConocoPhillips gained the required Queensland government environmental approvals for their Australia Pacific LNG (APLNG) project. The corresponding Commonwealth Government approvals were granted in February 2011. In April 2011 APLNG completed binding agreements with Sinopec of China for the sale of 4.3 Mtpa of LNG over 20 years. Sinopec has also taken a 15% equity interest in the project. The deal effectively accounted for all production from the first train of the project which was subsequently committed under a final investment decision (FID) taken in July 2011. First LNG production from Train 1 is scheduled in mid 2015. APLNG expects to take FID on Train 2 during 2012, with first LNG production from Train 2 by early 2016.
- The Arrow Energy LNG project (AELNG; Shell/PetroChina) is designed to produce up to 16 Mtpa of LNG through the phased construction of up to four LNG trains on Curtis Island at Gladstone. Stage 1 involves the construction of two trains each of around 4 Mtpa capacity. AELNG submitted a detailed Environmental Impact Statement in early 2012. Subject to receipt of the necessary environmental and other development approvals and a positive final investment decision, it is anticipated that first LNG shipments from the project could occur in 2016/17.

In summary, it is now confirmed that at least 20.8 Mtpa of CSG-based LNG production capacity will be constructed at Gladstone, and it is likely that this figure will rise. A positive development decision by the APLNG partners on a second LNG train later this year would see committed CSG LNG capacity at Gladstone increase to more than 25 Mtpa, while development of all four projects to their maximum announced target capacity would increase aggregate capacity to almost 60 Mtpa.

Committed and planned Queensland CSG LNG production capacity associated with the four active projects is summarised in Figure 4.

Figure 4 **Committed and planned Queensland CSG LNG production capacity**



Data source: ACIL Tasman compilation of public domain sources

2.2 The study scenarios

This study presents an assessment of the economic benefits arising from three Queensland CSG growth scenarios. In order to assess the resulting economic benefits, each of these scenarios is compared with a **Reference Scenario** (counterfactual) in which no further development of Queensland or New South Wales CSG occurs beyond current levels. Such a scenario would see no export LNG developments, declining production of Queensland CSG over time and heavy reliance on conventional gas reserves and discovery of new conventional and tight gas resources in areas such as Bass Strait and the Cooper Basin. The key assumptions and modelling outcomes for the Reference Scenario are discussed in Chapter 3.

The Reference Scenario is compared with the following three CSG development scenarios:

- A **Base Case** under which the industry grows to support six LNG export trains (nominal production capacity 24 million tonnes per year of LNG) with additional production available to supply domestic customers. The results of the Base Case scenario are set out in Chapter 4.
- An **8-train Expansion Case** under which the industry grows to support eight LNG export trains (nominal production capacity 32 million tonnes per year of LNG) with additional production available to supply domestic customers. The results of the Base Case scenario are set out in Chapter 5.

- A **10-train Expansion Case** under which the industry grows to support ten LNG export trains (nominal production capacity 40 million tonnes per year of LNG) with additional production available to supply domestic customers. The results of the Base Case scenario are set out in Chapter 6.

3 The Reference Scenario

The Reference Scenario establishes the base line against which the three other scenarios—Base Case, 8-train Expansion Case and 10-train Expansion Case—are compared to demonstrate the economic impacts of the CSG industry in Queensland.

The Reference Scenario effectively establishes, as a comparative benchmark, what the economy would look like without the CSG industry. Under this counterfactual case we assume no further development of Queensland or New South Wales CSG beyond current levels (a situation that would imply government intervention to put a hold on further CSG drilling and production activity). As a result, no CSG LNG export developments occur. Existing CSG fields continue to produce gas for local markets, but aggregate production capacity declines over time as individual CSG wells produce at lower rates and are not replaced with new wells. Gas prices have been effectively capped at LNG import parity by including (on the supply side) the option of importing LNG if local prices reach levels that would make this economically viable. The Reference Scenario reflects relatively low levels of gas demand for electricity generation because of constrained gas supply and high gas prices. The assumed level of new gas-fired electric generating plant included under this scenario is consistent with the corresponding electricity modelling scenario established using the *PowerMark LT* model. Importantly, we assume that current policies in relation to greenhouse gas abatement are maintained and that no new coal-fired generating plant is built until such time as carbon capture and storage (CCS) technologies can be technically and commercially deployed to reduce emissions from coal-fired plant.

Figure 5 shows the level of gas demand in Eastern Australia, by State, under the Reference Scenario. Demand (which is an input to the gas model) falls significantly from 2030 on because, with constrained gas supply and high gas prices, new low emission electricity generation technologies (coal with carbon capture & storage, geothermal) are assumed to become viable and competitive alternatives and become the preferred new entrant technologies for electricity generation.

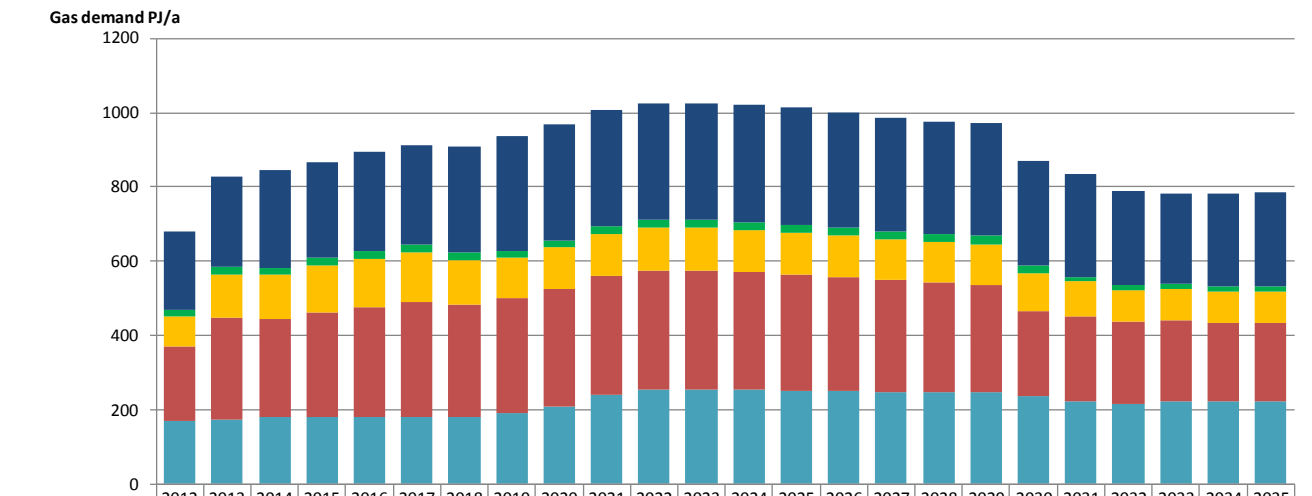
Figure 6 shows the corresponding level of gas consumption (model output). It is notable that a significant supply gap emerges after 2020 as the level of total demand cannot be satisfied from available supply.

Figure 7 shows modelled gas production (conventional and CSG) in Eastern Australia, by State, under the Reference Scenario. CSG production in Queensland continues to rise until 2013 as wells already drilled ramp up to full production. After 2013 Queensland CSG production declines steadily from a

peak of 279 PJ/a to 81 PJ/a by the end of the projection period. The decline in production from Victoria and South Australia in the period after 2023 is primarily a response to falling demand, but also reflects resource constraints in the Gippsland, Bass, Otway and Cooper Basins.

Figure 8 illustrates the modelled gas prices under the Reference Scenario, relative to a base year price index (2012) of 100 at each key market node. The results show that under the Reference Scenario wholesale gas prices rise most strongly in Queensland (Brisbane and Wallumbilla nodes). Initially prices rise strongly to 2014. They then fall briefly as new sources of supply (tight gas and "infill gas") are assumed to become available from the Cooper Basin providing some relief to the prevailing supply constraints. From 2015 prices rise fairly steadily with rising demand until 2029. Price differences between regions reflect localised production and/or transmission constraints. The mild softening of prices from 2030 is consistent with the weaker gas demand assumptions after this time and the entry of new low-emission electricity generation technologies (geothermal, CCS coal).

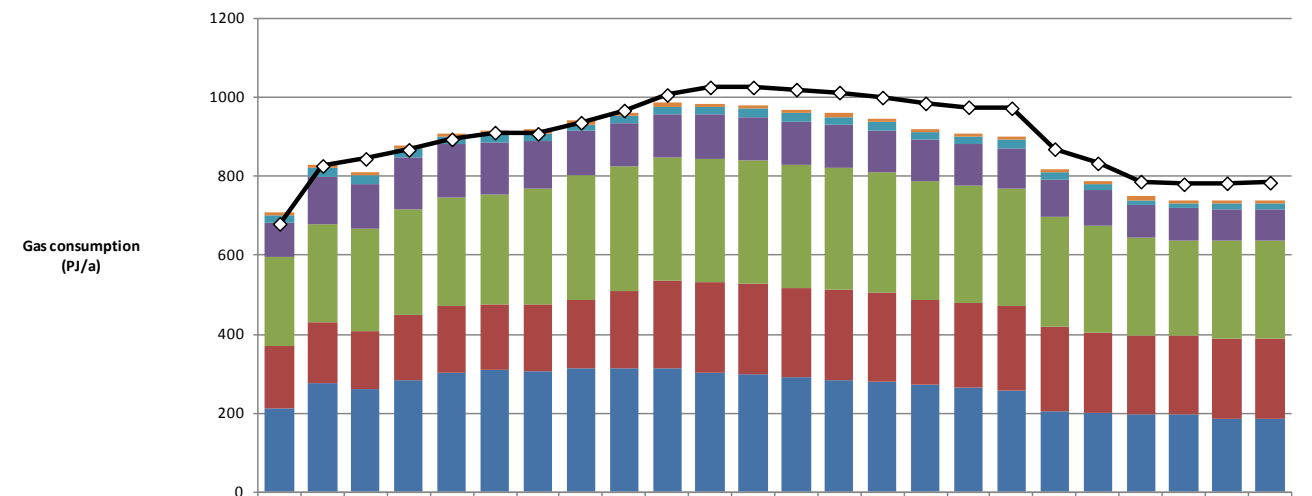
Figure 5 **Reference Scenario: Gas demand by State**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Victoria	211	242	262	258	268	268	286	308	311	314	315	316	316	315	309	304	302	305	282	275	251	242	250	252
Tasmania	19	22	21	21	20	20	20	18	19	20	20	21	21	21	21	21	21	22	20	13	13	13	13	13
South Australia	81	116	119	127	129	134	119	108	110	112	114	114	114	114	113	112	111	111	101	96	86	86	85	85
Queensland	201	272	264	281	299	311	303	312	317	320	323	320	316	313	308	300	292	286	230	226	221	218	213	212
NSW/ACT	169	176	180	181	179	180	181	190	210	242	254	255	254	252	250	249	249	249	237	224	217	222	223	222

Source: ACIL Tasman GMG Australia modelling

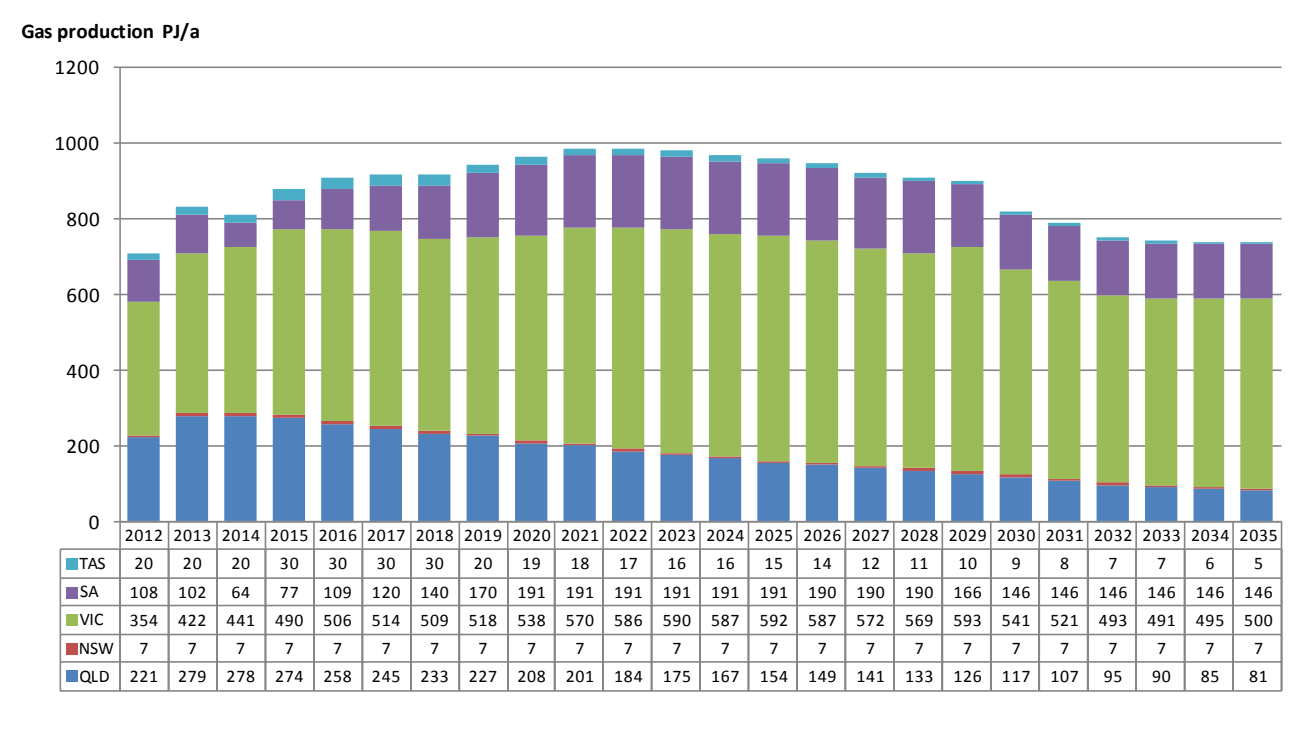
Figure 6 **Reference Scenario: Modelled gas consumption, by State, compared to demand**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Australian Capital Territory	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9
Tasmania	20	23	20	21	20	21	20	18	20	19	20	20	20	20	20	21	21	21	19	12	12	12	12	13
South Australia	88	119	115	131	134	135	121	111	111	111	112	111	110	109	108	106	106	103	96	92	83	83	81	81
Victoria	222	248	259	266	278	277	294	315	316	314	313	313	312	310	304	298	295	298	277	272	249	240	247	248
New South Wales	160	156	147	167	167	167	167	175	194	221	229	230	229	227	226	216	216	215	215	203	198	202	202	202
Queensland	212	276	261	284	303	309	307	313	315	313	303	297	289	285	280	272	264	256	204	200	199	195	187	187
Total DEMAND	680	827	845	868	895	912	909	937	968	1007	1027	1026	1021	1013	1001	986	976	974	870	834	788	781	783	785

Source: ACIL Tasman GMG Australia modelling

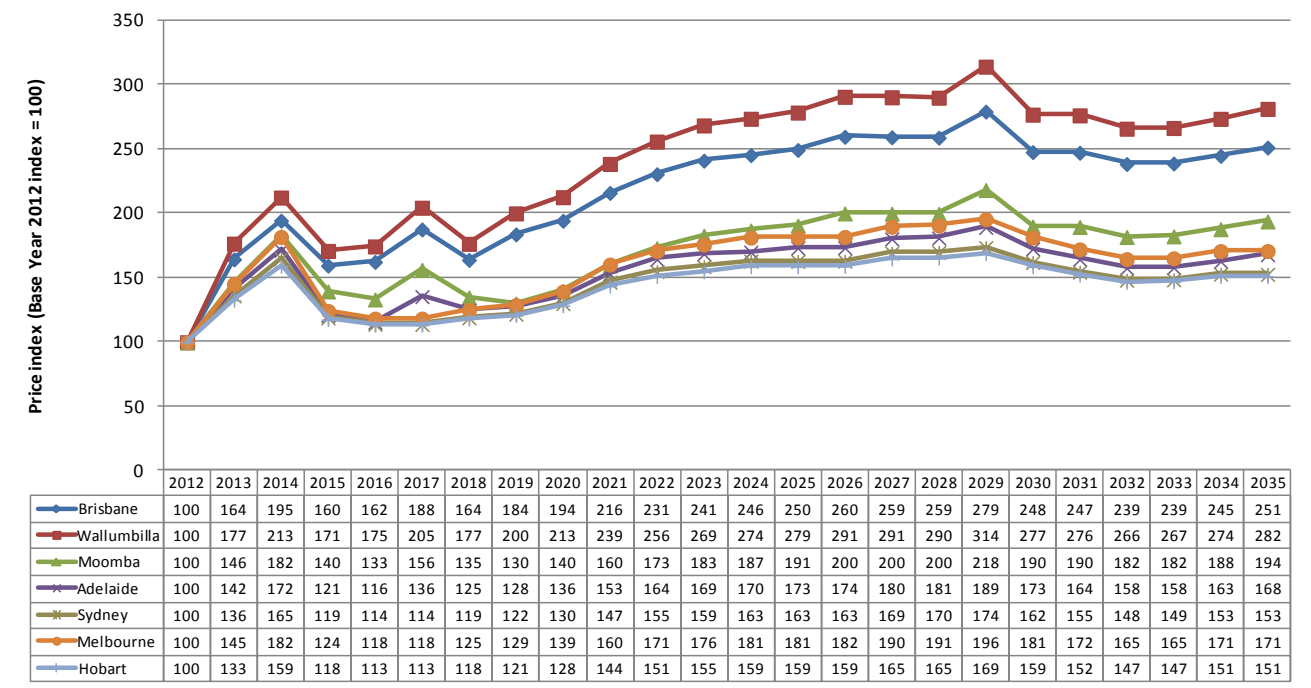
Figure 7 **Reference Scenario: Eastern Australia gas production**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TAS	20	20	20	30	30	30	30	20	19	18	17	16	16	15	14	12	11	10	9	8	7	7	6	5
SA	108	102	64	77	109	120	140	170	191	191	191	191	191	191	190	190	190	166	146	146	146	146	146	146
VIC	354	422	441	490	506	514	509	518	538	570	586	590	587	592	587	572	569	593	541	521	493	491	495	500
NSW	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
QLD	221	279	278	274	258	245	233	227	208	201	184	175	167	154	149	141	133	126	117	107	95	90	85	81

Source: ACIL Tasman *GMG Australia* modelling

Figure 8 **Reference Scenario: modelled gas prices**



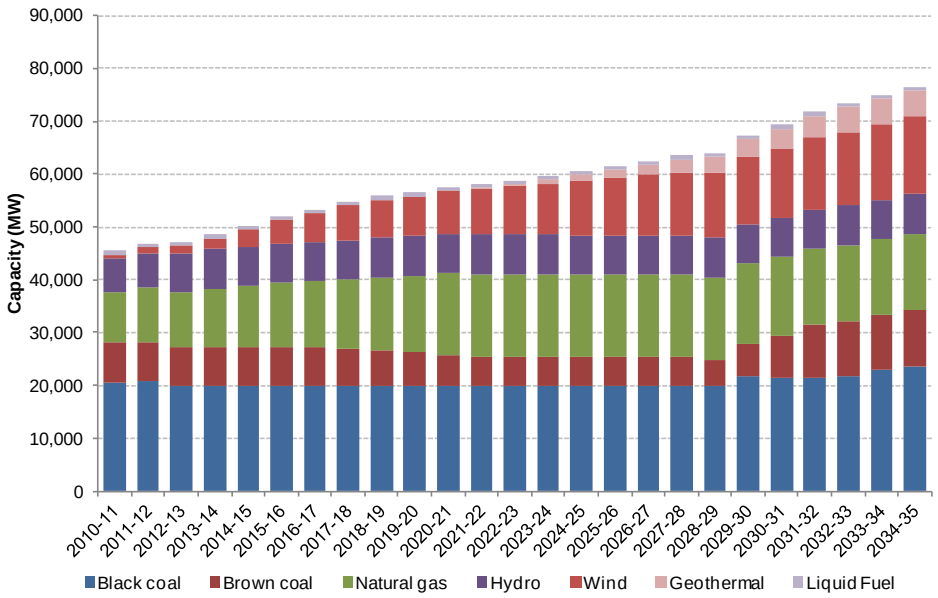
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Brisbane	100	164	195	160	162	188	164	184	194	216	231	241	246	250	260	259	259	279	248	247	239	239	245	251
Wallumbilla	100	177	213	171	175	205	177	200	213	239	256	269	274	279	291	291	290	314	277	276	266	267	274	282
Moomba	100	146	182	140	133	156	135	130	140	160	173	183	187	191	200	200	200	218	190	190	182	182	188	194
Adelaide	100	142	172	121	116	136	125	128	136	153	164	169	170	173	174	180	181	189	173	164	158	158	163	168
Sydney	100	136	165	119	114	114	119	122	130	147	155	159	163	163	163	169	170	174	162	155	148	149	153	153
Melbourne	100	145	182	124	118	118	125	129	139	160	171	176	181	181	182	190	191	196	181	172	165	165	171	171
Hobart	100	133	159	118	113	113	118	121	128	144	151	155	159	159	159	165	165	169	159	152	147	147	151	151

Source: ACIL Tasman *GMG Australia* modelling

Note: Based on wholesale delivered prices at the relevant market location, with index based on Reference Case 2012 = 100

Figure 9 shows the mix of electricity generation plant in the National Electricity Market (NEM) under the Reference Scenario. Note the inclusion of significant levels of geothermal capacity (after 2020) and new black and brown coal plant (with carbon capture & storage, CCS) after 2030. Other renewable technologies such as solar, bagasse and biomass contribute to total energy supply outside the NEM but are not represented in the NEM generation mix which comprises individual generating units of at least 30MW capacity.

Figure 9 **Reference Scenario: NEM electricity generating plant mix**

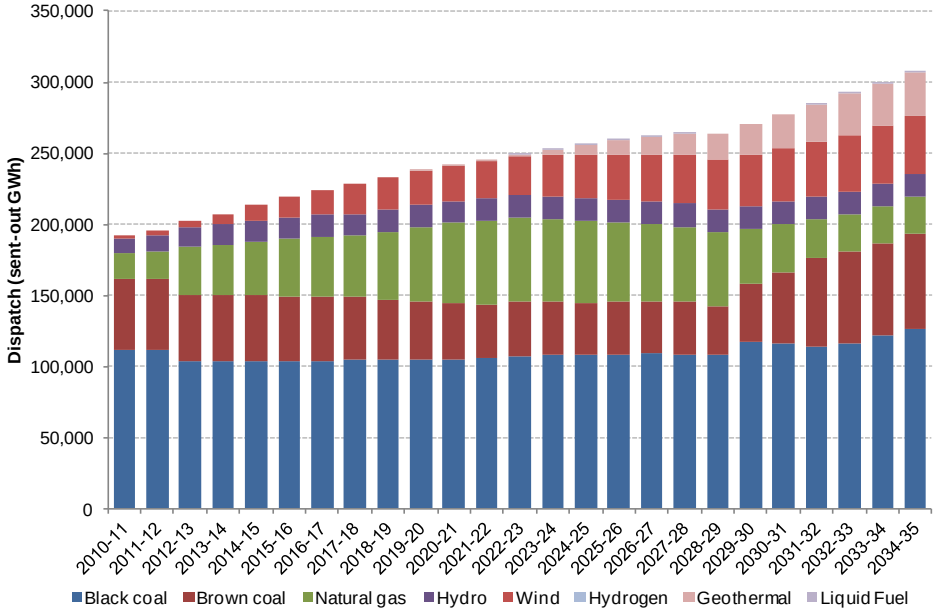


Source: ACIL Tasman *PowerMark LT* modelling

Total plant dispatch for the NEM, by plant type, is shown in Figure 10. Total sent-out energy reaches 306,600 GWh by 2034-35. Dispatch of gas-fired generating plant peaks at 23,200 GWh in 2021–22, then begins to decline in the face of higher gas prices. From 2029–30 dispatch of gas-fired generators drops sharply as new, low-emission black and brown coal plant with CCS becomes available.

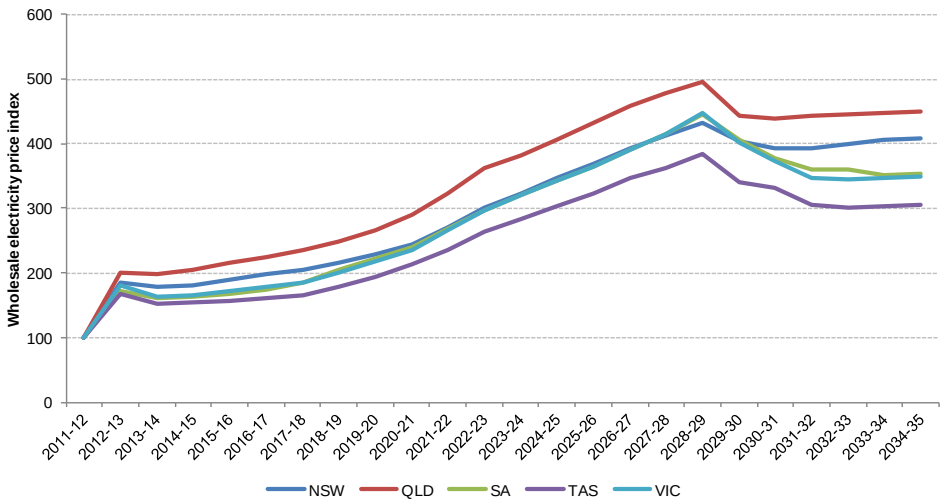
Figure 11 shows wholesale electricity price indices under the Reference Scenario (based on time-weighted regional reference prices expressed in real 2011-12 $/MWh; base year 2011-12 index = 100). Prices step up sharply in 2012-13 in response to the commencement of carbon emission pricing under the Clean Energy Futures legislation. Prices then continue to rise in real terms, peaking in 2029–30, before falling as clean coal generating technologies with CCS and geothermal start to enter the market. The strongest price rises are expected to occur in Queensland, reflecting the rapid rise of wholesale gas prices.

Figure 10 **Reference Scenario: NEM electricity plant dispatch by fuel type**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 11 **Reference Scenario: NEM wholesale electricity prices**



Note: Wholesale price indices based on time-weighted regional reference prices expressed in real 2011-12 $/MWh; base year 2011-12 index = 100

Source: ACIL Tasman *PowerMark LT* modelling

4 The Base Case

Under the Base Case we assume that production of CSG in Queensland continues to expand thereby supporting the establishment of three separate LNG projects, each having two liquefaction trains with nominal capacity of 4 Mtpa each, for a total combined LNG capacity of 24 Mtpa. The gross feedstock requirement for the six LNG trains would be approximately 1,440 PJ/a. Continuing growth of CSG production capacity in both Queensland and NSW also contributes to an increasing level of supply into local markets.

4.1 Base Case key assumptions

The following summarises the key assumptions that have been made in modelling the Base Case:

- "Mid range" supply and demand side assumptions. On the demand side, assumptions regarding retail loads (residential, commercial and small industrial customers serviced by gas distribution businesses and retail energy sellers) take into account information drawn from recent access regulation cases. In particular there has been a marked decrease in average household consumption as a result of warmer winters and the effects of State and Commonwealth government energy efficiency initiatives.
- Gas demand—in particular for electricity generation—reflects a carbon price trajectory based on the 10 July 2011 policy document from the Australian Government, "*Securing a Clean Energy Future*", which foreshadows the introduction of a carbon tax commencing on 1 July 2012 at a nominal rate of $23.00 per tonne which is then replaced by an emissions permit trading scheme from July 2012. The policy document was accompanied by a Treasury report, *"Strong Growth, Low Pollution"* which provided information on an estimated carbon price trajectory out to 2050 and estimated effects of the emissions abatement package. Under the medium global action scenario, Treasury has estimated that the international market price in 2015/16 will average around $A29/t CO_2-e in nominal terms and increase at around 5 percent per year in real terms to 2050.
- Gas demand for power generation also reflects recent downgraded assessments of the contribution from low-emission technologies. Based on the slow rate of technical progress and current estimates of technology costs, ACIL Tasman does not expect carbon capture & storage (CCS) coal or Hot Rock Geothermal (HRG) technologies to be viable at large scale and on a fully commercial basis before 2030.
- Consistent with Queensland CSG LNG project commitments over the past 18 months, we have assumed six LNG trains at Gladstone, each of 4 million tonne per year (Mtpa) capacity. These developments see a total of 24 Mtpa of net LNG production capacity (26.4 Mtpa gross, including gas

used in processing) commissioned over the period from late 2014 to early 2017. Total CSG feed requirement for LNG production (including upstream/midstream requirements) reaches about 1,440 PJ/a at full development. The Queensland CSG production cost curve reflects recent insights into costs of CSG production (see below) with total available resources sufficient to support up to ten LNG trains (40 Mtpa net production). This assumption allows the same CSG reserves assumptions to be used for all modelling scenarios.

  - Producible reserves of Queensland CSG are assumed to be a little over 100,000 PJ across a range of price points.

- Total production capability from NSW CSG is assumed to rise from around 6 PJ/a at present (excluding methane production associated with mining operations) to 133 PJ/a (69% of NSW gas demand) across a range of price points by 2020, and 222 PJ/a (75% of NSW gas demand) by 2030. The production cost curve for NSW CSG reflects recent insights into costs of CSG production (see below).
- Gas transmission pipeline extensions and expansions are assumed to occur in line with market opportunities, with tariffs for expansion capacity consistent in real terms with current tariffs.

4.1.1 CSG supply cost curve

The CSG supply cost curve represents the amount of CSG resource that is potentially recoverable on an economic basis at any given market price for gas. All else being equal, the amount of CSG that can be economically recovered in a particular region will rise as the market price for gas in that region rises. However, at the extremes of the price distribution there are typically limited quantities of reserves available (that is, below a certain low market price there is little CSG that can be produced on a commercially viable basis, and as prices rise a point is reached at which further increases in price draw forth increasingly small increments of supply). As a result, the supply cost curve is typically "S-shaped"—see Figure 12.

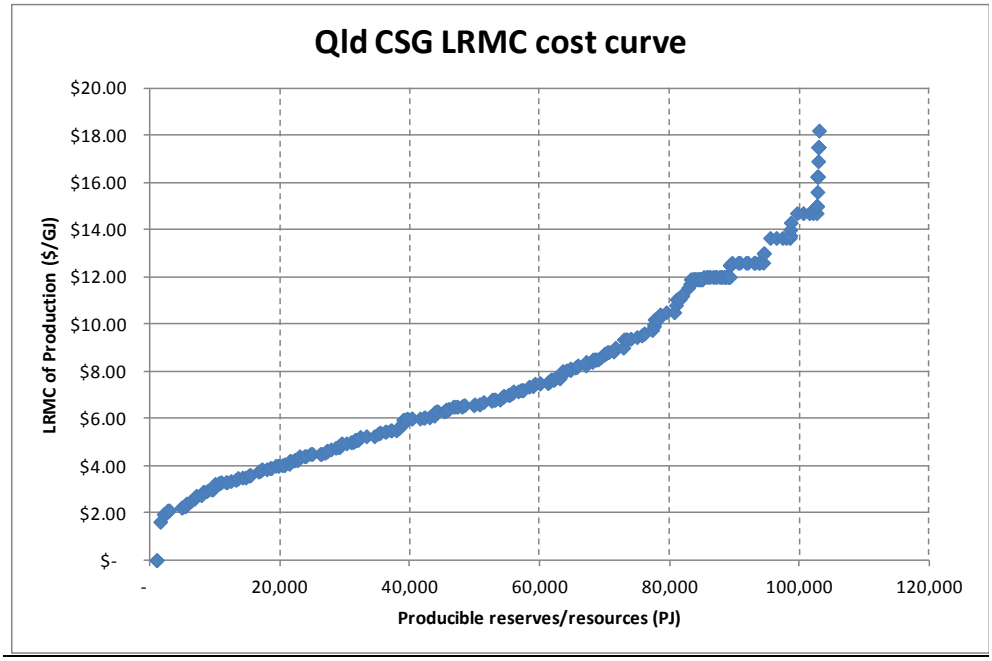
The supply cost curve assumptions for Queensland CSG used in this analysis are summarised in Figure 12. Producible reserves and resources of CSG in Queensland are assumed to be a little over 100,000 PJ across all price points. The costs shown in Figure 12 represent the long-run marginal costs of production inclusive of a commercial return on capital. They therefore equate to the selling prices that a producer would need to achieve in order to justify the investment to bring the fields into production.

The cost curve assumptions have been compiled by ACIL Tasman based on public statements by various gas exploration companies with regard to reserves and resource assessments, together with information on production cost

ranges gained through interaction with clients involved in CSG exploration and development.

It is important to note that the estimation of CSG supply cost curves is subject to significant uncertainty. The exploration for and demonstration of CSG reserves and resources is an on-going process and many factors, both geological and commercial, can influence CSG production costs. Furthermore, supply cost curves may change shape and shift over time as a result of "learning curve" effects and technological developments.

Figure 12 **Queensland CSG production cost curve**



Data source: ACIL Tasman analysis

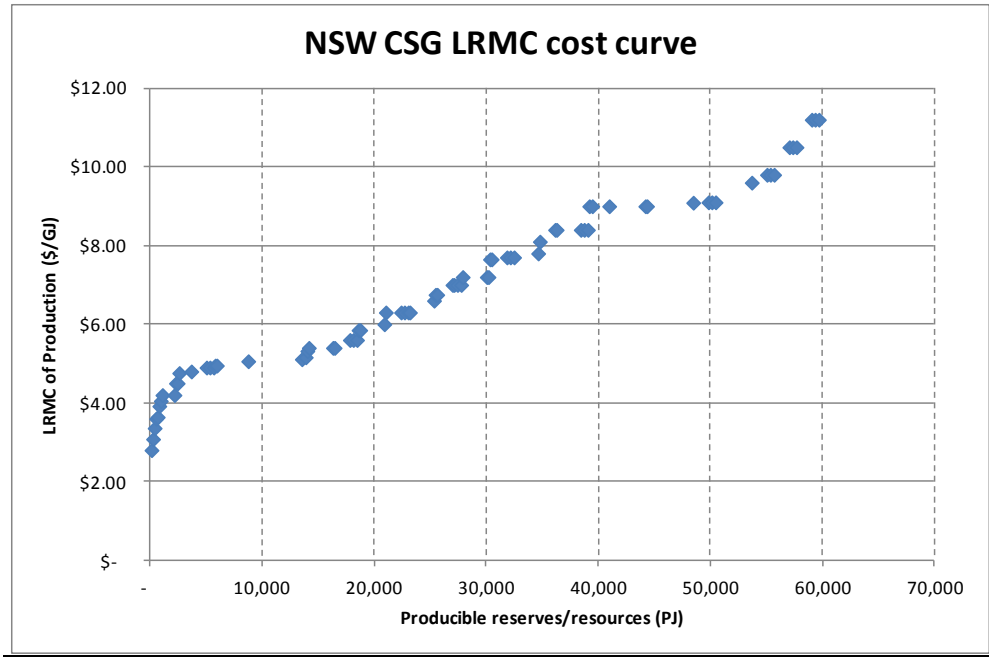
Other analysts may make different assumptions and reach different conclusions regarding the shape of the CSG supply cost curve. So, for example, Intelligent Energy Systems (IES) in a recent draft report for the Office of the Queensland Gas Commissioner has assumed a cost curve encompassing around 100,000 PJ of producible resources at LRMC of $9/GJ or less, and with 60,000 PJ available at $6/GJ or less[9]. By contrast, we have assumed for the purposes of this study a producible resource of 100,000 PJ at $14/GJ or less, with 60,000 PJ available at $7.50/GJ or less (Figure 12). The IES cost curve incorporates estimates of current high case and low case CSG production costs based on "a notional CSG field delivering 60 TJ per day for 15 years ... with each well producing an average 600 GJ per day". We note that

[9] See Intelligent Energy Systems, 2012: "Gas Market Review 2012: A Report to the OQGC", 21 May 2012 Draft, Figure 5.1.

while there are a number of CSG fields in the Bowen and Surat Basin that meet or exceed this average level of production, other fields in the region fall well short of this benchmark. The IES cost curve also appears to incorporate some contribution from shale gas: the draft report states that it is based on assumptions "that the current cost trend continues and that shale would be in the economic mix by 2020 (by which time 2P reserves may have increased over 60,000 PJ)". Such factors may help to explain the differences between the ACIL and IES cost curves—they reflect the very real uncertainties in estimating future unit costs of CSG production in deposits that remain sparsely explored. Despite these differences, we consider that the cost curve that we have used for this analysis is reasonable. It draws on considerable detail in terms of field level resource estimation and site specific cost analysis which we believe lends considerable weight to the ACIL Tasman assumptions.

The resources under the Queensland cost curve are sufficient to support the expansion of LNG production up to ten trains totalling 40 Mtpa net LNG. This level of Queensland CSG reserves is assumed in all modelling scenarios: by assuming a resource base sufficient to support the most expansive CSG scenario and then adopting that resource base for all scenarios we effectively remove from the analysis any effects arising from changes to the reserves assumptions. With lower levels of LNG production under the Base Case and 8-Train Expansion Case, the actual calls on these reserves would be significantly reduced and only those resources in the lower parts of the cost curve would be brought into production.

Figure 13 **NSW CSG production cost curve**



Data source: ACIL Tasman analysis

The corresponding CSG production cost curve for New South Wales is illustrated in Figure 13. The smaller resource base implied by the NSW cost curve—up to 60,000 PJ of producible resource across all price points—reflects the earlier stage of CSG exploration and development in NSW when compared with Queensland and is consistent with the exploration and production results achieved to date.

CSG supply cost curve and the Reference Case

In order to provide a benchmark against which to measure the impacts of the CSG industry, we have analysed a Reference Case which assumes that no further CSG development occurs in Queensland or New South Wales. As previously noted, the Reference Case adopts the same underlying CSG supply cost curve as the three CSG LNG Development Cases. However, in effect this supply capability is assumed to be withheld from the market as a matter of policy intervention. The resource basically remains untapped and out of reach. Supply under the Reference Case has to be obtained mainly from conventional gas sources that are not represented in the CSG supply cost curves. This explains why modelled gas prices under the Reference Case are higher than in the Base Case and 8-train Expansion Case, despite the fact that these cases see much greater quantities of CSG produced to support LNG production.

4.2 Gas Modelling Results—Base Case

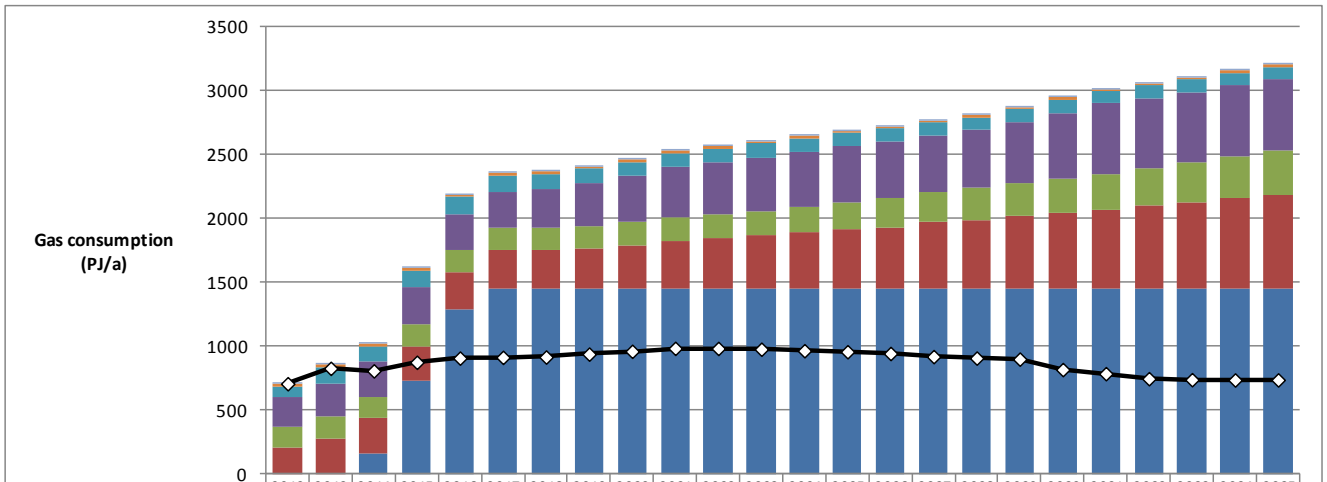
4.2.1 Gas demand and consumption

Figure 14 shows the modelled gas consumption, by State, for Eastern Australia including CSG produced for LNG manufacture in Queensland, under the Base Case. LNG manufacture accounts for more than half of total production with some 1,447 PJ/a used for LNG from 2017 on. Domestic consumption grows most strongly in Queensland and Victoria, with Queensland consumption rising 176% from 267 PJ in 2015 to 738 PJ in 2035. NSW consumption grows some 104% over the same period, from 172 PJ to 351 PJ, while in Victoria consumption rising 95% from 287 PJ to 561 PJ. This reflects an assumption that most new entrant combined-cycle gas turbine (CCGT) generating plant will locate in Queensland, Victoria and NSW because of a combination of proximity to gas supply and location relative to existing generation sites, including (in the case of Victoria) plant likely to be partially or wholly replaced as a result of carbon pricing.

Over the same time period, gas consumption in South Australia and Tasmania is projected to decline by 30% and 25% respectively as these are the regions least competitive for gas-fired electricity generation as new low-emission technologies start to enter the market.

Total production at the end of the projection period is a little over 3,200 PJ/a — some 335% higher than the 739 PJ under the Reference Scenario.

Figure 14 **Base Case: Eastern Australia modelled gas consumption, by State, including CSG for LNG production**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Australian Capital Territory	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	8	9
Tasmania	20	23	21	21	20	21	21	18	19	19	19	19	19	19	19	20	20	20	20	18	17	17	17	16
South Australia	89	126	127	132	130	129	121	111	110	109	108	109	103	102	102	102	103	102	102	96	100	99	95	93
Victoria	223	256	274	287	285	286	301	337	363	396	409	417	433	444	444	438	449	470	512	547	544	548	552	561
New South Wales	163	166	167	172	173	175	175	174	176	184	184	193	201	211	226	239	250	263	272	282	296	312	335	351
Queensland	213	284	271	267	288	303	308	322	348	374	402	421	445	466	486	523	545	573	596	624	653	684	710	738
Not Specified	0	0	164	734	1293	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447	1447
Reference Scenario Total	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

Source: ACIL Tasman *GMG Australia* modelling

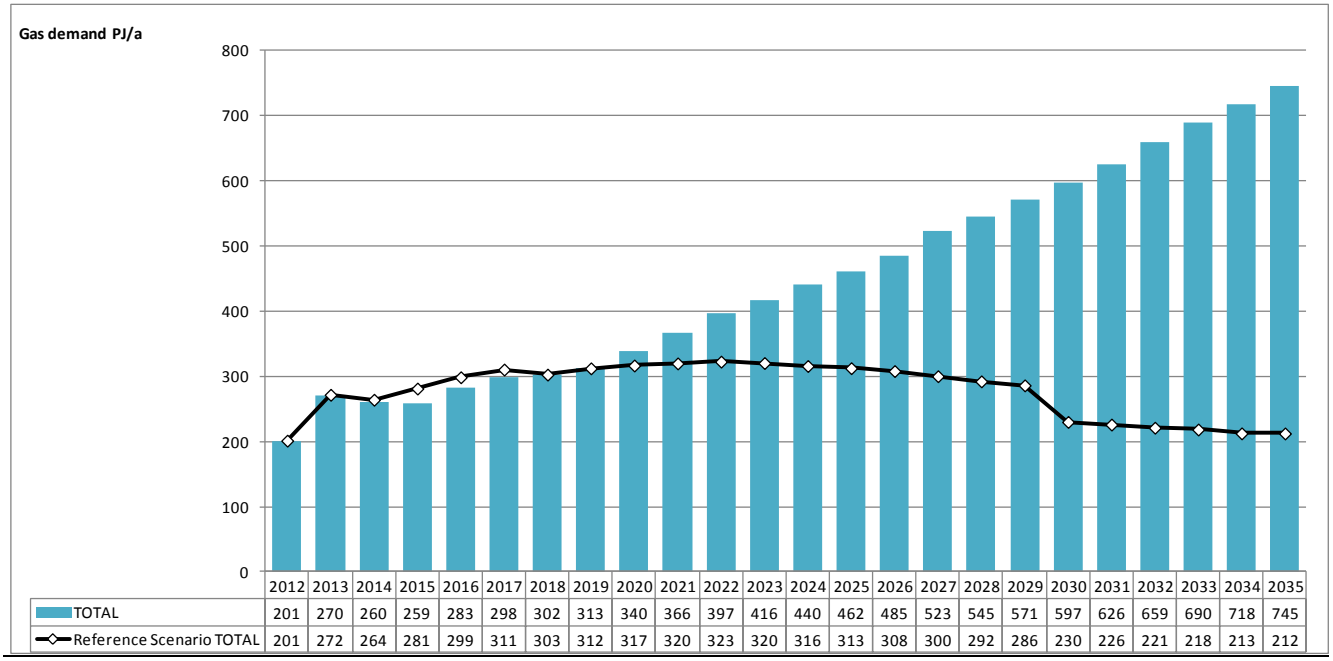
Figure 15 shows the modelled gas demand inputs for Queensland, excluding gas for LNG export production, under the Base Case. Gas demand in Queensland grows steadily at first, rising more rapidly in later years as a result of increasing demand for gas-fired power generation. Compared to the Reference Scenario, Queensland domestic gas demand over the period 2015 to 2035 is on average 196 PJ/a or 81% higher under the Base Case.

Figure 16 shows the corresponding gas consumption[10] model outputs, by load type, for Queensland under the Base Case. It highlights the fact that growth in gas consumption will be driven very much by the requirements of combined cycle gas turbine (CCGT) electricity generation. Indeed, under the model assumptions, consumption in the industrial, commercial and residential sectors is not expected to grow significantly. Consumption in open cycle gas turbine (OCGT) generating plant grows strongly in the period to 2014 as a result of

[10] In this study the term *"consumption"* refers to the amount of gas that each customer consumes in a given year, and is an *output result* from the model. The term *"demand"* is the amount of gas that each customer is seeking to buy (at the price they expect to pay: the model takes account of price elasticity of demand) and is an *input assumption* to the model.

availability of ramp-up gas prior to LNG start up, but is projected to decline towards the end of the modelling period as excess CSG supply is taken up by the LNG plants.

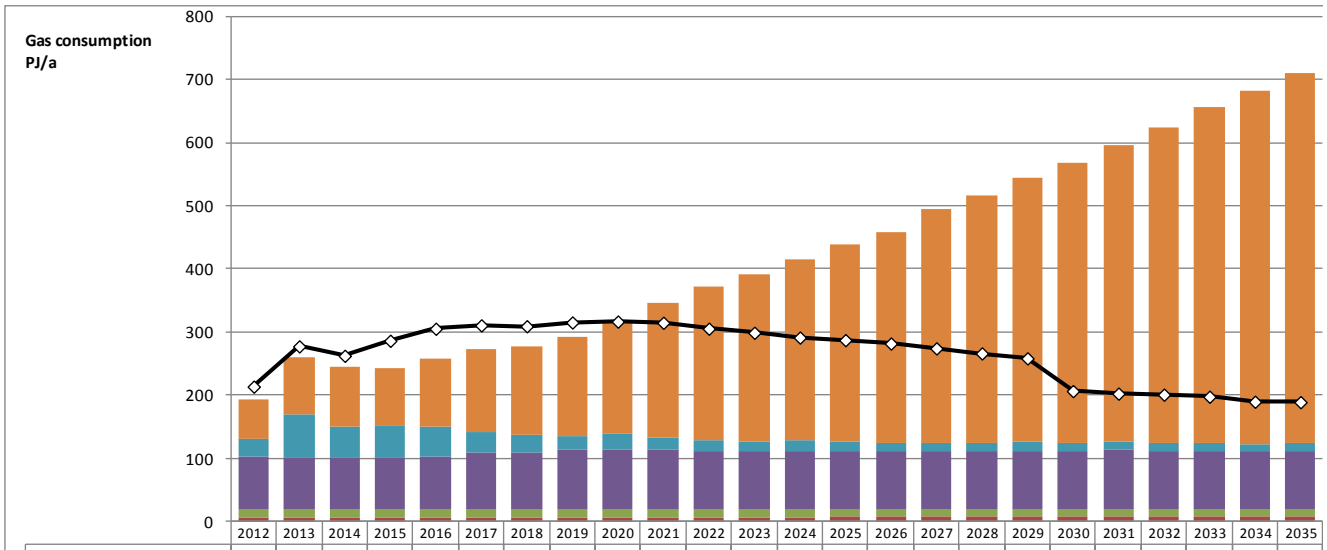
Figure 15 **Base Case: Queensland gas demand (model inputs)**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL	201	270	260	259	283	298	302	313	340	366	397	416	440	462	485	523	545	571	597	626	659	690	718	745
Reference Scenario TOTAL	201	272	264	281	299	311	303	312	317	320	323	320	316	313	308	300	292	286	230	226	221	218	213	212

Source: ACIL Tasman *GMG Australia* modelling

Figure 16 **Base Case: Queensland gas consumption (modelled outputs), by load type**



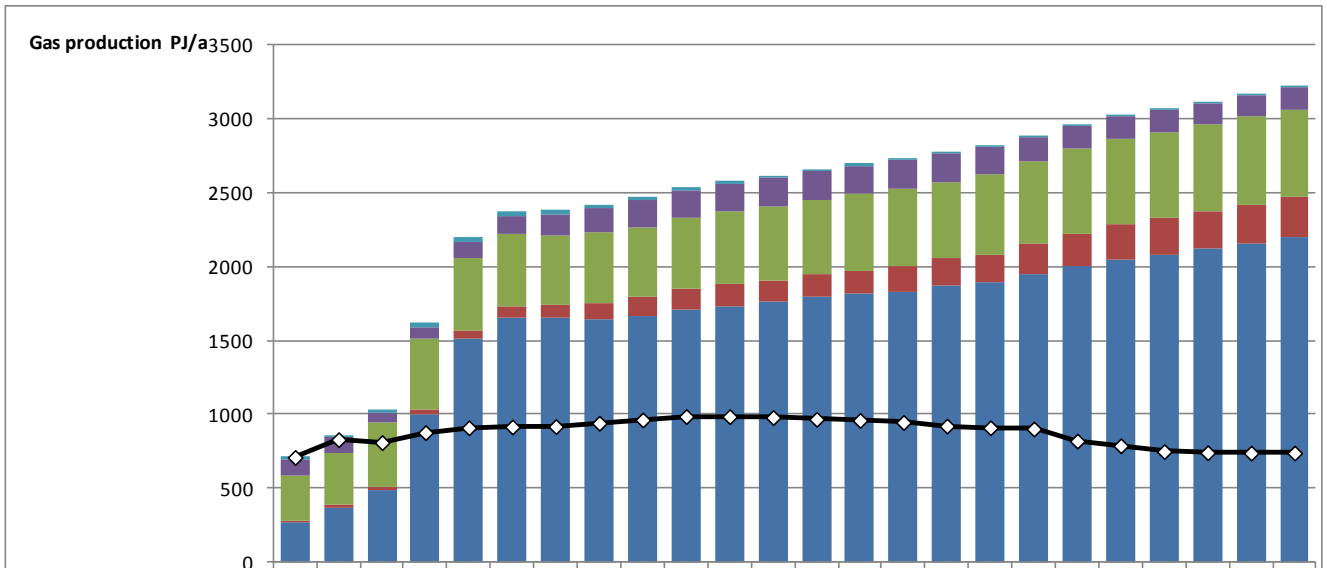
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Power Generation - CCGT	62	91	96	91	108	131	140	157	178	212	243	264	286	312	334	370	392	419	443	470	501	532	559	586
Power Generation - OCGT	29	68	49	50	47	33	27	23	27	21	18	15	17	14	14	14	13	13	13	13	13	13	12	12
Large Industrial	84	83	82	83	85	91	92	94	94	94	92	92	93	93	92	92	93	93	93	93	92	92	91	92
Small Industrial	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Commercial/Residential	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Reference Scenario TOTAL	214	277	262	286	305	311	309	315	317	315	305	299	291	287	282	274	266	258	206	202	201	198	190	189

Source: ACIL Tasman *GMG Australia* modelling

4.2.2 Gas supply

Figure 17 shows modelled CSG production, by State, under the Base Case. The sharp rise in production in Queensland, coinciding with the commencement of LNG operations, is very apparent. Production in New South Wales also grows rapidly as CSG in the Sydney and Gunnedah Basins is developed to supply local markets.

Figure 17 **Base Case: Eastern Australian gas production by State**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TAS	20	20	20	30	30	30	30	20	19	18	17	16	16	15	14	12	11	10	9	8	7	7	6	5
SA	108	102	64	77	109	120	140	170	191	191	191	191	191	191	190	190	190	166	146	146	146	146	146	146
VIC	309	355	441	479	495	492	472	477	467	483	490	497	506	518	521	522	538	552	581	585	585	585	590	589
NSW	13	20	26	42	51	69	84	110	129	140	145	146	146	159	175	185	195	210	222	236	247	256	270	280
QLD	265	367	482	995	1513	1658	1653	1641	1666	1704	1734	1764	1799	1815	1832	1868	1888	1945	2000	2046	2080	2122	2151	2194
Reference Scenario TOTAL	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

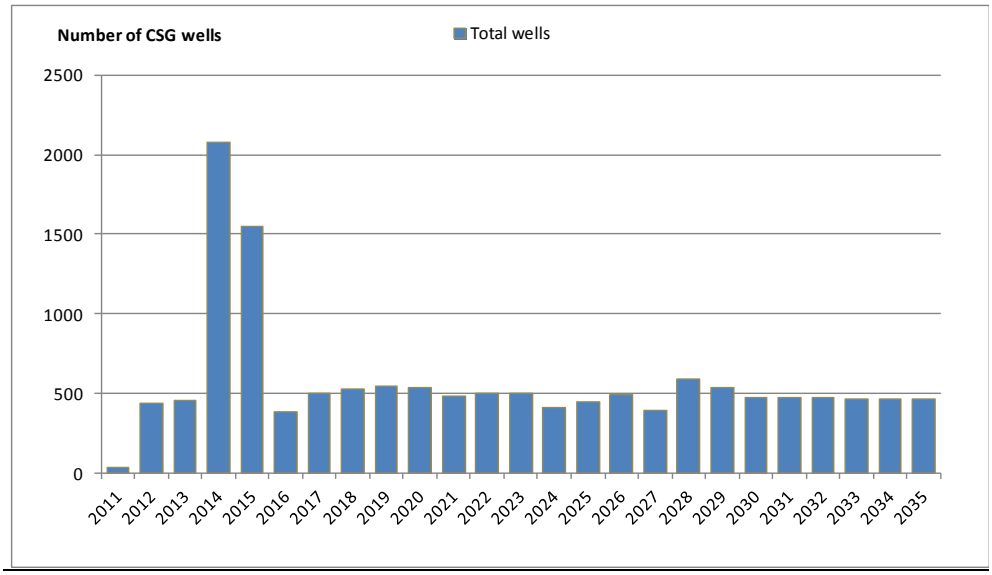
Source: ACIL Tasman *GMG Australia* modelling

4.2.3 Upstream CSG development

ACIL Tasman has used its in-house CSG field development model in order to estimate what this level of Queensland CSG production would mean in terms of number of CSG wells drilled, upstream CSG development capital expenditure and recurrent expenditure. Based on an assumption that half of Queensland's CSG production is sourced from surface to in-seam multi-lateral completions and the other half from vertical well completions, and adopting what we consider to be reasonable assumptions about average well performance and costs, we estimate that the level of production capacity under the Base Case would imply drilling of about 14,200 CSG production wells in

Queensland over the period 2011 to 2035 (see Figure 18) [11]. According to this analysis, the period of most intense drilling activity will be in 2014 and 2015, in the lead up to commencement of LNG production, with between 1,500 and 2,000 wells per year drilled at that time. After commissioning of the LNG facilities, the ongoing drilling requirement is estimated to fall to around 500 wells per year.

Figure 18 **Queensland CSG drilling under the Base Case**

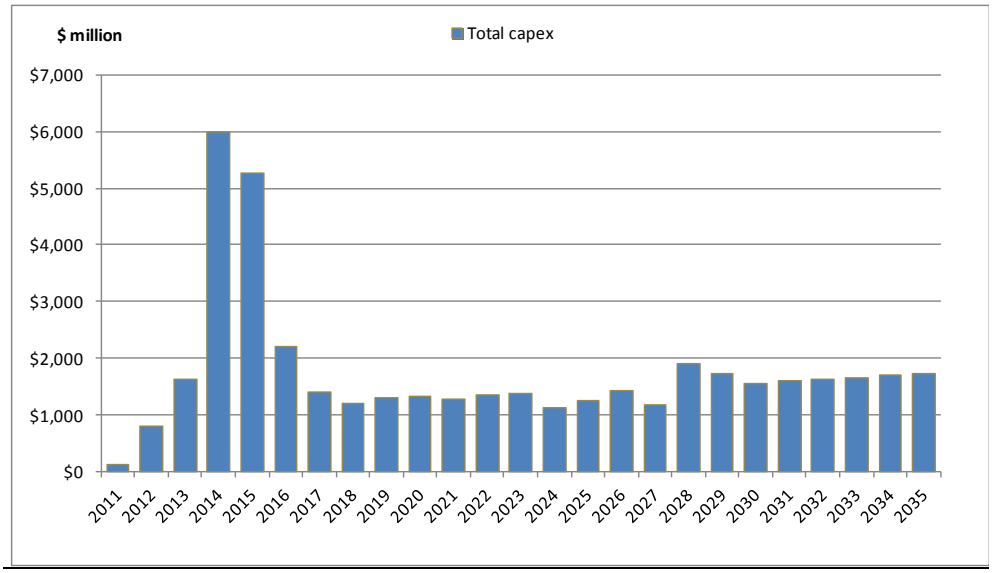


Source: ACIL Tasman analysis

This level of upstream development would imply capital expenditure (for drilling and completion of wells, gas gathering, processing and compression and water gathering, treatment and disposal) totalling more than $43 billion over the period 2011 to 2035 (see Figure 19).

[11] ACIL Tasman's CSG-field development model schedules drilling investment efficiently to achieve a defined production target (in this case the production profile illustrated in Figure 17). Because of the lag in ramp up of CSG production from each new well, the model may tend to "overshoot" production targets in some years resulting in lower levels of drilling in a subsequent year. The CSG Field Development model is currently limited to a 20-year production time frame from 2010 to 2029 inclusive. The estimates of drilling requirements in years 2030 to 2035 are based on extrapolation of the modelled trends, and are consistent with the demand growth profile.

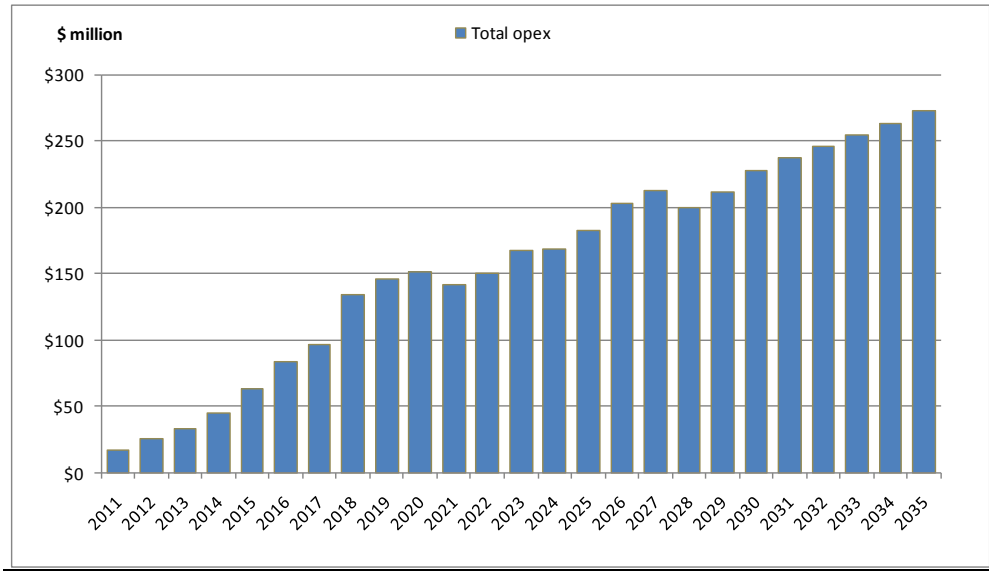
Figure 19 **CSG Upstream Capital Expenditure under the Base Case (nominal A$)**



Source: ACIL Tasman analysis

The corresponding level of recurrent operating expenditure is estimate to total around $37 billion over the same period (Figure 20).

Figure 20 **CSG Recurrent Operating Expenditure under the Base Case**



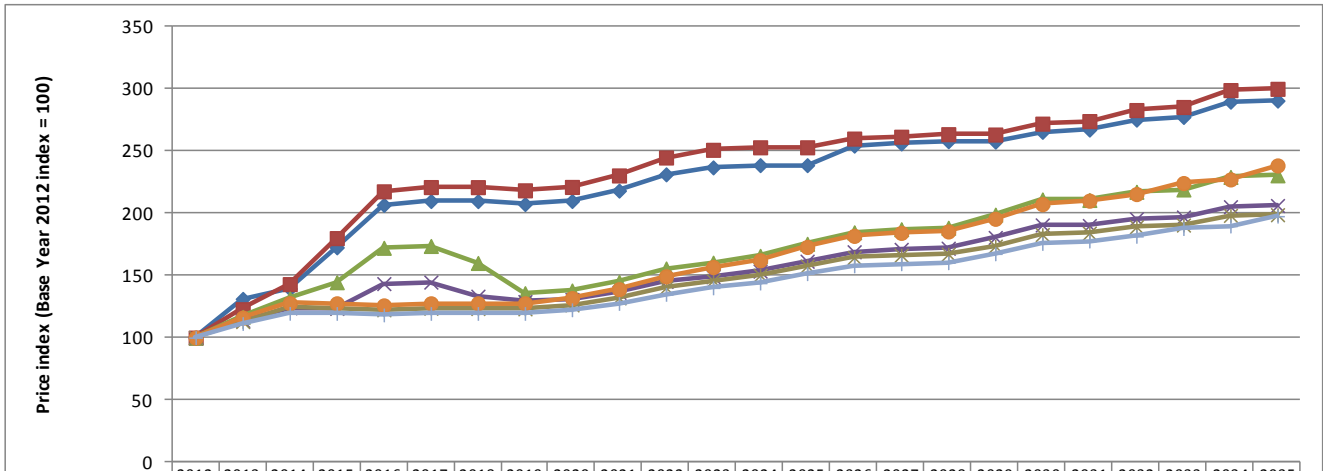
Source: ACIL Tasman analysis

4.2.4 Gas prices

As shown in Figure 21, the modelled wholesale price trends for Queensland (taking an index of prices for gas delivered at Brisbane City Gate and Wallumbilla hub as reference points) show a rapid rise over the period 2012 to 2016. These price rises are influenced by the commencement of LNG

production and sales. Wholesale prices in Queensland then settle on a trajectory broadly paralleling those observed at major market nodes in the southern states.

Figure 21 **Base Case: model wholesale gas prices at major Eastern Australian market nodes**



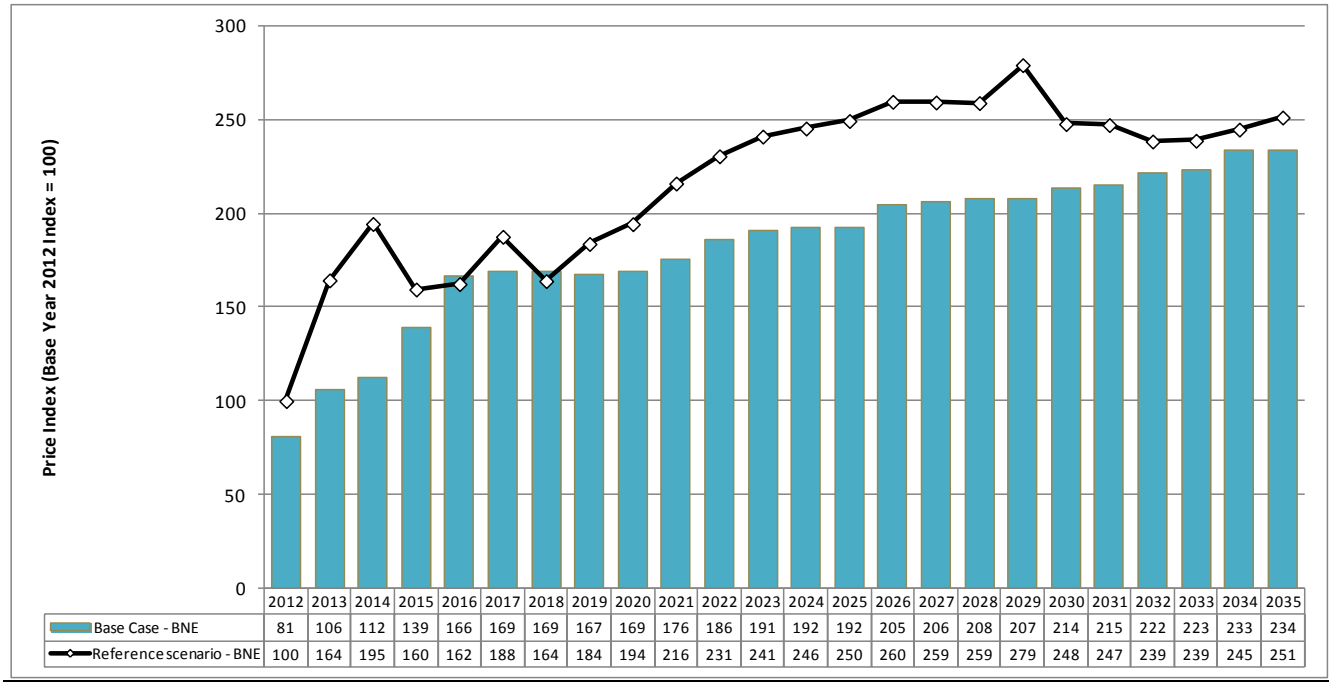
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Brisbane	100	131	139	173	207	210	210	207	210	218	231	237	239	239	254	256	258	258	265	267	275	277	290	291
Wallumbilla	100	123	143	180	218	221	221	218	221	230	245	251	253	253	260	261	264	263	272	274	283	285	299	300
Moomba	100	117	131	145	172	174	160	136	138	145	156	160	166	175	185	187	188	199	211	211	217	219	229	230
Adelaide	100	114	124	124	143	145	133	129	131	136	145	149	153	161	169	171	172	181	191	190	196	197	205	206
Sydney	100	113	124	124	122	124	123	123	126	132	140	146	150	158	164	166	167	174	183	184	189	190	198	199
Melbourne	100	116	128	128	126	128	128	128	132	139	149	157	162	173	182	184	185	196	207	210	215	224	227	238
Hobart	100	111	120	119	118	119	119	119	122	127	135	140	144	151	158	159	160	167	176	178	181	188	190	198

Source: ACIL Tasman *GMG Australia* modelling

Note: Based on real wholesale delivered prices at the relevant market location, indexed to 2012 = 100

Figure 22 compares the modelled wholesale prices for gas delivered to Brisbane under the Base Case assumptions with the corresponding prices under the Reference Scenario. The price indices are based on the Reference Scenario 2012 price having an index value of 100. On average over the period 2015 to 2035, real wholesale gas prices at Brisbane under the Base Case are 14% lower than under the Reference Scenario.

Figure 22 **Modelled wholesale gas prices at Brisbane: Base Case vs Reference Scenario**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Base Case - BNE	81	106	112	139	166	169	169	167	169	176	186	191	192	192	205	206	208	207	214	215	222	223	233	234
Reference scenario - BNE	100	164	195	160	162	188	164	184	194	216	231	241	246	250	260	259	259	279	248	247	239	239	245	251

Source: ACIL Tasman GMG Australia modelling

Note: Based on wholesale delivered prices at the relevant market location, with index based on Reference Case 2012 = 100

4.3 Electricity Modelling Results—Base Case

In this section we summarise the results of modelling of outcomes in the National Electricity Market (NEM) based on ACIL Tasman's modelling using the *PowerMark LT* model.

4.3.1 Key assumptions

This section sets out the key input assumptions used to develop the Base Case projection. Key inputs include plant characteristics and operating costs, fuel costs, electricity demand, new entrant costs and renewable energy plant commitments and energy generation.

Carbon price

A price on carbon will affect thermal plant in two major ways:

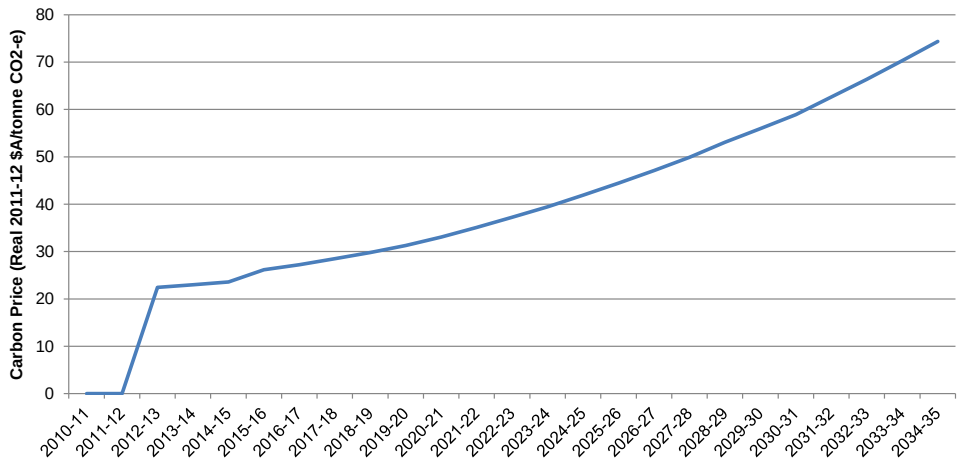
- The carbon prices will reduce the competitiveness of less efficient/higher carbon emitting thermal plant which will lead to a reduction in dispatch of the plant as other more efficient/lower carbon emitting plant enter the market.

- The net revenues of the less efficient/higher carbon emitting thermal plant will fall because of reduced margins (higher SRMC due to cost of carbon) and lower levels of dispatch.

The carbon price is an exogenous input to *PowerMark LT* with all plant costs being automatically updated according to the carbon price assumptions. For this analysis, we have taken account of the latest government announcements and have included an assumed carbon tax commencing on 1 July 2012 at $23/tCO_2e$ with the price escalating at 5% in nominal terms during the fixed price period to 30 June 2015 after which we have adopted Treasury 's "core policy" carbon price trajectory to 2035[12].

The carbon price trajectory used in the Base Case modelling is illustrated in Figure 23.

Figure 23 **Carbon price assumptions**



Source: ACIL Tasman based on Treasury modelling for "Clean Energy Futures"

New entrant plant and plant closures

PowerMark LT is a forward-looking inter-temporal model which maintains an efficient generation mix based on the initial plant fleet and a range of new entrant technology options, each of which has cost structures and operational characteristics that may change over time (for example as new technologies are developed and "learning curve effects" are taken into account). The model shuts down plant once it becomes unprofitable on a sustained basis, and schedules new entrant plant to replace retired plant as well as to meet new demand growth. It does this by choosing the most economical available generation options taking into account the assumptions regarding cost

[12] The Treasury, Commonwealth of Australia, 2011: *"Strong growth, low pollution: modelling a carbon price"* Chart 5.1, p.90.

structures, operational characteristics, deployment constraints and other factors relevant to each technology option.

GECs and NGACs

We assume that the Queensland Gas Scheme and the NSW Greenhouse Gas Abatement Scheme (GGAS) close when a price on carbon commences.

Our analysis suggest that the Queensland Gas Scheme is oversubscribed and is likely to continue to be oversubscribed and the Gas Electricity Certificates (GEC) have little value, with current spot prices at about $3.00.

The NSW GGAS scheme is less clear because a number of eligible entities were excluded from the scheme as it was being wound up in anticipation of the introduction of a price on carbon. However current spot prices of around $5/certificate indicate that the market anticipates the NSW Government making further amendments to the scheme to increase NGAC supply. Hence we assume a price of around $5/certificate until the scheme closes.

Demand projection

For the Base Case we have used the official projection of regional summer and winter peak demands and annual energy to 2020–21 published in the Electricity Statement of Opportunities (ESOO) by AEMO as a basis for the demand projections.

The load forecast from 2020–21 to 2030–31 has been taken from the load forecast being used for the 2011 National Transmission Network Development Plan (NTNDP). The load forecast beyond 2030–31 is extrapolated by ACIL Tasman.

The load forecast is based on the medium growth outlook and peak summer and winter peak demands are the 50% Probability of Exceedence (POE) level. All load forecast data is on an "as generated" basis.

The load forecast includes an allowance for coal seam gas (CSG) pumping and compression and associated loads load in Queensland commencing in 2011-12 at around 100 MW and increasing to around 700 MW by 2017–18.

The energy and load projections used in the Base Case are the "medium" energy and "50% POE" peak demands. The energy forecast is related to a set of underlying GDP growth assumptions: put simply, the energy forecast used in the scenarios assumes the most likely economic growth conditions in each region of the NEM. The peak load forecast takes into account typical ambient temperature conditions and is developed by each of the regional transmission

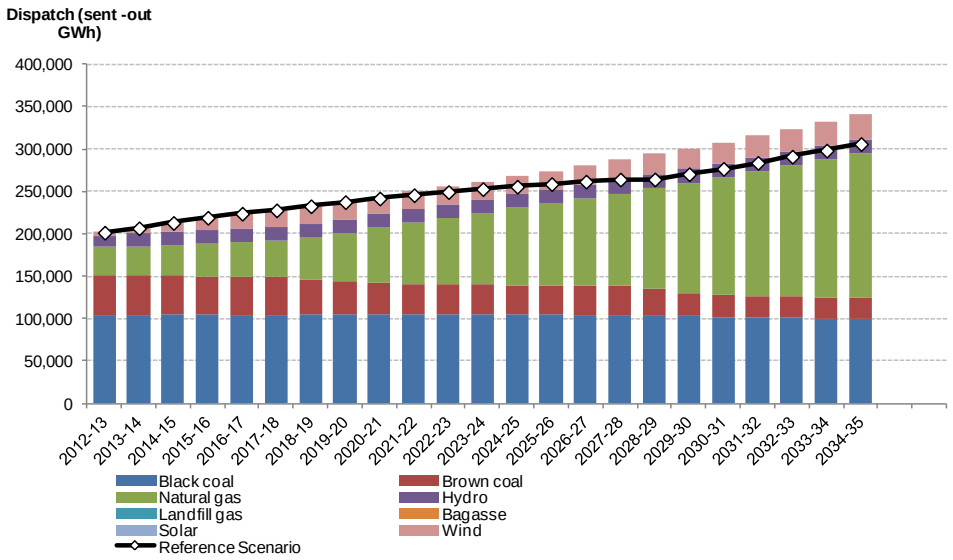
authorities. These assumptions are implicit within the Annual Planning Review forecasts and are not explicitly available to ACIL Tasman.

4.3.2 Electricity modelling results—Base Case

Electricity generation

Figure 24 summarises overall electricity generation in the NEM under the Base Case assumptions, by fuel type. Total energy generated rises from just over 200,000 GWh in 2012-13 to around 340,000 GWh in 2034-35 (Reference Scenario 306,600 GWh). Dispatch of black coal plant falls 3%, from about 103,000 GWh in 2012-13 to 100,000 GWh in 2034-35. Over the same period the dispatch of brown coal plant declines by 49% from 47,300 GWh to 23,900 GWh. In percentage terms, renewable (wind) grows very strongly—a six-fold increase—but in absolute terms the contribution of renewables to overall energy supply from the NEM remains relatively modest at around 9% for wind and 5% for hydro in 2034-35. Natural gas is the key growth fuel, with gas-fired energy increasing four-fold over the period, and accounting for 50% of energy output by 2034-35.

Figure 24 **Base Case: Whole-of-NEM generated electricity, by fuel type**

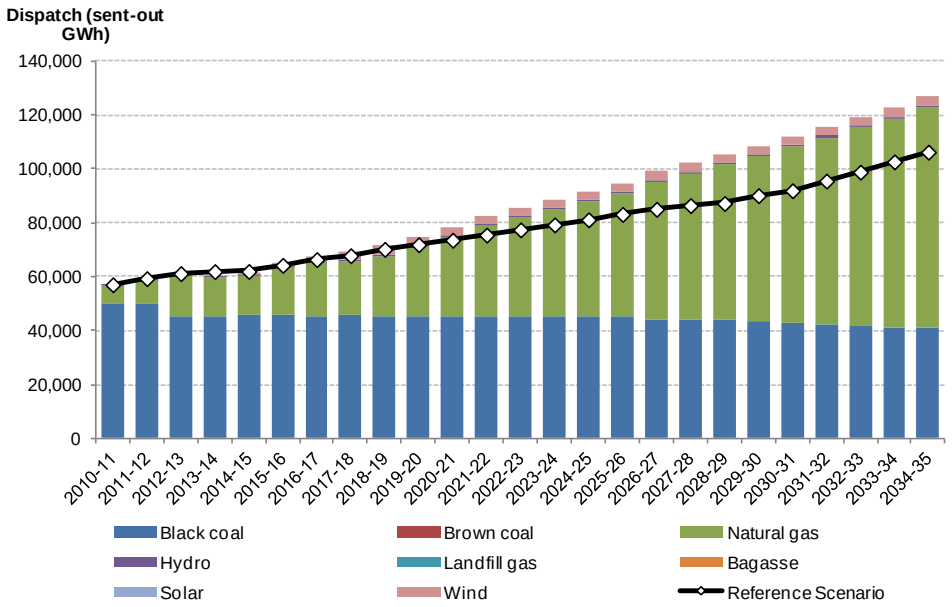


Source: ACIL Tasman *PowerMark LT* modelling

Total electricity generated in Queensland under the Base Case assumptions reaches 127,000 GWh by 2034-35. This is 18,500 GWh or 17% higher than for the Reference Scenario (Figure 25). The fuel mix for electricity generation in Queensland is currently dominated by black coal which accounts for 87% of total generation at present. While the contribution of black coal as a proportion of total generation in Queensland is projected to decline to around

32% by 2034-35, actual output from black coal plant falls by only 17%, from 50,000 to 41,000 GWh over the same period. Wind generation in Queensland is projected to grow rapidly off a low base to more than 3,700 GWh, but again it is gas-fired generation that is expected to account for the bulk of the growth in energy generated, rising eleven-fold from 6,700 GWh (12% of Queensland generation) at present to 81,300 GWh (64% of Queensland generation) by 2034-35.

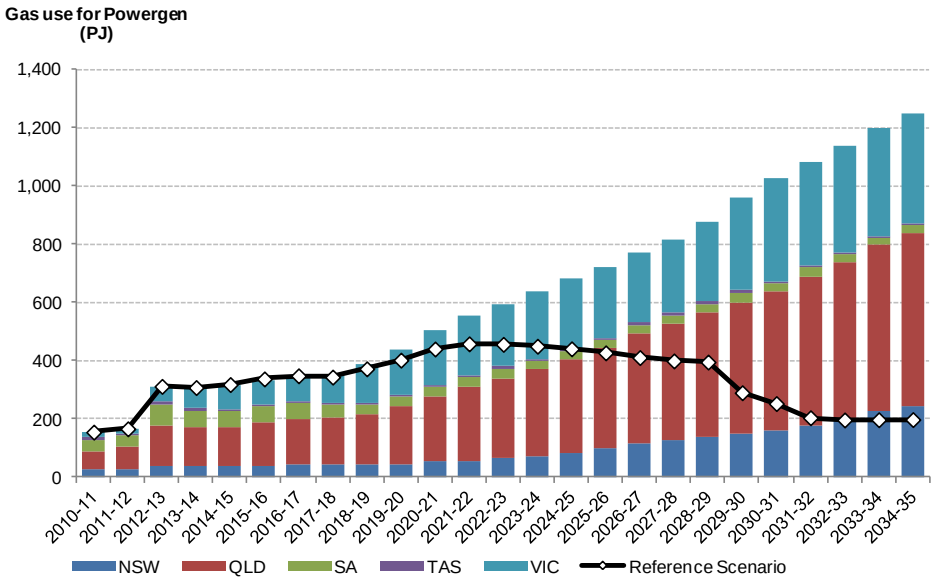
Figure 25 **Base Case: Queensland generated electricity, by fuel type**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 26 summarises the modelled consumption of gas for electricity generation in the NEM, by State, over the period to 2034-35. Total gas-for-power generation consumption is projected to grow dramatically, from 156 PJ in 2010-11 to 1,250 PJ in 2034-35. The largest increases in gas consumption for electricity generation occur in Queensland and Victoria.

Figure 26 **Base Case: modelled gas consumption for electricity generation, by state**



Source: ACIL Tasman *PowerMark LT* modelling

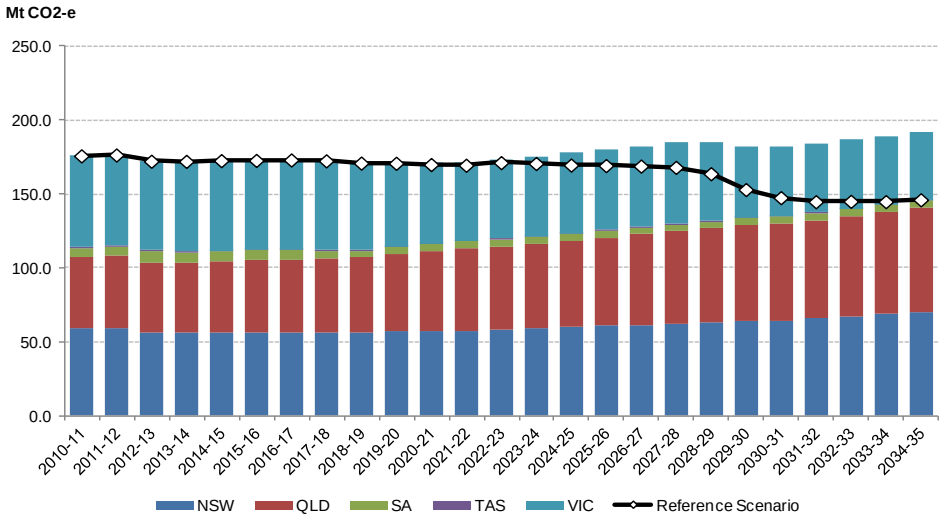
CO_2 emissions

The changing fuel mix under the Base Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.56 tCO_2e/MWh (sent out) by 2034-35. However, our modelling shows that under the Base Case assumptions NEM-wide emissions will increase by around 9% from 176 to 192 Mt-CO_2e between 2010-11 and 2034-35 (Figure 27).

The corresponding projected change in Queensland is a 46% increase in emissions from about 48 to 71 Mt-CO_2e driven by the very strong growth of gas-fired generation in the State.

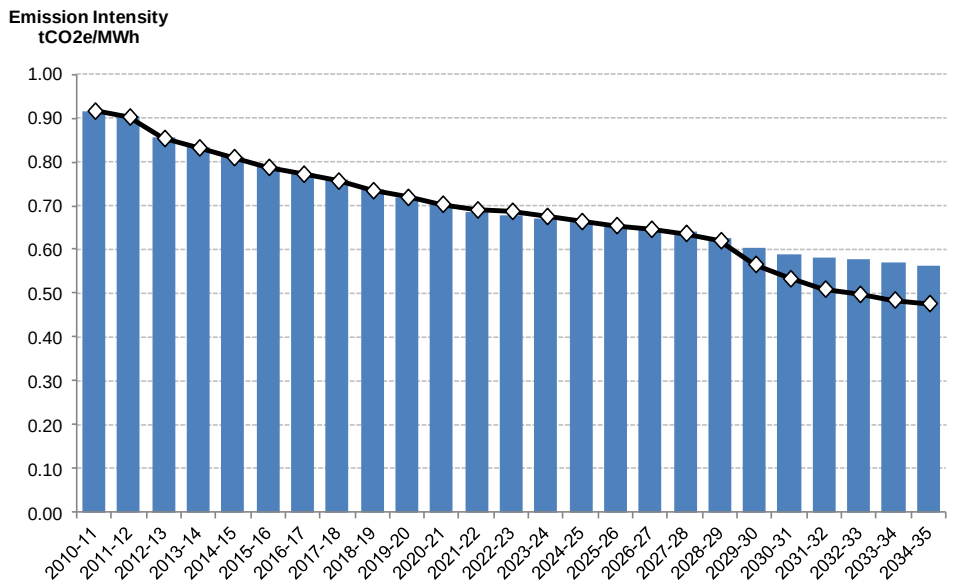
The NEM-wide CO_2 emission intensity trend under the Base Case assumptions is shown in Figure 28. Emission intensity under the Base Case is virtually identical to that under the Reference Scenario until 2029-30. After this time, emission intensity under the Reference Scenario falls relative to the Base Case because of the entry of large scale low-emission clean coal generating plant with CCS.

Figure 27 **Base Case: modelled CO_2 emissions from electricity generation**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 28 **Base Case: NEM-wide CO_2 emission intensity**



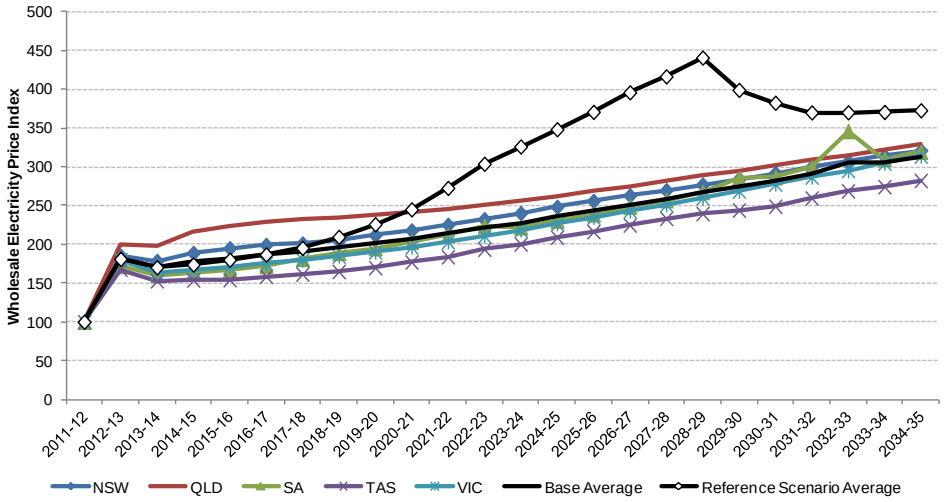
Source: ACIL Tasman *PowerMark LT* modelling

Wholesale electricity prices

Wholesale electricity prices across the NEM are projected to see a step-change increase in 2012-13 with the introduction of carbon pricing, declining reserve margins and upward pressure on fuel prices. Subsequently, prices under the Base Case assumptions are projected to rise steadily in real terms in the face of rising carbon costs and gas prices. Wholesale electricity prices in Queensland are projected to rise to a greater extent than in the southern states immediately

following the commissioning of the LNG production facilities, but will then fall relative to prices in the other NEM regions so that by the end of the projection period all of the mainland NEM states will have seen a similar increase in real wholesale electricity prices of around 3.25 times current levels.

Figure 29 **Base Case: modelled wholesale electricity prices**



Note: Wholesale price indices based on time-weighted regional reference prices expressed in real 2011-12 $/MWh; base year 2011-12 index = 100

Source: ACIL Tasman *PowerMark LT* modelling

Compared to the Reference Scenario, average electricity prices[13] in the NEM under the Base Case over the period 2014-15 to 2034-35 will be 20% lower.

4.4 Economic Impacts Modelling Results—Base Case

In this section, we compare the results of the *Tasman Global* CGE modelling of the economic impacts of under the Base Case assumptions with the corresponding modelling results for the Reference Scenario. These results incorporate the projected revenue effects from CSG production as determined from the *GasMark* modelling as well as the projected detailed changes in electricity generation by technology and state and projected dispatch weighted prices and investment implications from *PowerMark LT*.

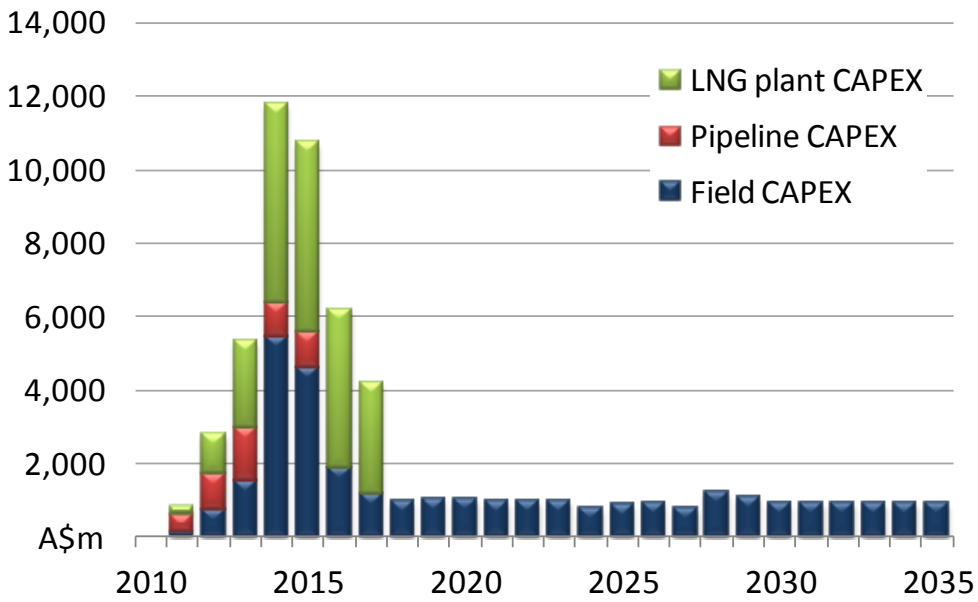
4.4.1 Annual investment

Over the period to 2034-35, total additional investment related to Queensland CSG and LNG production activities is projected to be $59.2 billion higher

[13] Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

under the Base Case, relative to the Reference Scenario (Figure 30). Although much of the additional investment occurs in the current decade, there is still substantial ongoing investment related to developing upstream CSG fields over the entire projection period.

Figure 30 **Base Case: Projected annual investment related to Queensland CSG production activities (in 2010-11 terms)**



Source: ACIL Tasman

4.4.2 Real economic output and real income

One of the most commonly quoted macroeconomic variables at a national level is GDP which is a measure of the aggregate output generated by an economy over a period of time (typically a year). From the expenditure side, GDP is calculated by summing total private and government consumption, investment and net trade.[14] At the regional level the GDP equivalent is called GRP (Gross Regional Product), while at the state level it is called GSP (Gross State Product). To reduce the potential confusion with the various acronyms, the term **economic output** has been used in the discussion of the results presented in this report.

Although changes in real economic output are useful measures for estimating how much the output of an economy may change under different industry or policy scenarios, differences in the **real income** of a region are more important since they provide an indication of the change in economic welfare of the residents of a region. Indeed, it is possible that real economic output can

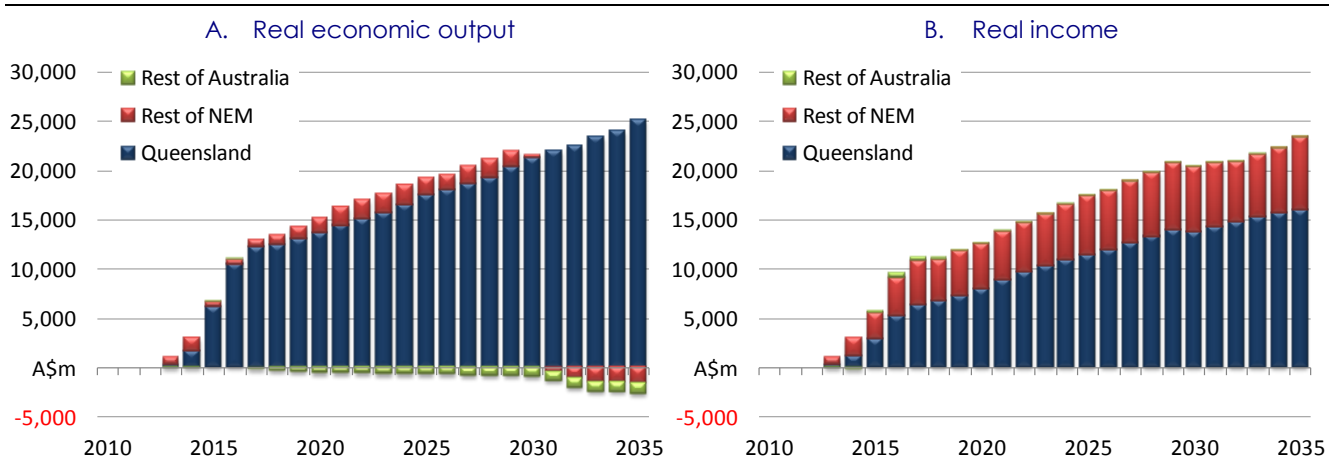
[14] From the income side, GDP is equal to the returns to factors plus all tax revenues.

increase with no, or possibly negative, changes in real income. In *Tasman Global*, changes in real income at the national level is synonymous with real gross national disposable income (RGNDI) reported by the ABS.

The change in real income is equivalent to the change in real economic output, plus the change in net foreign income transfers, plus the change in terms of trade (which measures changes in the purchasing power of a region's exports relative to its imports). As Australians have experienced first-hand in recent years, changes in terms of trade can have a substantial impact on people's welfare independently of changes in real GDP. The change in real income (as projected by *Tasman Global*) is ACIL Tasman's preferred measure of the change in economic welfare of residents.

Figure 31 shows the change in real economic output and real income in each region for each year of the projection period (2010-11 to 2034-35) under the Base Case relative to the Reference Scenario.

Figure 31 **Change in real economic output and real income – Base Case relative to the Reference Scenario (in 2010-11 terms)**



Source: ACIL Tasman

It can be seen that the Base Case is projected to have a greater impact on the real economic output in Queensland compared to the real income of Queensland residents.

Table 1 shows the cumulative impacts of the Base Case relative to the Reference Scenario for each region while Table 2 presents a decomposition of the changes in Queensland real economic output and real income.

Table 1 **Projected changes in real economic output and real income by region – Base Case relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
REAL ECONOMIC OUTPUT			
Queensland	363,711	210,617	146,617
Other NEM regions	18,273	13,799	11,177
Rest of Australia	–13,401	–7,348	–4,871
Australia (Real GDP)	**368,583**	**217,068**	**152,923**
REAL INCOME			
Queensland	231,366	132,155	90,943
Other NEM regions	117,778	70,235	50,024
Rest of Australia	2,220	1,560	1,233
Australia (Real income)	**351,364**	**203,950**	**142,200**

Note: For the purposes of this modelling Other NEM regions includes New South Wales, Victoria, Tasmania, South Australia and the ACT. NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the Base Case scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Table 2 **Decomposition of changes in Queensland real economic output and real income – Base Case relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
Private consumption	116,870	67,109	46,356
Government consumption	21,814	12,494	8,614
Investment	76,670	44,925	31,538
Net foreign and interstate trade	119,526	70,916	50,326
Real QLD economic output (GSP)	**363,711**	**210,617**	**146,617**
Terms of trade	87,855	50,352	34,819
Net foreign income transfers	–194,211	–112,513	–78,491
Real QLD income	**231,366**	**132,155**	**90,943**

Note: NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the Base Case scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Real economic output

Over the period 2011-12 to 2034-35, the Base Case is projected to change the real economic output of:

- Queensland (i.e. real GSP) by a cumulative total of +$364 billion relative to the Reference Scenario (with a net present value of +$147 billion, using a 7 per cent real discount rate)

- Rest of NEM regions by a cumulative total of +$18.2 billion relative to the Reference Scenario (with a net present value of +$11.2 billion, using a 7 per cent real discount rate)
- Australia (i.e. real GDP) a cumulative total of +$368.6billion relative to the Reference Scenario (with a net present value of +$152.9 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value of the gain in real economic output is equivalent an increase of approximately 55 per cent in the level of Queensland's 2010-11 GSP and 10 per cent of Australia's 2010-11 GDP. This is a very substantial change in the level of economic activity as a result of production changes from a single industry.

Real income

The real income of Queensland is projected to be boosted significantly as a result of the development of CSG production and LNG exports under the Base Case. As presented in Table 1, the Base Case is projected to change the real economic output of

- Queensland by a cumulative total of +$231.4 billion relative to the Reference Scenario (with a net present value of +$90.9 billion, using a 7 per cent real discount rate)
- Rest of NEM regions by a cumulative total of +$117.8 billion relative to the Reference Scenario (with a net present value of +$50.0 billion, using a 7 per cent real discount rate)
- Australia (i.e. RGNDI) a cumulative total of +$351.3 billion relative to the Reference Scenario (with a net present value of +$142.2 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value (7% discount rate) of the gain in real income is approximately equivalent to a one-off increase in the average real income of all current Queensland residents of approximately $19,600 per person.

4.4.3 Labour market

As well as affecting long-term employment across the Queensland economy, the drilling and completion of CSG wells and associated infrastructure generates a substantial number of jobs during the exploration and development period. In addition to the direct jobs generated on-site, the construction and operation phases require significant quantities of Queensland sourced goods and services. Production of these inputs has further impacts on the demand for labour across the Queensland economy.

A key issue when estimating the impact of an investment, project or policy change is determining how the labour market will clear.[15] As discussed in Appendix C, for this analysis increases in the demand for labour in Queensland can be met by three mechanisms: increasing migration from the rest of Australia (migration is taken to include short-term fly-in fly-out or drive-in drive-out commuting); increasing participation rates and/or average hours worked; and by reducing the unemployment rate. The first two mechanisms are driven by changes in the real wages paid to workers in the local region while the third is a function of the additional labour demand relative to the reference case. Given the moderate unemployment rate assumed throughout the projection period, changes in the real wage rate accounts for the majority of the additional labour supply in the policy scenarios relative to the Reference Scenario.

This analysis does not assume any change in net foreign migration as a result of any of the alternative scenarios.

Employment

The projected changes in employment in Queensland and Australia are summarised in Table 3 and Figure 32.

Total employment across Queensland is projected increase substantially under the Base Case but is offset by a decrease in employment in the Rest of the NEM as CSG activities are relocated. More specifically, over the projection period under the Base Case:

- Queensland employment rises by a cumulative total of 327,552 employee years compared to the Reference Scenario – equivalent to an average gain of 14,242 FTE jobs each year
- Rest of Australia employment decreases by a cumulative total of 4,845 employee years compared to the Reference Scenario – equivalent to an average decrease of 211 FTE jobs each year
- Australian employment rises by a cumulative total of 322,710 employee years compared to the Reference Scenario – equivalent to an average gain of 14,031 FTE jobs each year.

On a year-on-year basis, the employment impacts track the changes in real incomes more closely than the change in real economic output. This is because there are significant levels of employment in the consumer orientated sectors

[15] CGE models place explicit limits on the availability of factors of production and the nature of the constraints can greatly change the magnitude and nature of the results. In contrast, most other tools used to assess economic impacts, including I-O multiplier analysis, do not place constraints on the availability of factors of production. Consequently, these tools tend to overestimate the impacts of a project or policy.

of the Queensland economy (such as retail trade, government services, recreation and other services) and these sectors are primarily influenced by household and government incomes.

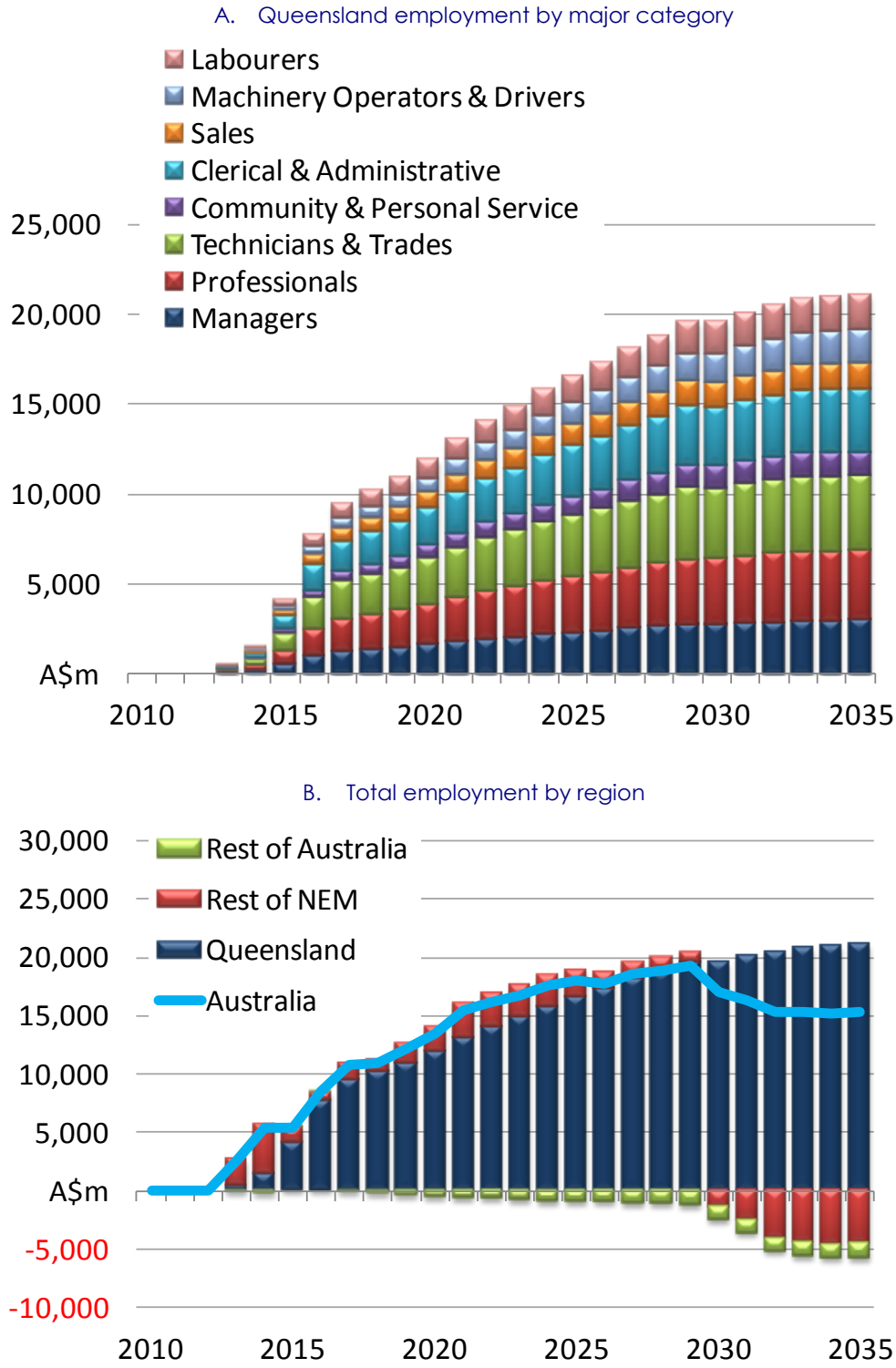
Table 3 **Projected change in employment by main occupation – Base Case relative to the Reference Scenario**

	Queensland		Australia	
	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)
	Employee years	Employee years	Employee years	Employee years
Managers	45,065	1,959	45,766	1,990
Professionals	61,120	2,657	69,178	3,008
Technicians & Trades	67,188	2,921	54,508	2,370
Community & Personal Service	20,329	884	25,396	1,104
Clerical & Administrative	55,704	2,422	53,607	2,331
Sales	23,307	1,013	26,662	1,159
Machinery Operators & Drivers	24,805	1,078	20,232	880
Labourers	30,037	1,306	27,361	1,190
Total	**327,556**	**14,242**	**322,710**	**14,031**

Notes: FTE = full time equivalent. An employee year is equivalent to one full time job held for a year or, for example, 0.5 of a full time job held for two years equals one FTE.

Source: ACIL Tasman modelling

Figure 32 **Projected annual change in employment – Base Case relative to the Reference Scenario**



Source: ACIL Tasman

Real wages

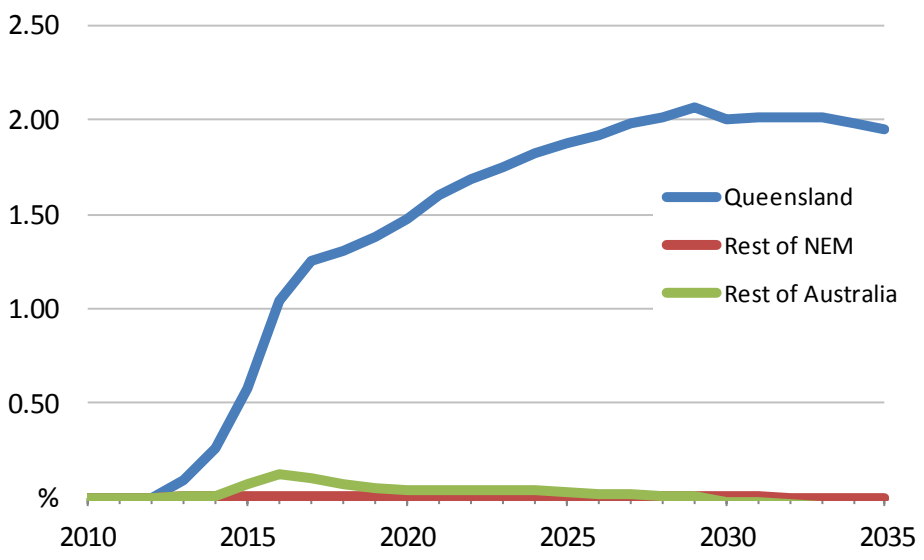
Figure 33 shows the projected changes in real wages under the Base Case relative to the Reference Scenario. The projected changes in real wages follow the changes in labour demand, with wages acting to balance demand and supply in each year. In addition, the magnitude of the projected changes in real wages is a function of the relative size of the demand and supply imbalance with respect to the overall size of the labour market (that is, large percentage increases in labour demand will tend to result in large percentage increases in real wages relative to the Reference Scenario).

Over the projection period, relative to the Reference Scenario, average real wages across Queensland under the Base Case rise by an average of:

- 0.8 per cent, over the period 2012-13 to 2019-20
- 1.9 per cent, over the period 2020-21 to 2034-35
- 1.5 per cent, over the entire projection period 2012-13 to 2034-35

These are sizeable changes in the context of the additional labour demand relative to the size of the entire Queensland economy.

Figure 33 **Change in average real wages by region – Base Case relative to the Reference Scenario**



Source: ACIL Tasman

4.5 Government revenues

Government revenues will rise significantly as a result of the additional CSG and LNG activities occurring in the Base Case relative to the Reference Scenario. It is likely that some of the additional revenue will be returned to private households through lower effective tax rates compared to the

Reference Scenario, while the rest will be used to provide public goods and services. Table 4 provides a summary of the anticipated total additional tax revenues generated under the Base Case relative to the Reference Scenario, while Figure 34 shows the changes in different revenue streams through time.

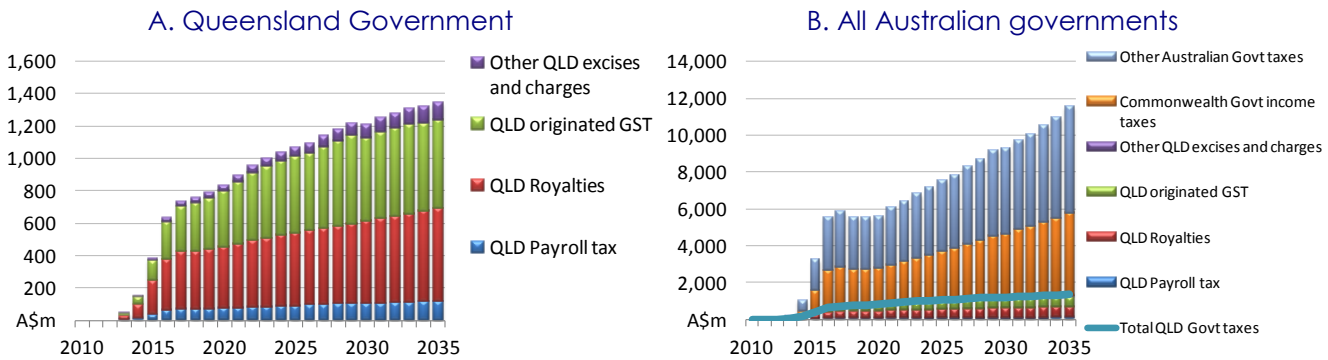
Table 4 **Cumulative change in real government tax revenues – Base Case relative to the Reference Scenario (2010-11 to 2034-35)**

	Total (2011-12 to 2034-35)	NPV (4% discount rate)	NPV (7% discount rate)
	2010-11$m	2010-11$m	2010-11$m
QLD Payroll tax	1,891	1,114	786
QLD Royalties	9,321	5,523	3,914
QLD originated GST	9,125	5,305	3,695
Other QLD excises and charges (not including taxes on property and motor vehicles)	1,275	713	483
Total Queensland	**21,612**	**12,655**	**8,879**
Commonwealth Government income taxes	58,484	33,715	23,440
Other Australian Government taxes	82,057	47,857	33,546
Total Australian Government taxes	**162,153**	**94,227**	**65,865**

[a] Note that GST revenues generated within the Queensland economy may not all be transferred back to Queensland. Similarly, a portion of other tax revenues may actually be transferred to Queensland (either directly or indirectly). Other tax revenues do not include the cost of emission permits (even though some or all may add to consolidated revenues), nor does it include stamp duties or other transfer taxes and taxes on motor vehicles.

Source: ACIL Tasman

Figure 34 **Changes in annual real government revenues – Base Case relative to the Reference Scenario (in 2010-11 terms)**



Note: All years are Australian financial years ending June 30.

Source: ACIL Tasman modelling

The Queensland Government is projected to benefit from higher tax revenues of around $21.6 billion as a result of the additional CSG and LNG activities in the Base Case relative to the Reference Scenario, including:

- $1.9 billion of additional payroll taxes
- $9.3 billion of additional royalties

- $9.1 billion of additional Queensland-originated GST revenues, which may or may not be distributed in full back to Queensland[16]
- $1.3 billion of other revenues from a range of Queensland excises and charges.

The Queensland Government should also experience higher revenues from transfer taxes (notably stamp duty) related to the increased employment and population associated with the Project. However, estimating the potential size of these revenues is beyond the scope of this analysis.

The Australian Government will be the major beneficiary through higher collections of company tax and personal income tax, which are projected to increase by a cumulative total of $58.5 billion over the forecast period under the Base Case relative to the Reference Scenario.

Cumulatively, government revenues throughout Australia are projected to increase by $162.2 billion, relative to the reference case (with a discounted value of $65.9 billion using a 7 per cent discount rate).

These estimates do not include any additional revenues that may be raised from greenhouse gas emission taxation or permit sales, which, depending on the policy framework, may be added to consolidated government revenue.

[16] Distribution of Commonwealth GST between States in not hypothecated back to States based on their contribution of gross revenue, but rather is distributed based on a complex formula calculated by the Commonwealth Grants Commission taking into account revenue-raising capacity, 'disabilities' and expenditure needs.

5 The 8-train Expansion Case

Under the 8-train Expansion Case we assume that production of CSG in Queensland continues to expand strongly thereby supporting the establishment of four separate LNG projects, each having two liquefaction trains with nominal capacity of 4 Mtpa each, for a total combined LNG capacity of 32 Mtpa. The gross feedstock requirement for the eight LNG trains would be approximately 1,920 PJ/a. Continuing growth of CSG production capacity in both Queensland and NSW also contributes to an increasing level of supply into local markets.

5.1 8-train Expansion Case key assumptions

The key assumptions under the 8-train Expansion Case are the same as those for the Base Case, with the following exceptions:

- Higher volume of LNG exports, and consequential scaling up of CSG production requirements. The assumptions regarding the underlying CSG production cost curve and resource endowment remain the same.
- Lower gas demand for electricity generation as a result of higher gas prices.

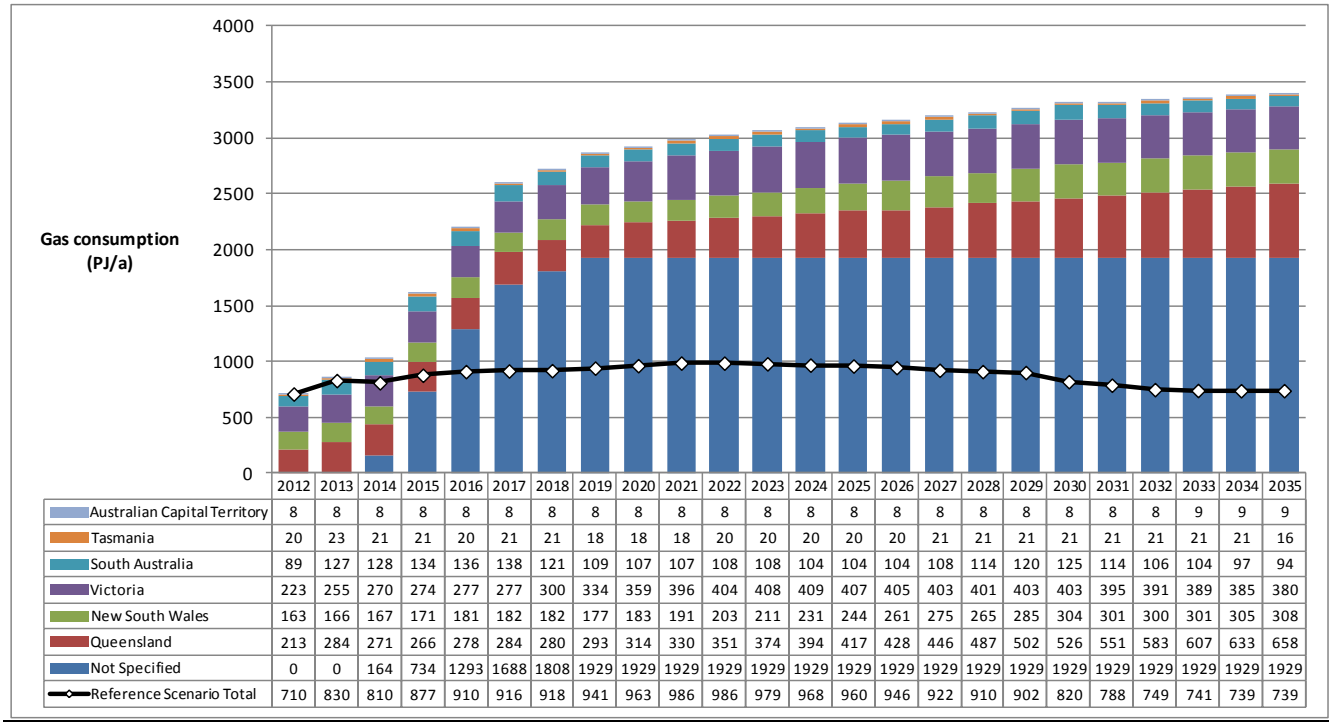
5.2 Gas Modelling Results—8-train Expansion Case

5.2.1 Gas demand and consumption

Figure 35 shows the modelled gas consumption, by State, for Eastern Australia including CSG produced for LNG manufacture in Queensland, under the 8-train Expansion Case. LNG manufacture accounts for around two-thirds of total production with some 1,929 PJ/a used for LNG from 2019 on. Domestic consumption grows most strongly in Queensland, New South Wales and Victoria, with Queensland consumption rising 147% from 266 PJ in 2015 to 658 PJ in 2035; New South Wales consumption rises 80% from 171 PJ to 308 PJ; and Victorian consumption rises 39% from 274 PJ in 2010 to 380 PJ in 2030. This reflects an assumption that most new entrant combined-cycle gas turbine (CCGT) generating plant will locate in Queensland, New South Wales and Victoria because of a combination of proximity to gas supply and location relative to existing generation sites, including (in the case of Victoria) plant likely to be partially or wholly replaced as a result of carbon pricing. Over the same time period, gas consumption in South Australia and Tasmania is projected to fall 30% and 26% respectively.

Total production at the end of the projection period is almost 3,400 PJ/a — almost five times higher than the 739 PJ under the Reference Scenario.

Figure 35 **8-train Expansion Case: Eastern Australia modelled gas consumption, by State, including CSG for LNG production**



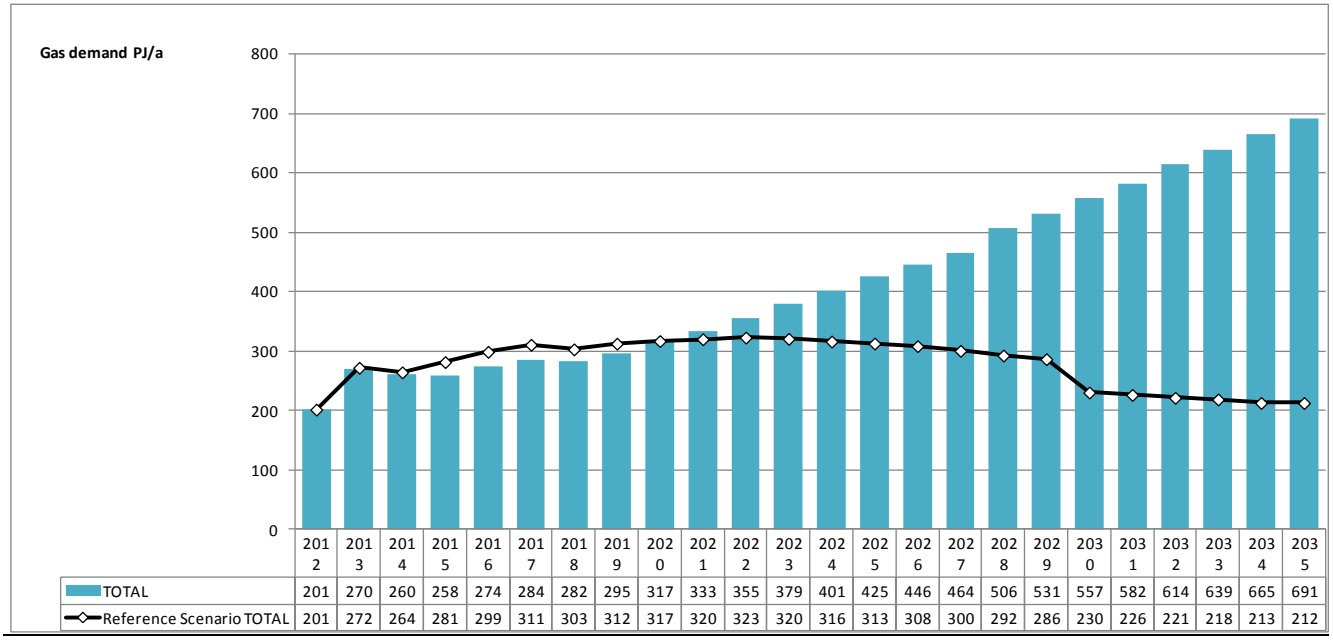
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Australian Capital Territory	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	9	9
Tasmania	20	23	21	21	20	21	21	18	18	18	20	20	20	20	20	21	21	21	21	21	21	21	21	16
South Australia	89	127	128	134	136	138	121	109	107	107	108	108	104	104	104	108	114	120	125	114	106	104	97	94
Victoria	223	255	270	274	277	277	300	334	359	396	404	408	409	407	405	403	401	403	403	395	391	389	385	380
New South Wales	163	166	167	171	181	182	182	177	183	191	203	211	231	244	261	275	265	285	304	301	300	301	305	308
Queensland	213	284	271	266	278	284	280	293	314	330	351	374	394	417	428	446	487	502	526	551	583	607	633	658
Not Specified	0	0	164	734	1293	1688	1808	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929	1929
Reference Scenario Total	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

Source: ACIL Tasman *GMG Australia* modelling

Figure 36 shows the modelled gas demand inputs for Queensland, excluding gas for LNG export production, under the 8-train Expansion Case. Gas demand in Queensland reaches 691 PJ/a by the end of the projection period in 2035. This is some 54 PJ/a lower than for the Base Case as a result of higher gas prices which result in reduced gas demand for power generation. Compared to the Reference Scenario, Queensland domestic gas demand over the period 2015 to 2035 is on average 161 PJ/a or 68% higher under the 8-train Expansion Case.

Figure 37 shows the corresponding gas consumption for Queensland (excluding LNG), by load type, under the 8-train Expansion Case. Overall Queensland domestic consumption reaches 660 PJ/a by 2035. This is 80 PJ/a less than under the Base Case (reflecting lower gas-for-power generation demand and higher gas prices) but some 471 PJ/a more than under the Reference Scenario.

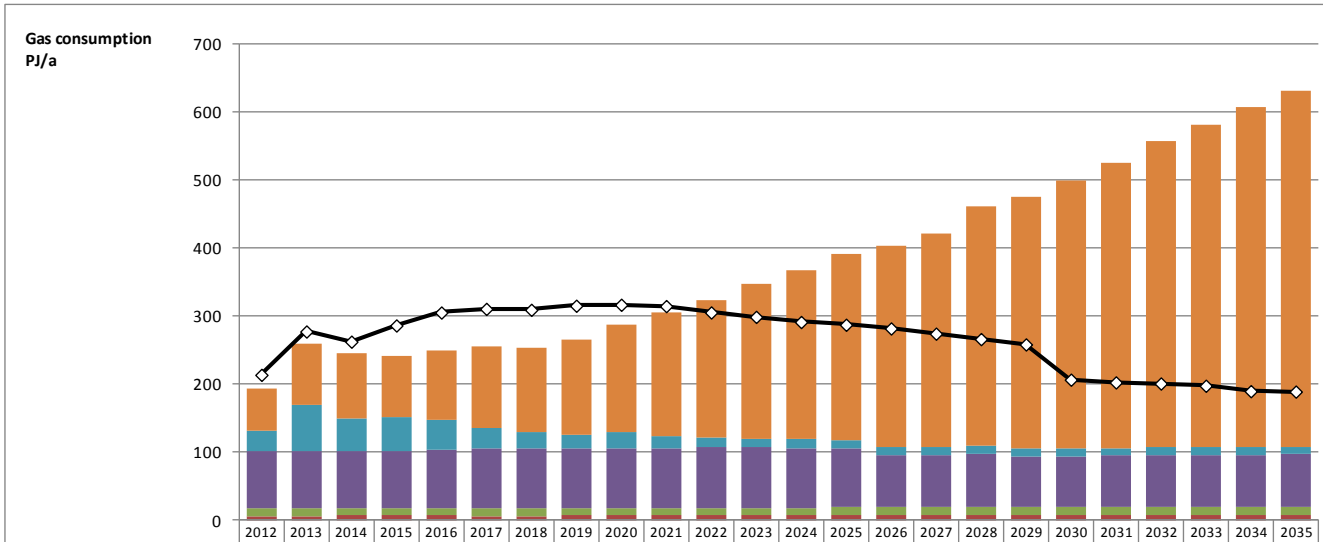
Figure 36 **8-train Expansion Case: Queensland gas demand (model input)**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL	201	270	260	258	274	284	282	295	317	333	355	379	401	425	446	464	506	531	557	582	614	639	665	691
Reference Scenario TOTAL	201	272	264	281	299	311	303	312	317	320	323	320	316	313	308	300	292	286	230	226	221	218	213	212

Source: ACIL Tasman *GMG Australia* modelling

Figure 37 **8-train Expansion Case: Queensland gas consumption (modelled outputs), by load type**



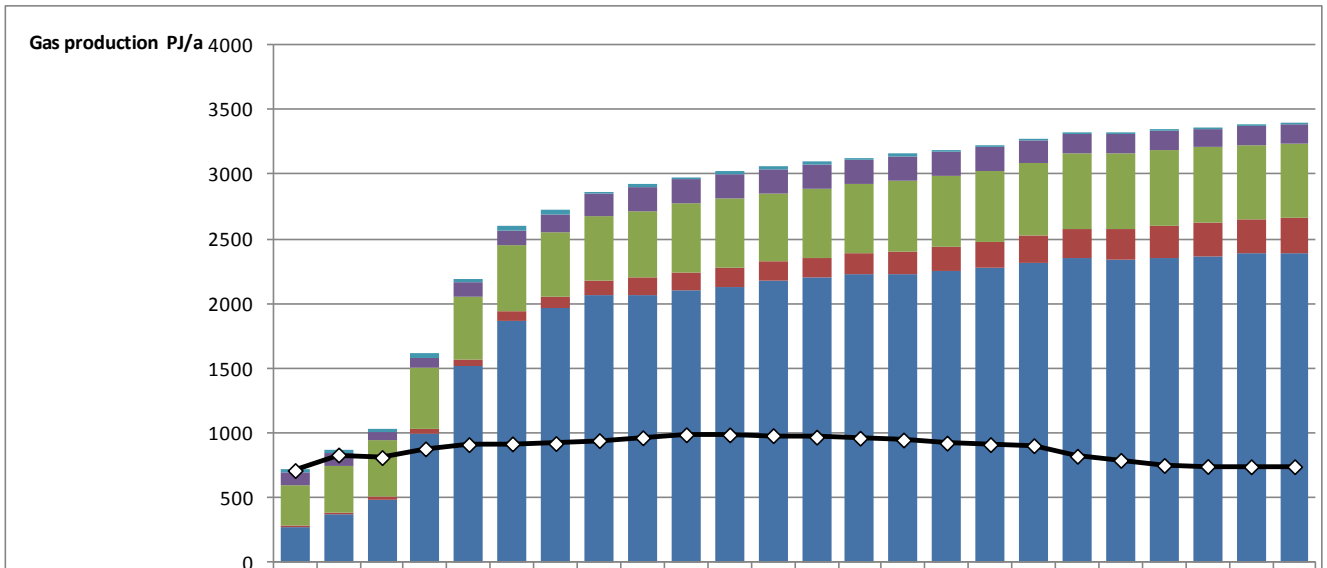
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Power Generation - CCGT	62	91	96	90	102	120	124	140	158	180	202	227	247	273	294	313	352	371	395	419	450	474	499	524
Power Generation - OCGT	29	68	49	50	44	30	24	20	24	18	15	13	15	13	12	12	12	12	12	12	12	11	11	11
Large Industrial	84	83	82	83	85	88	87	88	87	88	88	88	87	87	78	78	78	75	75	76	76	76	77	77
Small Industrial	12	12	12	12	12	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Commercial/Residential	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7
Reference Scenario TOTAL	214	277	262	286	305	311	309	315	317	315	305	299	291	287	282	274	266	258	206	202	201	198	190	189

Source: ACIL Tasman *GMG Australia* modelling

5.2.2 Gas supply

Figure 38 shows modelled CSG production, by State, under the 8-train Expansion Case. Total production reaches almost 3,400 PJ/a by 2035 (Reference Scenario 739 PJ/a). The sharp rise in production in Queensland coinciding with the commencement of LNG operations is very apparent. Production in New South Wales also grows rapidly as CSG in the Sydney and Gunnedah Basins is developed to supply local markets.

Figure 38 **8-train Expansion Case: Eastern Australian gas production by State**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TAS	20	20	20	30	30	30	30	20	19	18	17	16	16	15	14	12	11	10	9	8	7	7	6	5
SA	108	102	64	77	109	120	140	170	191	191	191	191	191	191	190	190	190	166	146	146	146	146	146	146
VIC	309	355	441	470	495	511	501	505	513	525	539	526	533	530	556	552	548	565	590	587	585	582	578	576
NSW	13	20	26	39	51	69	84	110	133	142	145	148	152	161	175	186	198	210	222	236	247	256	265	274
QLD	265	367	478	994	1510	1869	1966	2063	2062	2102	2130	2176	2203	2231	2221	2249	2278	2317	2350	2342	2353	2369	2383	2393
Reference Scenario TOTAL	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

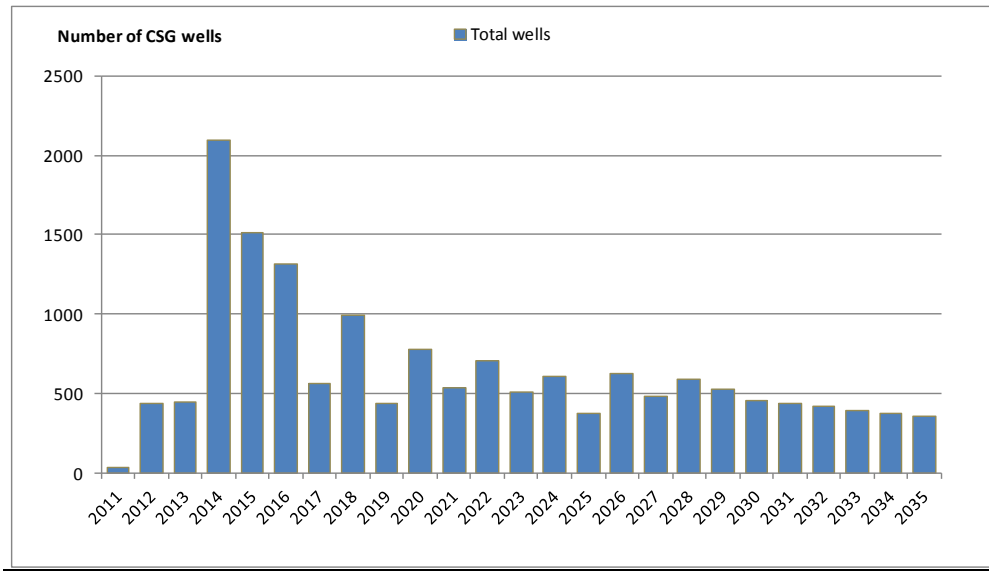
Source: ACIL Tasman *GMG Australia* modelling

5.2.3 Upstream CSG development

ACIL Tasman has used its in-house CSG field development model in order to estimate what this level of Queensland CSG production would mean in terms of number of CSG wells drilled, upstream CSG development capital expenditure and recurrent expenditure. Based on an assumption that half of Queensland's CSG production is sourced from surface to in-seam multi-lateral completions and the other half from vertical well completions, and adopting what we consider to be reasonable assumptions about average well performance and costs, we estimate that the level of production capacity under the 8-train Expansion Case would imply drilling of about 16,000 CSG production wells in Queensland over the period 2011 to 2035 (see Figure 39). According to this analysis, the period of most intense drilling activity will be in

2014 and 2016, in the lead up to commencement of LNG production, with between 1,300 and 2,100 wells per year drilled at that time. After commissioning of the LNG facilities, the ongoing drilling requirement is estimated to fall to around 500 wells per year on average.

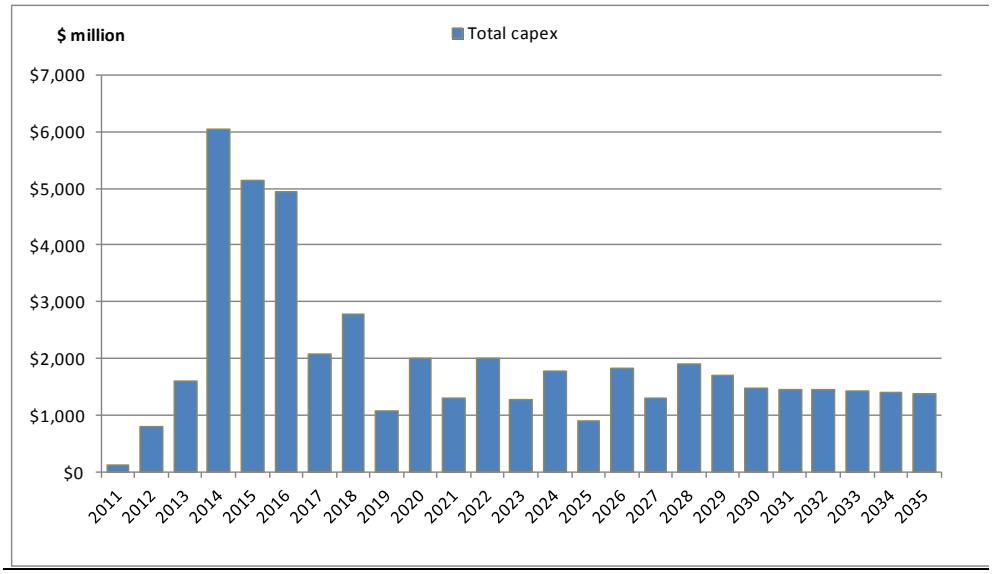
Figure 39 **Queensland CSG drilling under the 8-train Expansion Case**



Source: ACIL Tasman analysis

This level of upstream development would imply capital expenditure (for drilling and completion of wells, gas gathering, processing and compression and water gathering, treatment and disposal) totalling more than $49 billion over the period 2011 to 2035 (see Figure 40).

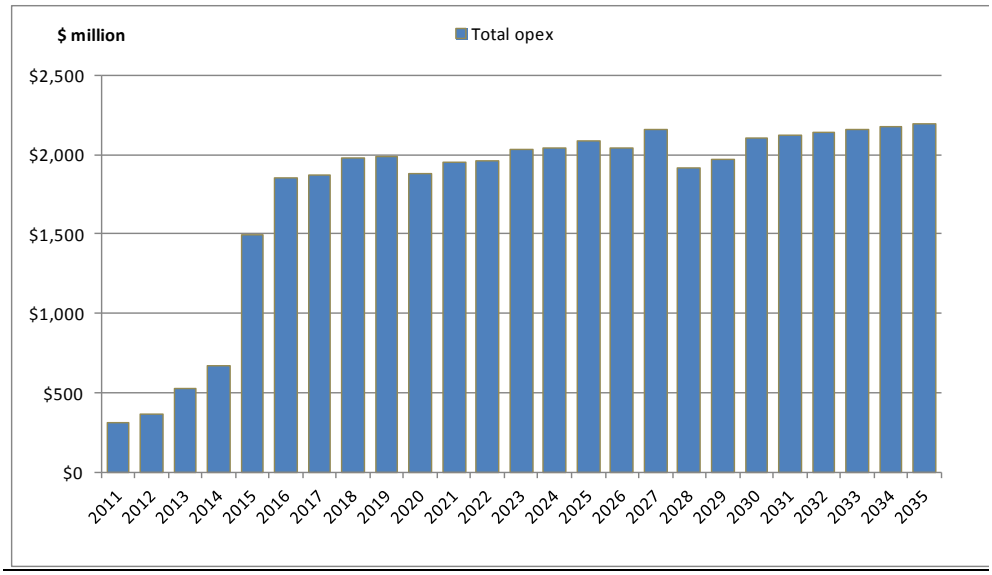
Figure 40 **CSG Upstream Capital Expenditure under the 8-train Expansion Case**



Source: ACIL Tasman analysis

The corresponding level of recurrent operating expenditure is estimated to total around $44 billion over the same period (Figure 41).

Figure 41 **CSG Recurrent Operating Expenditure under the 8-train Expansion Case**



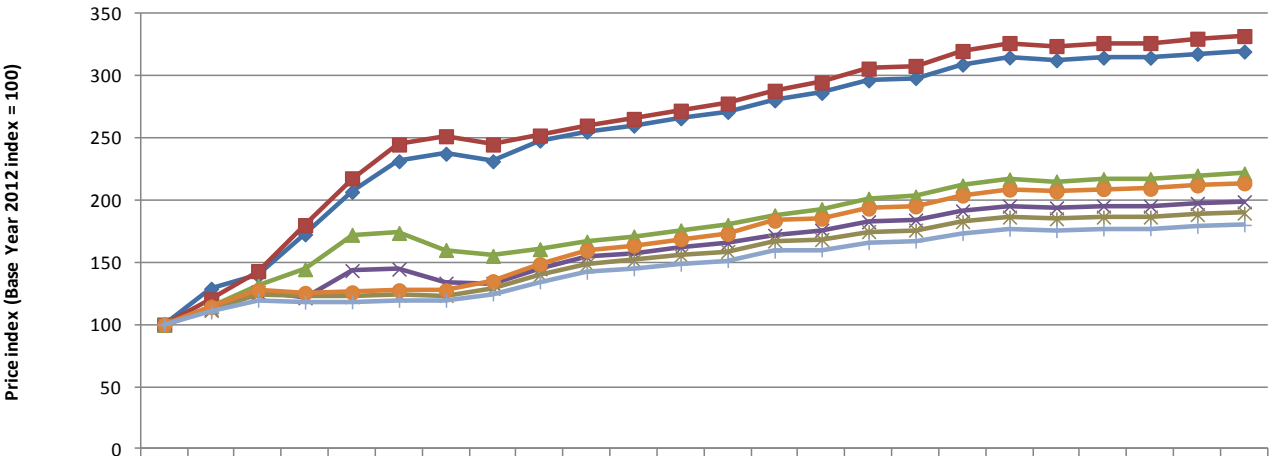
Source: ACIL Tasman analysis

5.2.4 Gas prices

As shown in Figure 42, under the 8-train Expansion Case the modelled wholesale price trends for Queensland (taking prices for gas delivered at Brisbane City Gate and Wallumbilla hub as reference points) show a rapid rise

over the period 2012 to 2018. This price rise is influenced by the commencement of LNG production and sales. The rate of increase in wholesale prices in Queensland then settles back to a similar level to the rates observed at major market nodes in the southern states.

Figure 42 **8-train Expansion Case: model wholesale gas prices at major Eastern Australian market nodes**



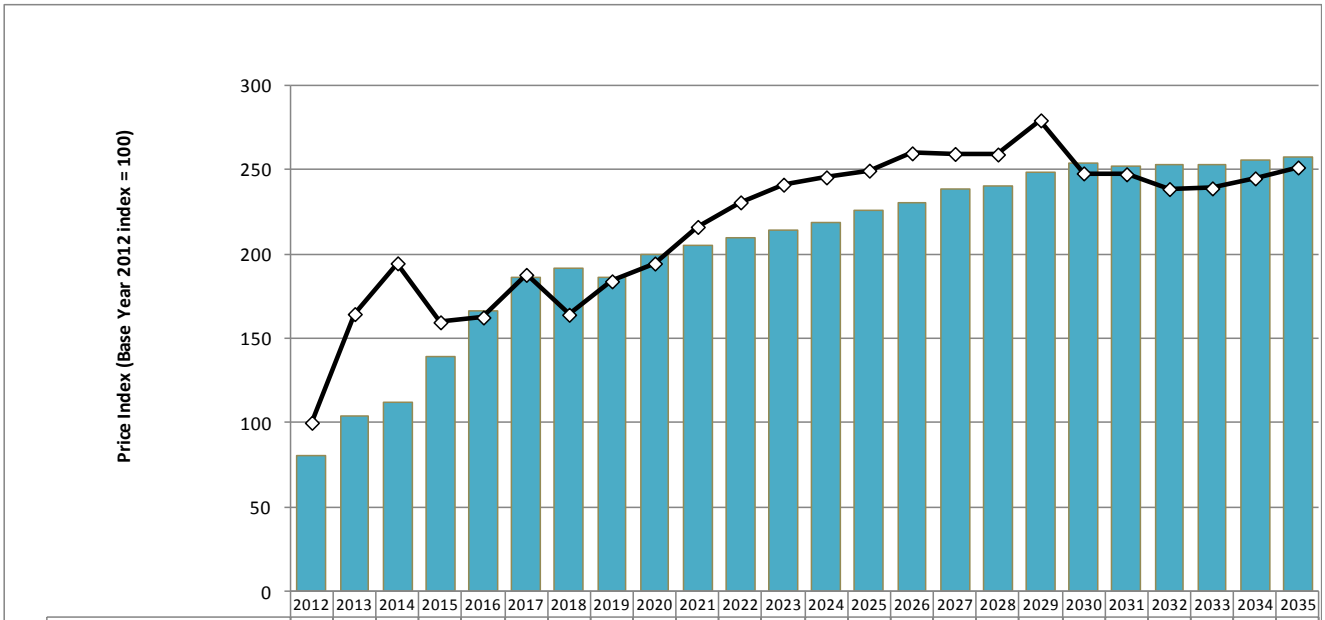
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Brisbane	100	129	139	173	207	231	237	231	248	255	260	266	271	280	286	296	298	309	315	313	315	315	318	320
Wallumbilla	100	120	143	180	218	245	251	245	252	260	265	272	278	288	295	306	308	320	326	324	326	326	330	332
Moomba	100	115	131	145	172	174	160	155	161	167	171	176	180	188	193	201	203	212	217	215	217	217	220	221
Adelaide	100	112	126	122	143	145	133	133	145	154	158	162	165	172	176	183	184	191	195	194	195	195	197	199
Sydney	100	111	124	122	122	124	123	129	140	149	152	156	159	167	168	175	176	183	186	185	186	186	188	190
Melbourne	100	114	128	125	126	128	128	135	149	159	164	169	173	184	185	193	195	204	209	207	209	209	212	214
Hobart	100	110	120	118	118	119	119	125	134	142	145	148	151	159	160	166	167	173	177	176	177	177	179	180

Source: ACIL Tasman *GMG Australia* modelling

Note: Based on real wholesale delivered prices at the relevant market location, indexed to 2012 = 100

Figure 43 compares the modelled wholesale prices for gas delivered to Brisbane under the 8-train Expansion Case assumptions with the corresponding prices under the Reference Scenario. The price indices are based on the Reference Scenario 2012 price having an index value of 100. On average over the period 2015 to 2035, real wholesale gas prices at Brisbane under the 8-train Expansion Case are 2% lower than under the Reference Scenario.

Figure 43 **Modelled wholesale gas prices at Brisbane: 8-train Expansion Case vs Reference Scenario**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
8-train Expansion Case - BNE	81	104	112	139	166	186	191	186	200	205	209	214	218	226	231	239	240	249	254	252	253	253	256	257
Reference scenario - BNE	100	164	195	160	162	188	164	184	194	216	231	241	246	250	260	259	259	279	248	247	239	239	245	251

Source: ACIL Tasman GMG Australia modelling

Note: Based on wholesale delivered prices at the Brisbane City Gate, with index based on Reference Case 2012 = 100

5.3 Electricity Modelling Results—8-train Expansion Case

In this section we summarise the results of modelling of the National Electricity Market (NEM) under the 8-Train Expansion Case, based on ACIL Tasman's modelling using the *PowerMark LT* model.

5.3.1 Key assumptions

The key input assumptions used to develop the 8-train Expansion Case projection are the same as those for the Base Case with the exception of the gas price assumptions which are consistent with the results of the *GMG Australia* gas market modelling for the 8-train Expansion Case. All other inputs including carbon prices, plant characteristics and operating costs, electricity demand, and new entrant costs are as for the Base Case.

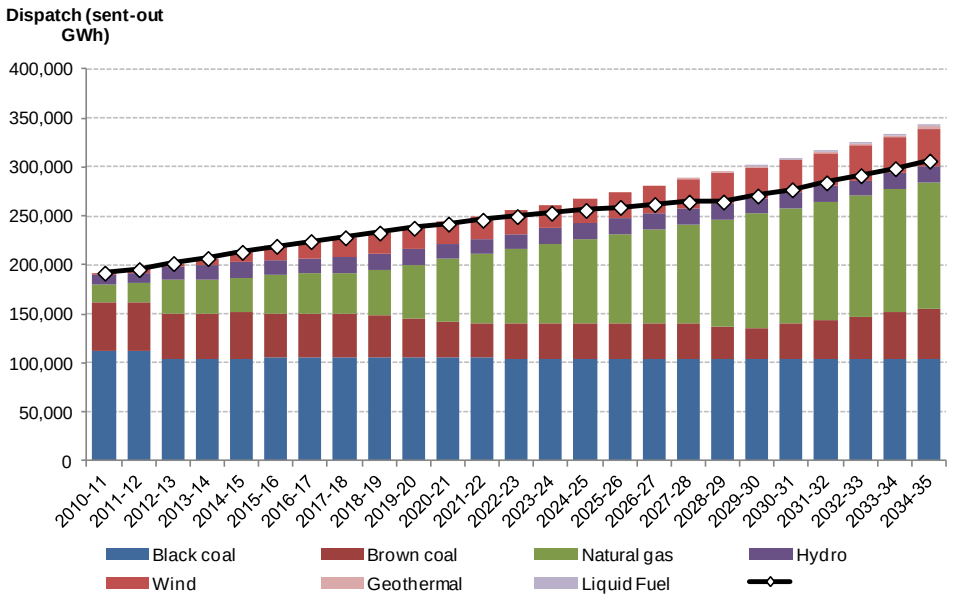
5.3.2 Electricity modelling results—8-train Expansion Case

Electricity generation

Figure 44 summarises overall electricity generation in the NEM under the 8-train Expansion Case assumptions, by fuel type. Total energy generated rises

from just under 200,000 GWh in 2010-11 to around 340,000 GWh in 2034-35 (Reference Scenario 306,600 GWh). Dispatch of black coal plant falls 7%, from about 111,000 GWh in 2010/11 to 104,000 GWh in 2034-35. Over the same period, dispatch of brown coal plant initially falls to as little as 31,147 GWh in 2029-30 before growing to 51,700 GWh—an increase of 4% on 2010-11 levels, once brown coal with CCS technology becomes commercially available. In percentage terms, renewable (wind) grows very strongly—a twenty-fold increase—but in absolute terms the contribution of renewables to overall energy supply from the NEM remains relatively modest at around 11% for wind and 5% for hydro in 2034-35. Natural gas is again a key growth fuel, with gas-fired energy increasing seven-fold over the period, and accounting for 38% of energy output by 2034-35.

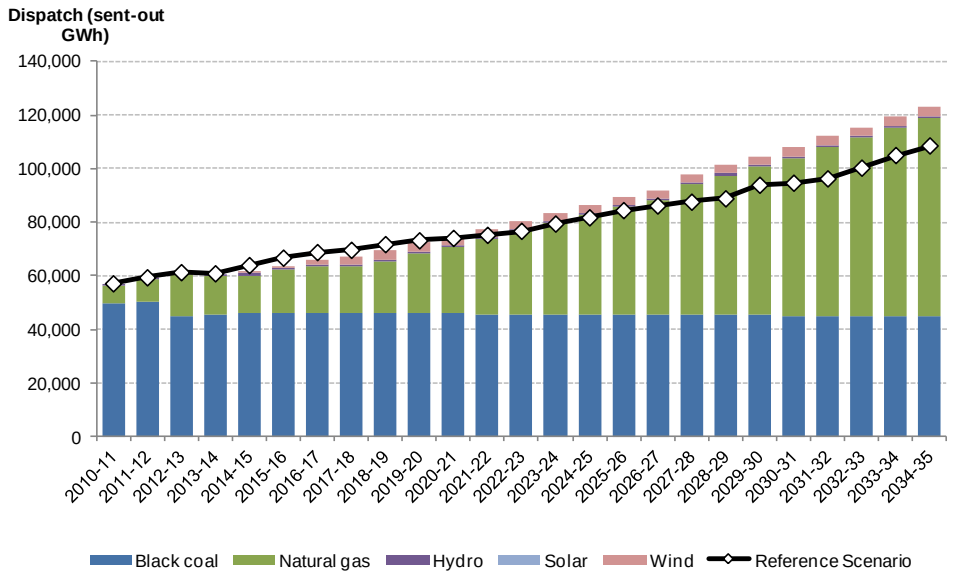
Figure 44 **8-train Expansion Case: Whole-of-NEM generated electricity, by fuel type**



Source: ACIL Tasman *PowerMark LT* modelling

Total electricity generated in Queensland under the 8-train Expansion Case assumptions reaches almost 127,000 GWh by 2034-35. This is 20,400 GWh or 19% higher than for the Reference Scenario (Figure 45). The contribution of black coal as a proportion of total generation is projected to decline to around 35% by 2034-35, although actual output from black coal plant falls by only 10%, from 49,900 to 44,700 GWh. Wind generation in Queensland is projected to grow rapidly off a low base to almost 7,500 GWh, but again it is gas-fired generation that is expected to account for the bulk of the growth in energy generated, rising ten-fold from 6,670 GWh (12% of Queensland generation) at present to 74,000 GWh (58% of Queensland generation) by 2034-35.

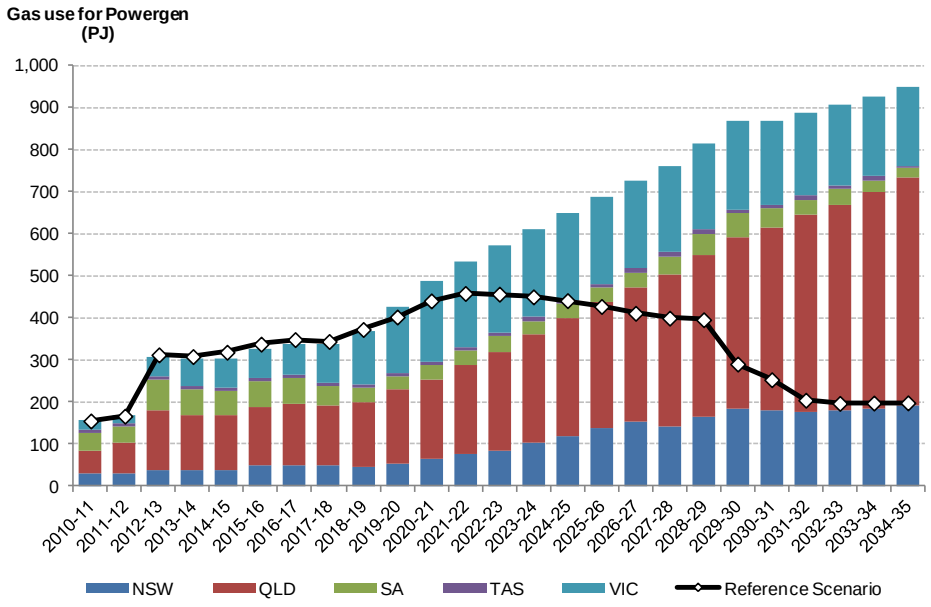
Figure 45 **8-train Expansion Case: Queensland generated electricity, by fuel type**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 46 summarises the modelled consumption of gas for electricity generation in the NEM, by State, over the period to 2034-35 under the 8-train Expansion Case. Total gas-for-power generation consumption is projected to grow very strongly, from 156 PJ in 2010-11 to 947 PJ/a in 2034-35 (Base Case 1,250 PJ/a; Reference Scenario 199 PJ/a). The largest increases in gas consumption for electricity generation occur in Queensland, New South Wales and Victoria.

Figure 46 **8-train Expansion Case: modelled gas consumption for electricity generation, by state**



Source: ACIL Tasman *PowerMark LT* modelling

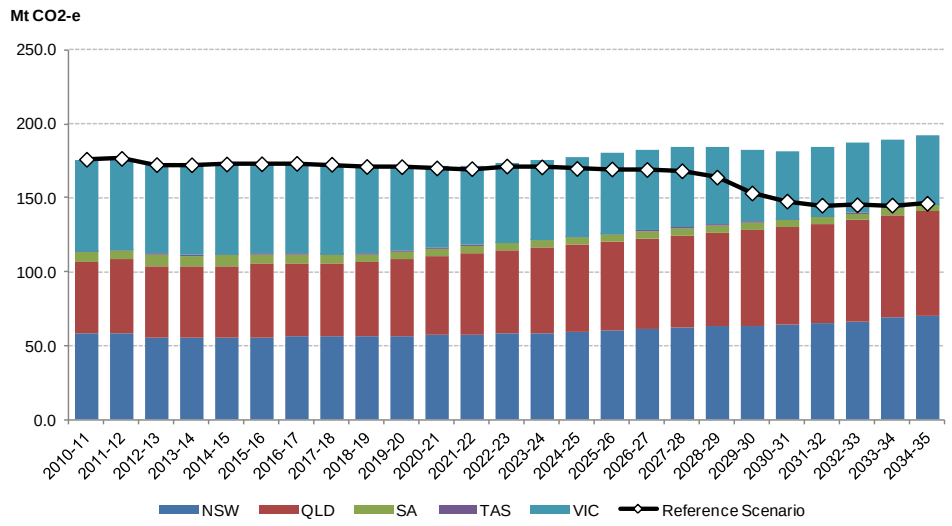
CO_2 emissions

The changing fuel mix under the 8-train Expansion Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.54 tCO_2e/MWh (sent out) by 2034-35. However, our modelling shows that under the 8-train Expansion Case assumptions NEM-wide emissions will increase by around 5% from 176 to 184 Mt-CO_2e between 2010-11 and 2034-35 (Figure 47).

The corresponding projected change in Queensland is a 47% increase in emissions from about 48 to 71 Mt-CO_2e driven by the very strong growth of gas-fired generation in the State.

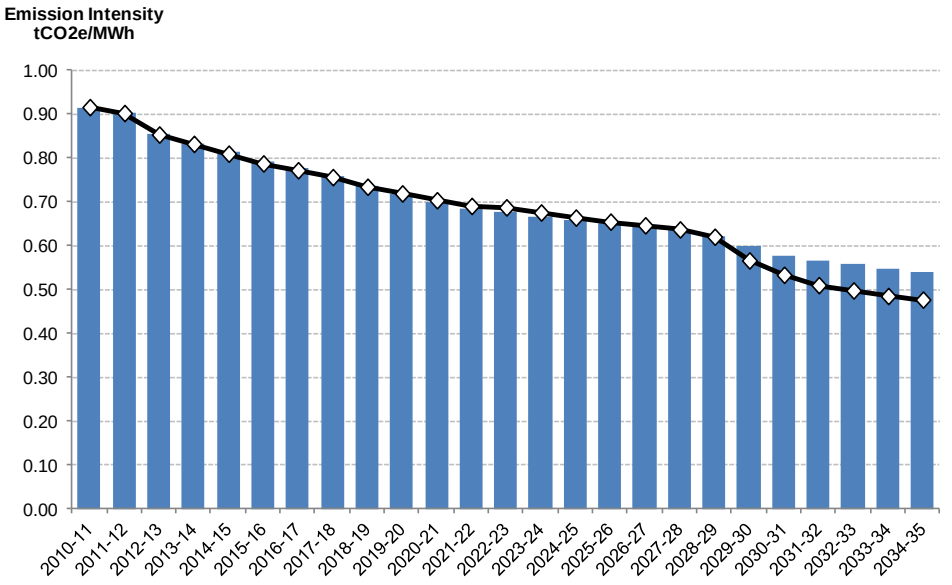
The NEM-wide CO_2 emission intensity trend under the 8-train Expansion Case assumptions is shown in Figure 48. Emission intensity under the 8-train Expansion Case is virtually identical to that under the Reference Scenario until 2028–29. After this time, emission intensity under the Reference Scenario falls relative to the 8-train Expansion Case because of the entry of large scale low-emission clean coal generating plant with CCS.

Figure 47 **8-train Expansion Case: modelled CO_2 emissions from electricity generation**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 48 **8-train Expansion Case: NEM-wide CO_2 emission intensity**



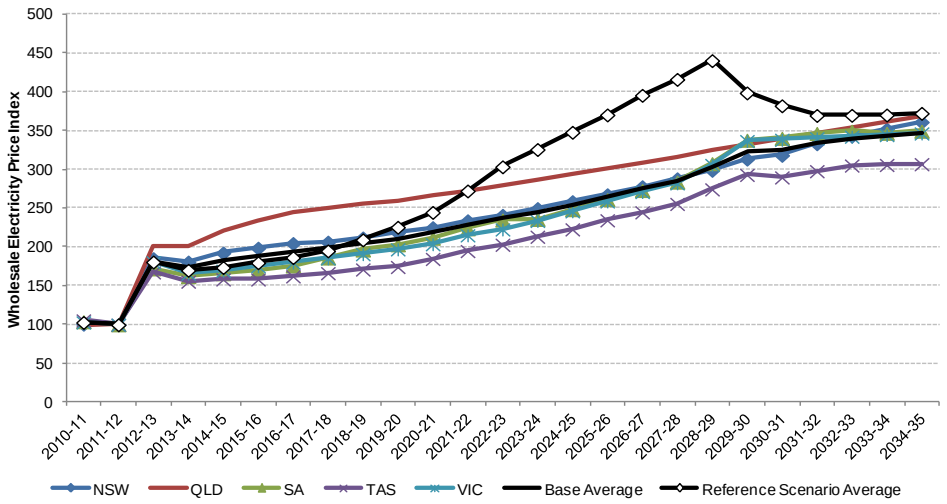
Source: ACIL Tasman *PowerMark LT* modelling

Wholesale electricity prices

Wholesale electricity prices across the NEM are projected to see a step-change increase in the 2012-13 financial year with the introduction of carbon pricing, declining reserve margins and upward pressure on fuel prices. Subsequently, prices under the 8-train Expansion Case assumptions are projected to rise steadily in real terms over the remainder of the modelling period. Wholesale

electricity prices in Queensland are projected initially to rise more quickly than in the southern states immediately following the commissioning of the LNG production facilities. However Queensland electricity prices fall relative to prices in the other NEM regions so that during the later years of the projection period they come back fairly well in line with the other mainland NEM states (Figure 49). By 2034-35 real wholesale electricity prices in Queensland are around 3.75 times current levels.

Figure 49 **8-train Expansion Case: modelled wholesale electricity prices**



Note: Wholesale price indices based on time-weighted regional reference prices expressed in real 2011-12 $/MWh; base year 2011-12 index = 100

Source: ACIL Tasman *PowerMark LT* modelling

Compared to the Reference Scenario, average electricity prices[17] in the NEM under the 8-train Expansion Case over the period 2014-15 to 2034-35 will be 13% lower.

5.4 Economic Impacts Modelling Results—8-train Expansion Case

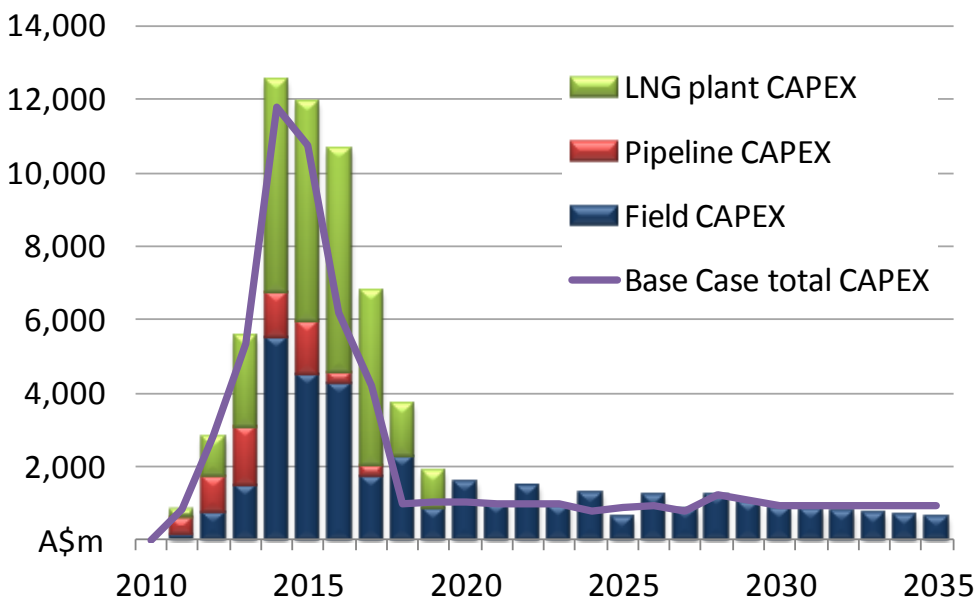
In this section, we compare the results of the *Tasman Global* CGE modelling of the economic impacts of under the 8-train Expansion Case assumptions with the corresponding modelling results for the Reference Scenario. Again, these results incorporate the projected CSG revenue effects from *GasMark* as well as the projected detailed changes in electricity generation by technology and state and projected dispatch weighted prices and investment implications from *PowerMark*.

[17] Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

5.4.1 Annual investment

Over the period to 2034-35, total additional investment related to Queensland CSG and LNG production activities is projected to be $72.3 billion higher under the 8-train Expansion Case, relative to the Reference Scenario (Figure 50). Compared to the Base Case, the additional investment largely extends the peak investment till later in the current decade rather than increasing the size of the peak.

Figure 50 **8-train Expansion Case: Projected annual investment related to Queensland CSG production activities (in 2010-11 terms)**

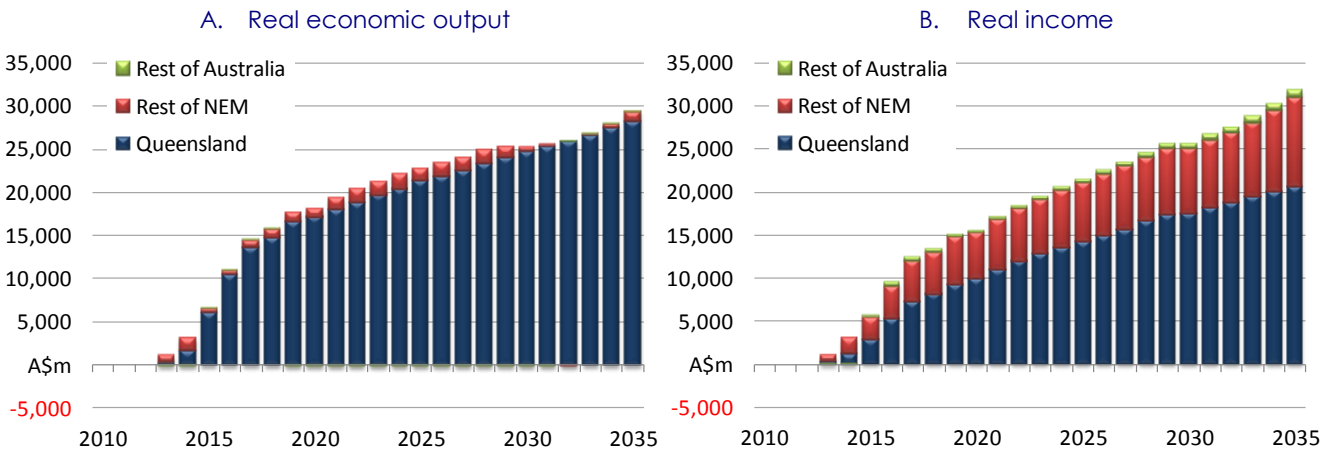


Source: ACIL Tasman

5.4.2 Real economic output and real income

Figure 51 shows the change in real economic output and real income in each region for each year of the projection period (2010-11 to 2034-35) under the 8-train Expansion Case relative to the Reference Scenario.

Figure 51 **Change in real economic output and real income – 8-train Expansion Case relative to the Reference Scenario (in 2010-11 terms)**



Source: ACIL Tasman

Table 5 shows the cumulative impacts of the 8-train Expansion Case relative to the Reference Scenario for each region while Table 6 presents a decomposition of the changes in Queensland real economic output and real income.

Table 5 **Projected changes in real economic output and real income by region – 8-train Expansion Case, relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
REAL ECONOMIC OUTPUT			
Queensland	427,774	247,838	172,343
Other NEM regions	23,324	15,346	11,665
Rest of Australia	–240	–169	–133
Australia (Real GDP)	**450,858**	**263,015**	**183,875**
REAL INCOME			
Queensland	286,414	162,300	110,940
Other NEM regions	142,065	83,236	58,539
Rest of Australia	9,987	5,664	3,883
Australia (Real income)	**438,466**	**251,200**	**173,362**

Note: For the purposes of this modelling Other NEM regions includes New South Wales, Victoria, Tasmania, South Australia and the ACT. NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the 8-train Expansion Scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Table 6 **Decomposition of changes in Queensland real economic output and real income – 8-train Expansion Case, relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
Private consumption	142,336	81,329	55,918
Government consumption	26,361	15,034	10,321
Investment	88,995	52,327	36,764
Net foreign and interstate trade	133,232	79,904	57,011
Real QLD economic output (GSP)	**427,774**	**247,838**	**172,343**
Terms of trade	127,790	71,330	48,331
Net foreign income transfers	–233,180	–134,581	–93,500
Real QLD income	**286,414**	**162,300**	**110,940**

Note: NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the 8-train Expansion Scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Real economic output

Over the period 2011-12 to 2034-35, the 8-train Expansion Case is projected to change the real economic output of:

- Queensland (i.e. real GSP) by a cumulative total of +$427.7 billion relative to the Reference Scenario (with a net present value of +$173.2 billion, using a 7 per cent real discount rate)
- Rest of NEM regions by a cumulative total of +$23.3 billion relative to the Reference Scenario (with a net present value of +$11.6 billion, using a 7 per cent real discount rate)
- Australia (i.e. real GDP) a cumulative total of +450.8 billion relative to the Reference Scenario (with a net present value of +183.8 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value of the gain in real economic output (at 7% real discount rate) is equivalent an increase of approximately 65 per cent in the level of Queensland's 2010-11 GSP and 13 per cent of Australia's 2010-11 GDP. This is a very substantial change in the level of economic activity as a result of production changes from a single industry.

Real income

The real income of Queensland is projected to be boosted significantly as a result of the development of CSG production and LNG exports under the

Base Case. As presented in Table 5, under the 8-train Expansion Case is projected to change the real economic output of

- Queensland by a cumulative total of +$286.4billion relative to the Reference Scenario (with a net present value of +$110.9 billion, using a 7 per cent real discount rate)
- Rest of NEM regions by a cumulative total of +$142.1 billion relative to the Reference Scenario (with a net present value of +$58.5 billion, using a 7 per cent real discount rate)
- Australia (i.e. RGNDI) a cumulative total of +$438.4 billion relative to the Reference Scenario (with a net present value of +$173.6 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value of the gain in real income is approximately equivalent to a one-off increase in the average real income of all current Queensland residents of approximately $23,900 per person.

Employment

The projected changes in employment in Queensland and Australia are summarised in Table 7, Figure 52 and Figure 53.

Total employment across Queensland is projected rise noticeably under the 8-train Expansion Case. More specifically, over the projection period under the 8-train Expansion Case:

- Queensland employment rises by a cumulative total of 383,868 employee years compared to the Reference Scenario – equivalent to an average gain of 17,125 FTE jobs each year
- Rest of Australia employment declines by a cumulative total of 2,510 employee years compared to the Reference Scenario – equivalent to an average decrease of 109 FTE jobs each year
- Australian employment rises by a cumulative total of 391,358 employee years compared to the Reference Scenario – equivalent to an average gain of 17,016 FTE jobs each year.

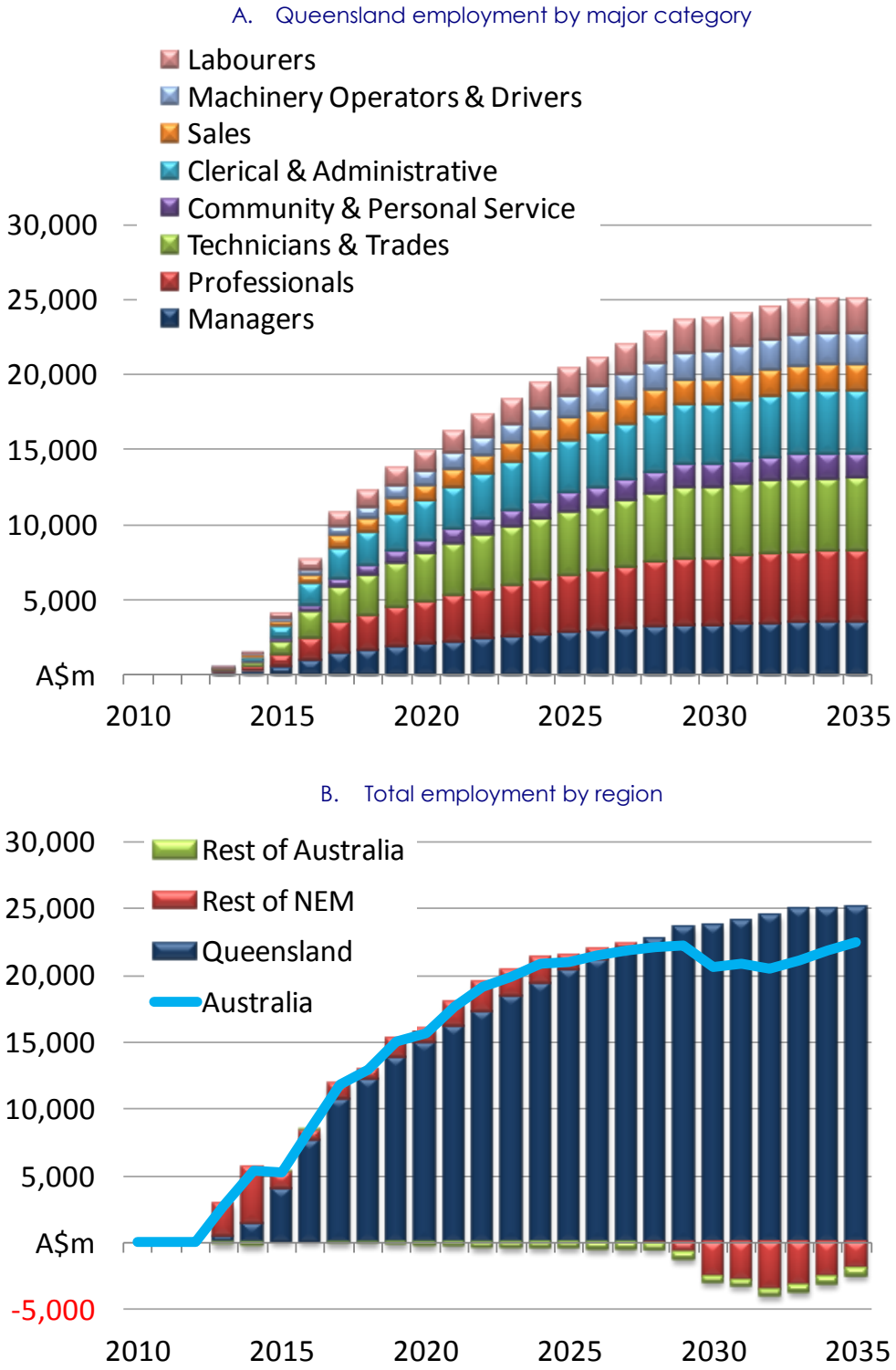
Table 7 **Projected cumulative change in employment by main occupation – 8-train Expansion Case, relative to the Reference Scenario**

	Queensland		Australia	
	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)
	Employee years	Employee years	Employee years	Employee years
Managers	54,245	2,358	54,439	2,367
Professionals	73,920	3,214	84,580	3,677
Technicians & Trades	80,104	3,483	68,245	2,967
Community & Personal Service	24,570	1,068	30,847	1,341
Clerical & Administrative	67,550	2,937	66,210	2,879
Sales	28,119	1,223	32,204	1,400
Machinery Operators & Drivers	29,335	1,275	22,273	968
Labourers	36,025	1,566	32,561	1,416
Total	**393,868**	**17,125**	**391,358**	**17,016**

Notes: FTE = full time equivalent. An employee year is equivalent to one full time job held for a year or, for example, 0.5 of a full time job held for two years equals one FTE.

Source: ACIL Tasman modelling

Figure 52 **Projected annual change in employment – 8-train Expansion Case relative to the Reference Scenario**



Source: ACIL Tasman

Real wages

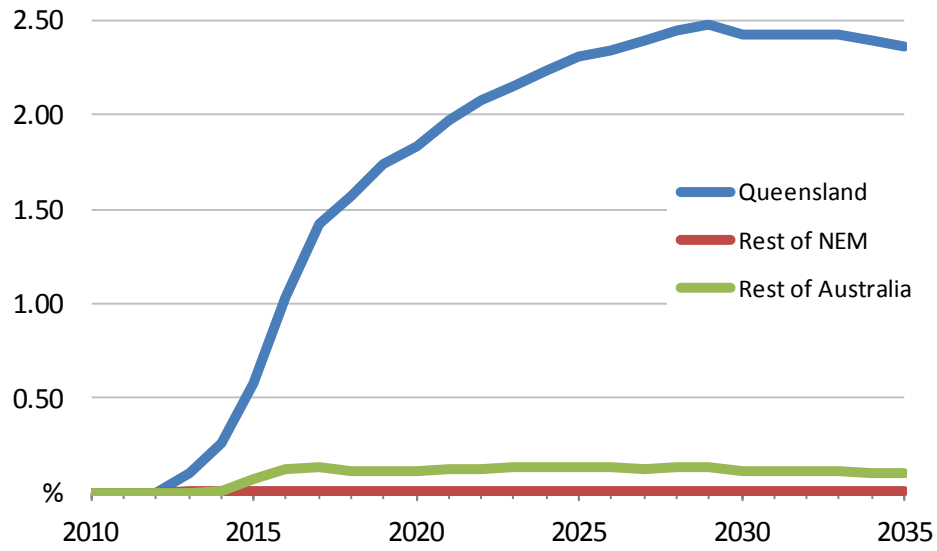
Figure 53 shows the projected changes in real wages under the 8-train Expansion Case relative to the Reference Scenario.

Over the projection period, relative to the Reference Scenario, average real wages across Queensland under the 8-train Expansion Case increase by an average of:

- 0.9 per cent, over the period 2012-13 to 2019-20
- 2.3 per cent, over the period 2020-21 to 2034-35
- 1.8 per cent, over the entire projection period 2012-13 to 2034-35

These are sizeable changes in the context of the size of the additional labour demand relative to the size of the entire Queensland economy.

Figure 53 **Change in average real wages by region – 8-train Expansion Case relative to the Reference Scenario**



Source: ACIL Tasman

5.5 Government revenues

Government revenues will rise significantly as a result of the additional CSG and LNG activities occurring in the 8-train Expansion Case relative to the Reference Scenario. As discussed in Section 4.5, it is likely that at least some of the additional revenue will be returned to private households through slightly lower effective tax rates compared to the Reference Scenario, while the rest will be used to provide public goods and services. Table 4 provides a summary of the anticipated total additional tax revenues generated under the 8-train Expansion Case relative to the Reference Scenario, while Figure 34 shows the changes in different revenue streams through time.

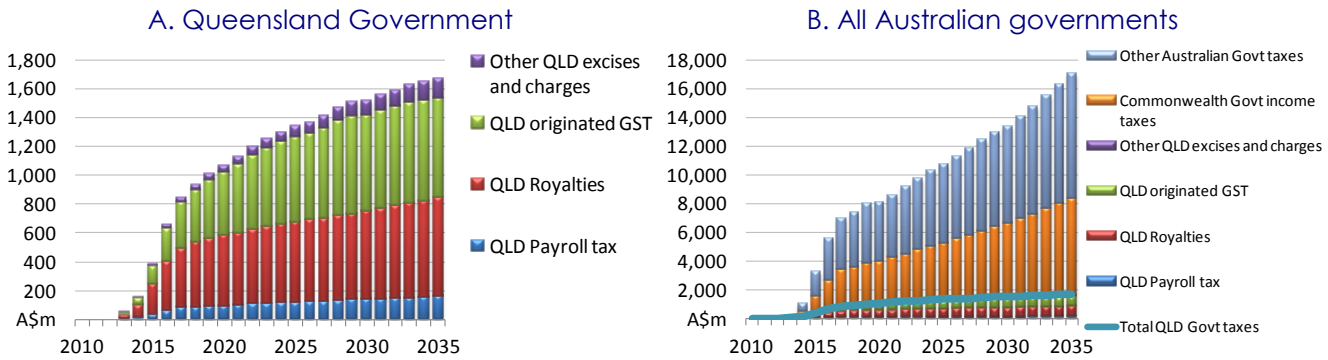
Table 8 **Cumulative change in real government tax revenues – 8-train Expansion Case, relative to the Reference Scenario (2010-11 to 2034-35)**

	Total (2011-12 to 2034-35)	NPV (4% discount rate)	NPV (7% discount rate)
	2010-11$m	2010-11$m	2010-11$m
QLD Payroll tax	2,434	1,417	990
QLD Royalties	11,330	6,699	4,734
QLD originated GST	11,355	6,552	4,536
Other QLD excises and charges (not including taxes on property and motor vehicles)	1,583	878	591
Total Queensland	**26,702**	**15,547**	**10,851**
Commonwealth Government income taxes	85,588	48,593	33,333
Other Australian Government taxes	116,048	66,472	45,908
Total Australian Government taxes	**228,338**	**130,611**	**90,093**

[a] Note that GST revenues generated within the Queensland economy may not all be transferred back to Queensland. Similarly, a portion of other tax revenues may actually be transferred to Queensland (either directly or indirectly). Other tax revenues do not include the cost of emission permits (even though some or all may add to consolidated revenues), nor does it include stamp duties or other transfer taxes and taxes on motor vehicles.

Source: ACIL Tasman

Figure 54 **Changes in annual real government revenues – 8-train Expansion Case, relative to the Reference Scenario (in 2010-11 terms)**



Note: All years are Australian financial years ending June 30.

Source: ACIL Tasman modelling

The Queensland Government is projected to benefit from higher tax revenues of around $26.7 billion as a result of the additional CSG and LNG activities in the 8-train Expansion Case relative to the Reference Scenario, including:

- $2.4 billion of additional payroll taxes
- $11.3 billion of additional royalties

- $11.4 billion of additional Queensland-originated GST revenues, which may or may not be distributed in full back to Queensland[18]
- $1.6 billion of other revenues from a range of Queensland excises and charges.

The Australian Government will be the major beneficiary through higher collections of company tax and personal income tax, which are projected to increase by a cumulative total of $85.6 billion over the forecast period under the 8-train Expansion Case relative to the Reference Scenario.

Cumulatively, government revenues throughout Australia are projected to increase by $228.3 billion, relative to the Reference Scenario (with a discounted value of $90.1 billion using a 7 per cent discount rate).

As discussed in Section 4.5, these estimates do not include any additional revenues that may be raised from transfer taxes, motor vehicle taxes or greenhouse gas emission taxation or permit sales.

[18] Distribution of Commonwealth GST between States in not hypothecated back to States based on their contribution of gross revenue, but rather is distributed based on a complex formula calculated by the Commonwealth Grants Commission taking into account revenue-raising capacity, 'disabilities' and expenditure needs.

6 The 10-train Expansion Case

Under the 10-train Expansion Case we assume that production of CSG in Queensland continues to expand rapidly thereby supporting the establishment of four separate LNG projects with a combined total of ten liquefaction trains each with nominal capacity of 4 Mtpa, for a total LNG capacity of 40 Mtpa. The gross feedstock requirement for the ten LNG trains would be approximately 2,400 PJ/a. Continuing growth of CSG production capacity in both Queensland and NSW also contributes to an increasing level of supply into local markets.

6.1 10-train Expansion Case key assumptions

The key assumptions under the 10-train Expansion Case are the same as those for the Base Case, with the following exceptions:

- Higher volume of LNG exports, and consequential scaling up of CSG production requirements. The assumptions regarding the underlying CSG production cost curve and resource endowment remain the same.
- Lower gas demand for electricity generation as a result of higher gas prices.

6.2 Gas Modelling Results—10-train Expansion Case

6.2.1 Gas demand and consumption

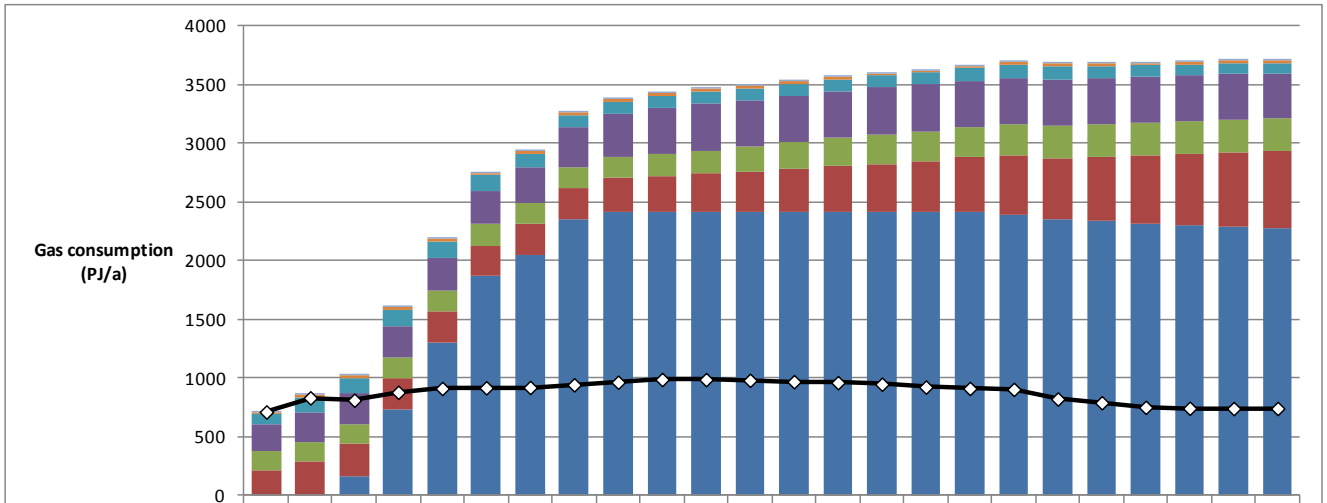
Figure 55 shows the modelled gas consumption, by State, for Eastern Australia including CSG produced for LNG manufacture in Queensland, under the 10-train Expansion Case. LNG manufacture accounts for more than two-thirds of total production with some 2,400 PJ/a used for LNG from 2020 on. After 2028 the amount of CSG consumed for LNG manufacture begins to decline, falling to 2,272 PJ/a by 2035 as reserves constrains take effect. Domestic consumption grows most strongly in Queensland, New South Wales and Victoria, with Queensland consumption rising 147% from 213 PJ in 2015 to 657 PJ in 2035, NSW consumption rising 67% from 170 PJ to 285 PJ over the same period, and Victorian consumption rising 40% from 272 PJ to 381 PJ. This reflects an assumption that most new entrant combined-cycle gas turbine (CCGT) generating plant will locate in Queensland, NSW and Victoria because of a combination of proximity to gas supply and location relative to existing generation sites, including (in the case of Victoria) plant likely to be partially or wholly replaced as a result of carbon pricing.

Gas consumption in South Australia and Tasmania declined over the same period by 34% and 7% respectively as electricity generation in those locations

is less competitive once new low-emission technologies (coal with CCS and geothermal) begin to enter the market in volume after 2030.

Total production at the end of the projection period is a little over 3,700 PJ/a —more than five times higher than the 739 PJ under the Reference Scenario.

Figure 55 **10-train Expansion Case: Eastern Australia modelled gas consumption, by State, including CSG for LNG production**



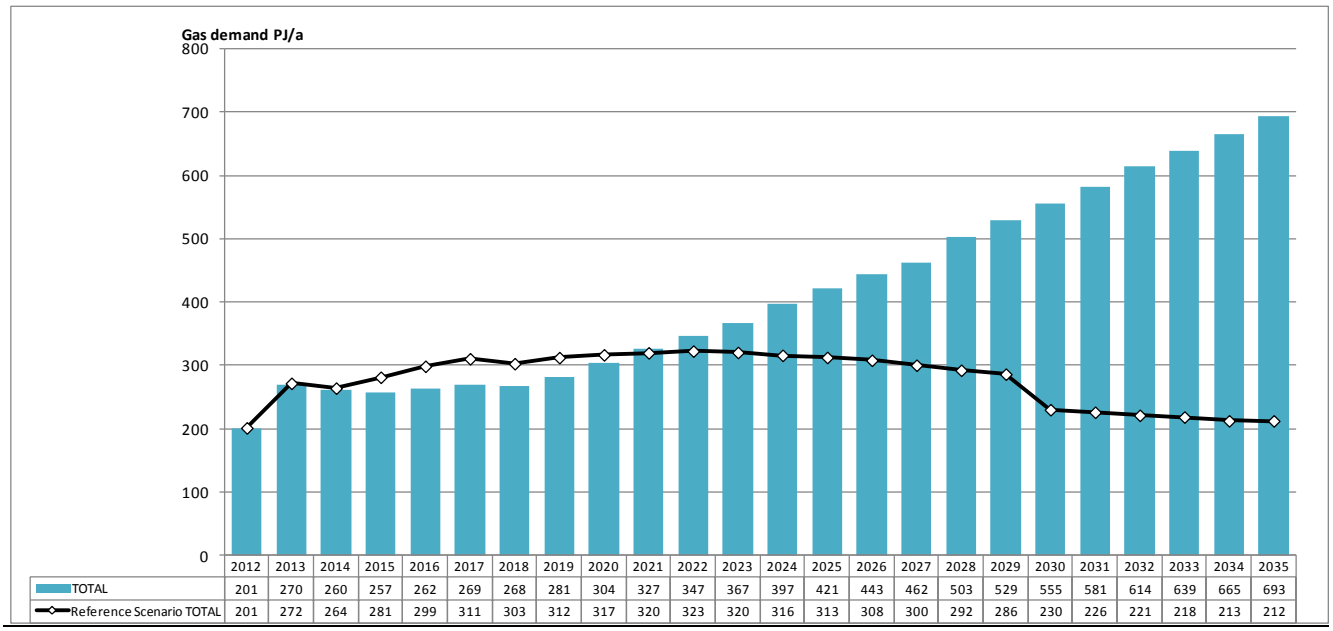
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Australian Capital Territory	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9
Tasmania	20	23	21	21	20	21	21	18	18	18	19	20	20	20	20	20	21	21	20	21	21	20	20	20
South Australia	89	127	128	136	141	141	116	107	107	105	105	105	100	100	100	102	108	111	114	104	100	97	93	90
Victoria	223	255	268	272	279	278	304	338	363	391	397	398	399	401	401	399	397	397	398	390	390	388	384	381
New South Wales	163	166	167	170	183	180	181	177	183	188	200	212	224	239	252	256	250	267	280	277	277	278	281	285
Queensland	213	284	272	266	266	265	262	271	290	308	327	345	370	393	414	432	472	497	522	548	580	605	631	657
Not Specified	0	0	164	734	1293	1863	2050	2345	2411	2411	2411	2411	2411	2411	2411	2411	2411	2395	2344	2339	2319	2306	2293	2272
Reference Scenario Total	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

Source: ACIL Tasman *GMG Australia* modelling

Figure 56 shows the modelled gas demand inputs for Queensland, excluding gas for LNG export production, under the 10-train Expansion Case. Gas demand in Queensland reaches 693 PJ/a by the end of the projection period in 2035. This is some 52 PJ/a lower than for the Base Case as a result of higher gas prices which result in reduced gas demand, particularly for electricity generation. Compared to the Reference Scenario, Queensland domestic gas demand over the period 2015 to 2035 is on average 196 PJ/a under the 10-train Expansion Case.

Figure 57 shows the corresponding gas consumption for Queensland (excluding LNG), by load type, under the 10-train Expansion Case. Overall Queensland domestic consumption reaches 660 PJ/a by 2035—80 PJ/a less than under the Base Case (reflecting lower gas-for-power generation demand and higher gas prices) but some 471 PJ/a more than under the Reference Scenario.

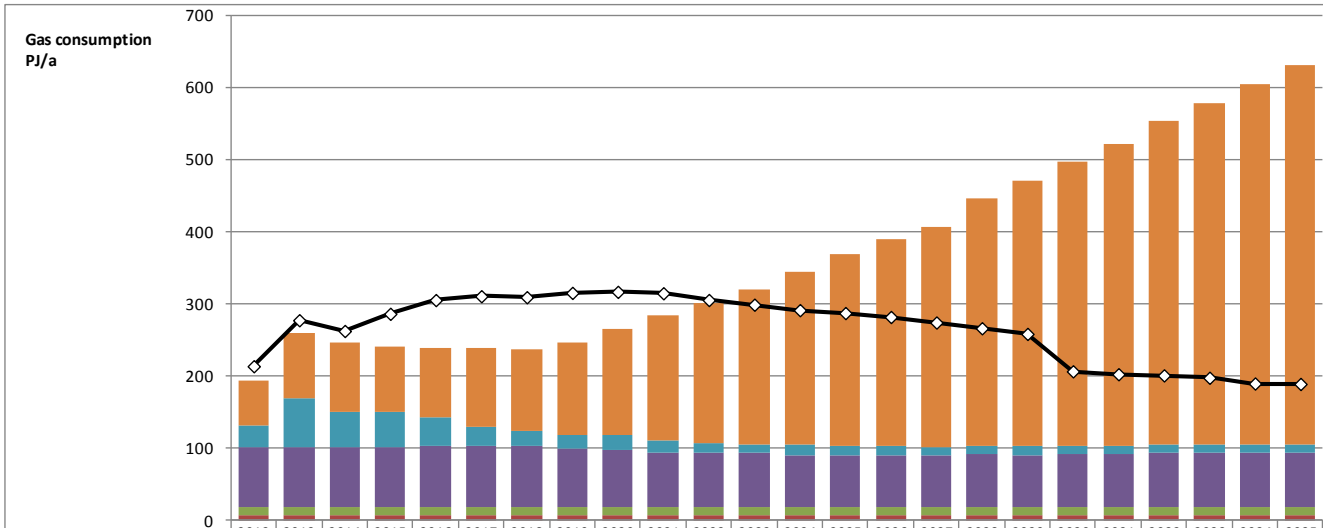
Figure 56 **10-train Expansion Case: Queensland gas demand (model input)**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL	201	270	260	257	262	269	268	281	304	327	347	367	397	421	443	462	503	529	555	581	614	639	665	693
Reference Scenario TOTAL	201	272	264	281	299	311	303	312	317	320	323	320	316	313	308	300	292	286	230	226	221	218	213	212

Source: ACIL Tasman *GMG Australia* modelling

Figure 57 **10-train Expansion Case: Queensland gas consumption (modelled outputs), by load type**



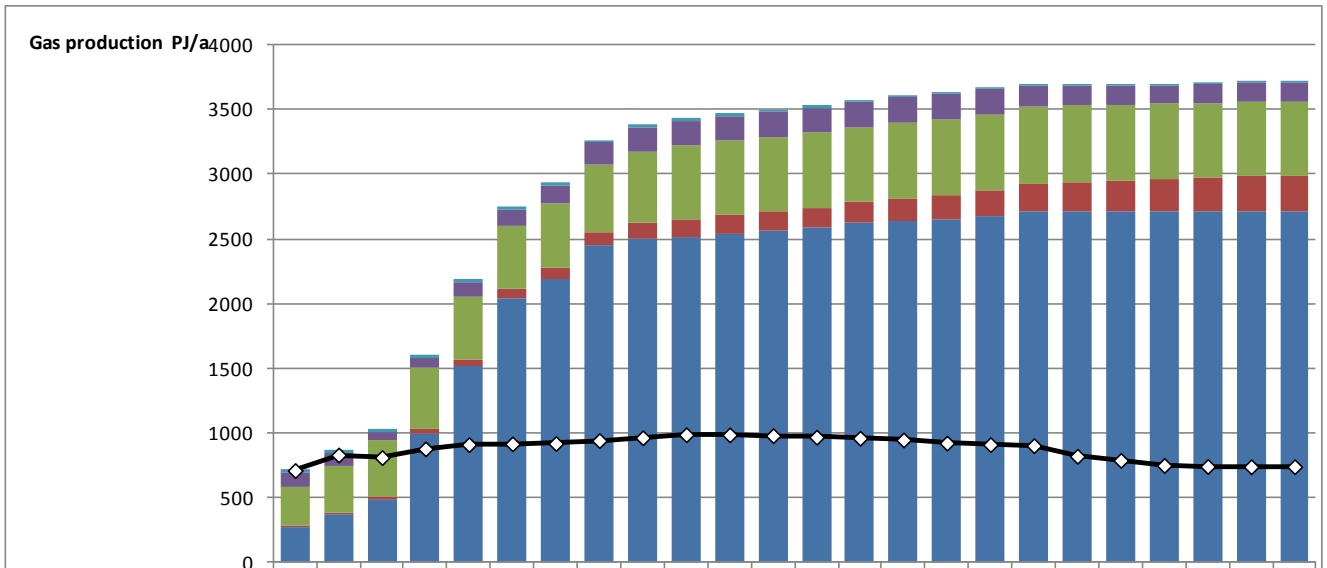
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Power Generation - CCGT	62	91	97	90	96	109	112	128	146	173	194	213	239	265	286	305	343	369	393	418	450	474	499	526
Power Generation - OCGT	29	68	49	50	40	27	21	19	22	17	14	13	14	12	12	12	12	12	11	11	11	11	11	11
Large Industrial	84	83	82	83	85	86	85	82	79	75	75	75	72	72	73	72	73	72	73	74	74	74	75	75
Small Industrial	12	12	12	12	12	11	11	11	11	11	11	11	11	11	11	11	11	11	11	12	12	12	12	12
Commercial/Residential	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7
Reference Scenario TOTAL	214	277	262	286	305	311	309	315	317	315	305	299	291	287	282	274	266	258	206	202	201	198	190	189

Source: ACIL Tasman *GMG Australia* modelling

6.2.2 Gas supply

Figure 58 shows modelled CSG production, by State, under the 10-train Expansion Case. Total production reaches more than 3,700 PJ/a by 2035 (Reference Scenario 739 PJ/a). The sharp rise in production in Queensland coinciding with the commencement of LNG operations is very apparent. Production in New South Wales also grows rapidly as CSG in the Sydney and Gunnedah Basins is developed to supply local markets.

Figure 58 **10-train Expansion Case: Eastern Australian gas production by State**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TAS	20	20	20	30	30	30	30	20	19	18	17	16	16	15	14	12	11	10	9	8	7	7	6	5
SA	108	102	64	77	109	120	140	170	191	191	191	191	191	191	190	190	190	166	146	146	146	146	146	146
VIC	309	355	441	468	482	494	493	520	542	567	576	583	581	584	586	588	591	596	598	585	581	578	575	572
NSW	13	20	26	39	55	69	85	110	133	142	145	148	152	161	175	186	198	210	222	236	248	259	270	280
QLD	264	367	477	994	1516	2043	2193	2445	2496	2511	2538	2560	2591	2621	2642	2653	2675	2714	2713	2713	2712	2712	2712	2711
Reference Scenario TOTAL	710	830	810	877	910	916	918	941	963	986	986	979	968	960	946	922	910	902	820	788	749	741	739	739

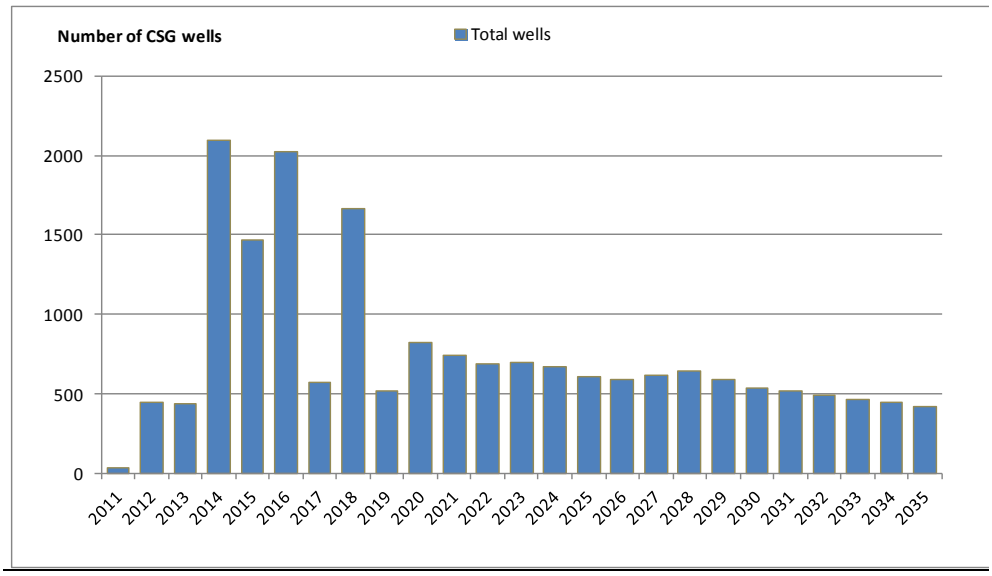
Source: ACIL Tasman *GMG Australia* modelling

6.2.3 Upstream CSG development

ACIL Tasman has used its in-house CSG field development model in order to estimate what this level of Queensland CSG production would mean in terms of number of CSG wells drilled, upstream CSG development capital expenditure and recurrent expenditure. Based on an assumption that half of Queensland's CSG production is sourced from surface to in-seam multi-lateral completions and the other half from vertical well completions, and adopting what we consider to be reasonable assumptions about average well performance and costs, we estimate that the level of production capacity under the 10-train Expansion Case would imply drilling of about 18,800 CSG production wells in Queensland over the period 2011 to 2035 (see Figure 59). According to this analysis, the period of most intense drilling activity will be

between 2014 and 2018, in the lead up to and immediately following commencement of LNG production, with an average of 1,570 wells per year drilled over this period. After commissioning of the LNG facilities, the ongoing drilling requirement is estimated to fall to an average of 600 wells per year from 2020 on.

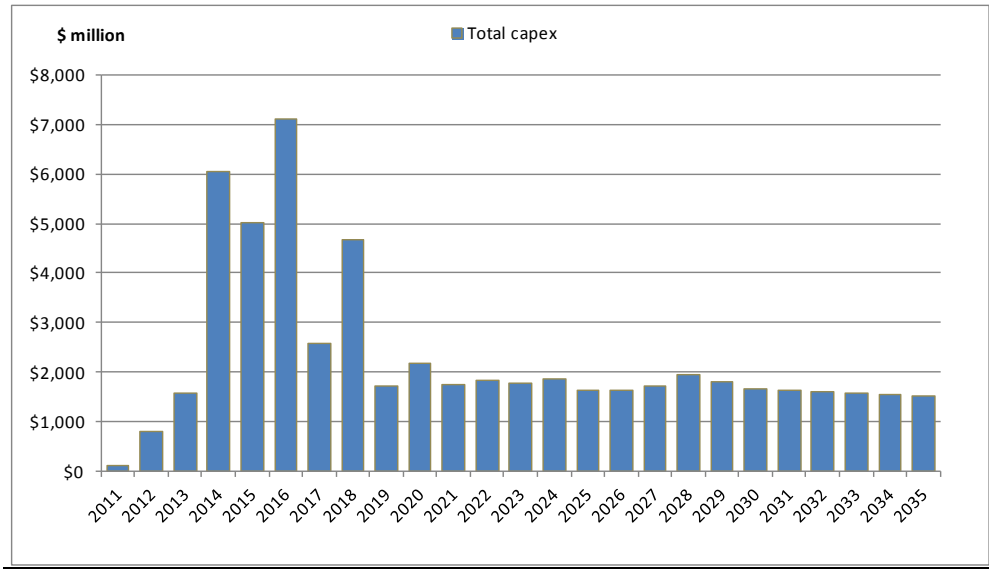
Figure 59 **Queensland CSG drilling under the 10-train Expansion Case**



Source: ACIL Tasman analysis

This level of upstream development would imply capital expenditure (for drilling and completion of wells, gas gathering, processing and compression and water gathering, treatment and disposal) totalling more than $57 billion over the period 2011 to 2035 (see Figure 60).

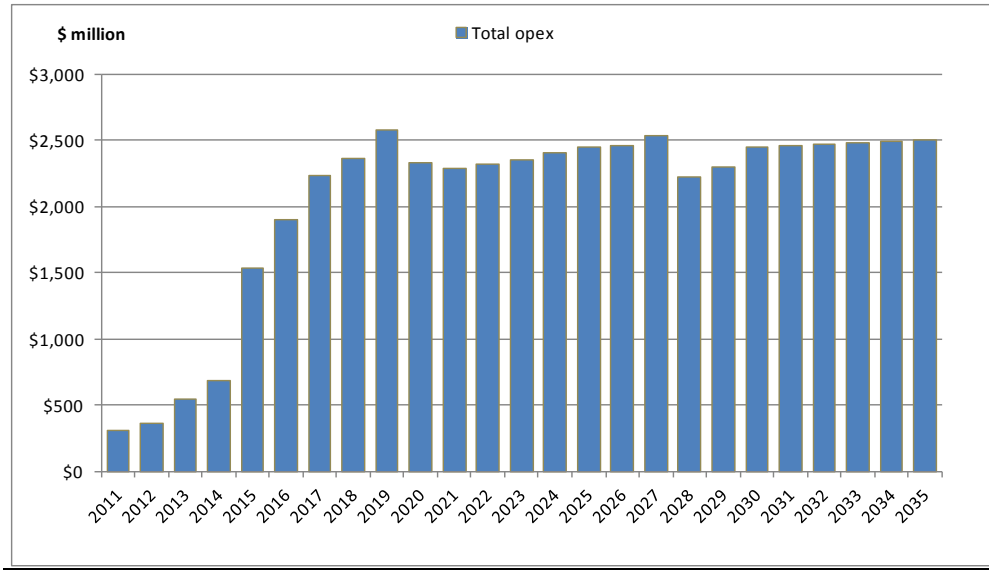
Figure 60 **CSG Upstream Capital Expenditure under the 10-train Expansion Case**



Source: ACIL Tasman analysis

The corresponding level of recurrent operating expenditure is estimated to total around $51 billion over the same period (Figure 61).

Figure 61 **CSG Recurrent Operating Expenditure under the 10-train Expansion Case**



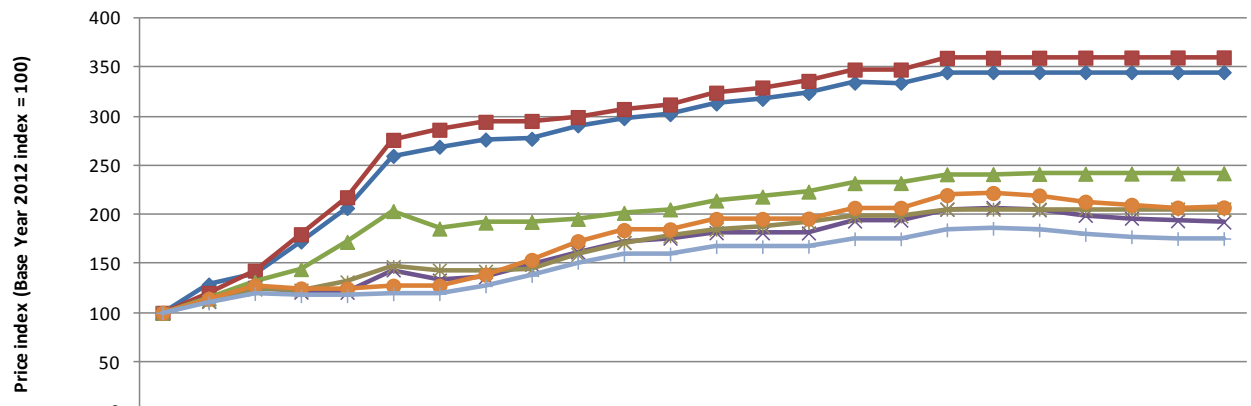
Source: ACIL Tasman analysis

6.2.4 Gas prices

As shown in Figure 62, under the 10-train Expansion Case the modelled wholesale price trends for Queensland (taking prices for gas delivered at Brisbane City Gate and Wallumbilla hub as reference points) show a rapid rise

over the period 2012 to 2017, driven by the commencement of large scale LNG production and sales. From 2029 on, wholesale prices in Queensland and at the Moomba hub remain constant in real terms at levels reflecting LNG netback prices.

Figure 62 **10-train Expansion Case: model wholesale gas prices at major Eastern Australian market nodes**



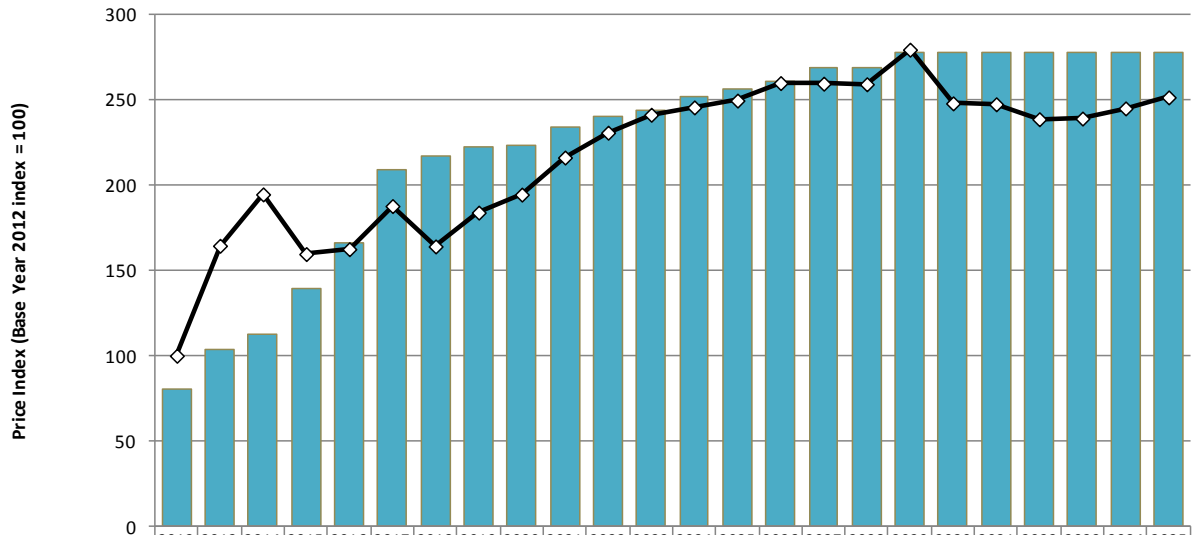
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Brisbane	100	129	139	173	207	260	269	276	277	291	298	302	313	318	324	334	334	345	345	345	345	345	345	345
Wallumbilla	100	120	143	180	218	276	286	294	295	299	307	312	324	329	336	348	348	359	360	360	360	360	360	360
Moomba	100	115	131	145	172	204	186	192	193	196	202	205	214	218	223	232	232	241	241	241	242	242	242	242
Adelaide	100	112	126	121	121	144	133	137	149	162	172	176	182	181	181	193	194	205	207	205	199	196	194	192
Sydney	100	111	124	123	131	147	144	142	144	159	171	178	185	188	192	199	199	205	205	205	206	206	206	206
Melbourne	100	114	128	125	125	128	128	139	154	173	184	185	196	196	196	207	207	220	222	219	213	210	207	207
Hobart	100	110	120	117	117	119	119	127	138	151	159	160	167	167	168	175	175	184	186	184	180	178	176	176

Source: ACIL Tasman *GMG Australia* modelling

Note: Based on real wholesale delivered prices at the relevant market location, indexed to 2012 = 100

Figure 63 compares the modelled wholesale prices for gas delivered to Brisbane under the 10-train Expansion Case assumptions with the corresponding prices under the Reference Scenario. The price indices are based on the Reference Scenario 2012 price having an index value of 100. On average over the period 2015 to 2035, real wholesale gas prices at Brisbane under the 10-train Expansion Case are 9% higher than under the Reference Scenario, driven by the heavy feedstock demands of the ten LNG trains which push marginal CSG production into the high end of the cost curve.

Figure 63 **Modelled wholesale gas prices at Brisbane: 10-train Expansion Case vs Reference Scenario**



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
10-train Expansion Case - BNE	81	104	112	139	166	209	217	223	223	234	240	243	252	256	261	269	269	278	278	278	278	278	278	278
Reference scenario - BNE	100	164	195	160	162	188	164	184	194	216	231	241	246	250	260	259	259	279	248	247	239	239	245	251

Source: ACIL Tasman GMG Australia modelling

Note: Based on wholesale delivered prices at the Brisbane City Gate, with index based on Reference Case 2012 = 100

6.3 Electricity Modelling Results—10-train Expansion Case

In this section we summarise the results of modelling of the National Electricity Market (NEM) under the 10-train Expansion Case, based on ACIL Tasman's modelling using the *PowerMark LT* model.

6.3.1 Key assumptions

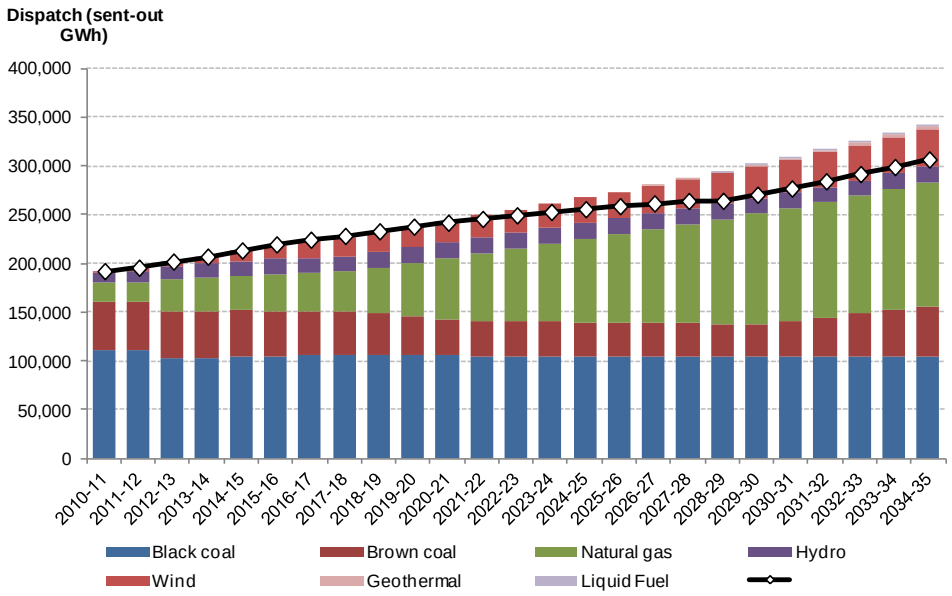
The key input assumptions used to develop the 10-train Expansion Case projection are the same as those for the Base Case with the exception of the gas price assumptions which are consistent with the results of the *GMG Australia* gas market modelling for the 10-train Expansion Case. All other inputs including carbon prices, plant characteristics and operating costs, electricity demand, and new entrant costs are as for the Base Case.

6.3.2 Electricity modelling results—10-train Expansion Case

Electricity generation

Figure 64 summarises overall electricity generation in the NEM under the 10-train Expansion Case assumptions, by fuel type. Total energy generated rises from just under 200,000 GWh in 2010-11 to around 341,000 GWh in 2034-35 (Reference Scenario 306,600 GWh). Dispatch of black coal plant falls 7%, from about 111,000 GWh in 2010/11 to 104,000 GWh in 2034-35. Over the same period, dispatch of brown coal plant actually increases by 5% from 50,000 GWh to 52,600 GWh after having fallen as low as 32,400 GWh in 2029-30. The recovery in brown coal usage reflects strong uptake of low-emission brown coal generating technology linked to CCS after 2030. In percentage terms, renewable (wind) grows very strongly—around twenty-fold increase—but in absolute terms the contribution of renewables to overall energy supply from the NEM remains relatively modest at around 11% for wind and 5% for hydro in 2034-35. Natural gas is again the key growth fuel, with gas-fired energy increasing six-fold over the period, and accounting for 37% of energy output by 2034-35.

Figure 64 **10-train Expansion Case: Whole-of-NEM generated electricity, by fuel type**

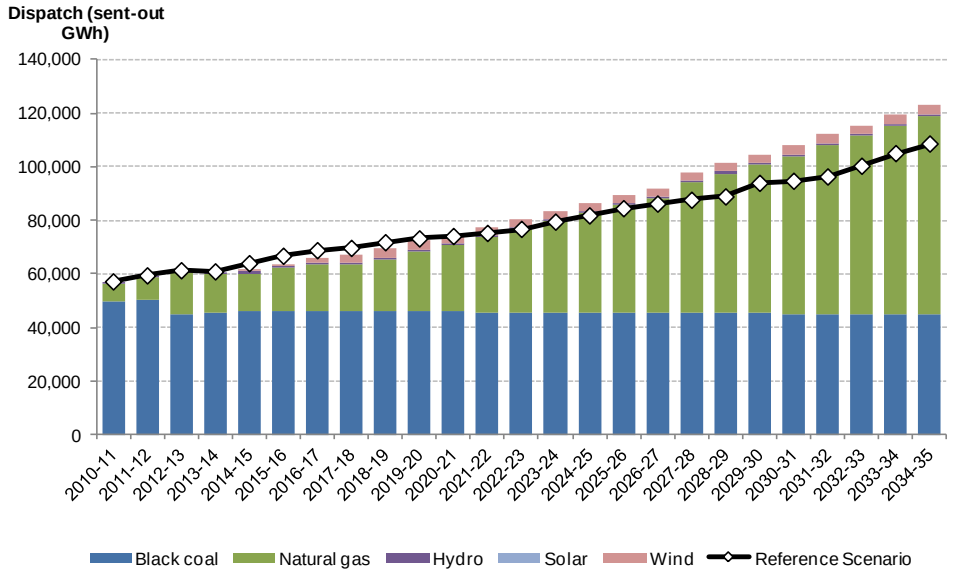


Source: ACIL Tasman *PowerMark LT* modelling

Total electricity generated in Queensland under the 10-train Expansion Case assumptions reaches about 126,800 GWh by 2034-35. This is 18,300 GWh or 17% higher than for the Reference Scenario (Figure 65). The contribution of black coal as a proportion of total generation in the State is projected to

decline to around 35% by 2034-35, although actual output from black coal plant falls by only 10%, from 50,000 to 44,600 GWh. Wind generation in Queensland is projected to grow rapidly off a low base to almost 7,500 GWh, but again it is gas-fired generation that is expected to account for the bulk of the growth in energy generated, rising ten-fold from 6,700 GWh (12% of Queensland generation) in 2010 to 74,200 GWh (58% of Queensland generation) by 2034-35.

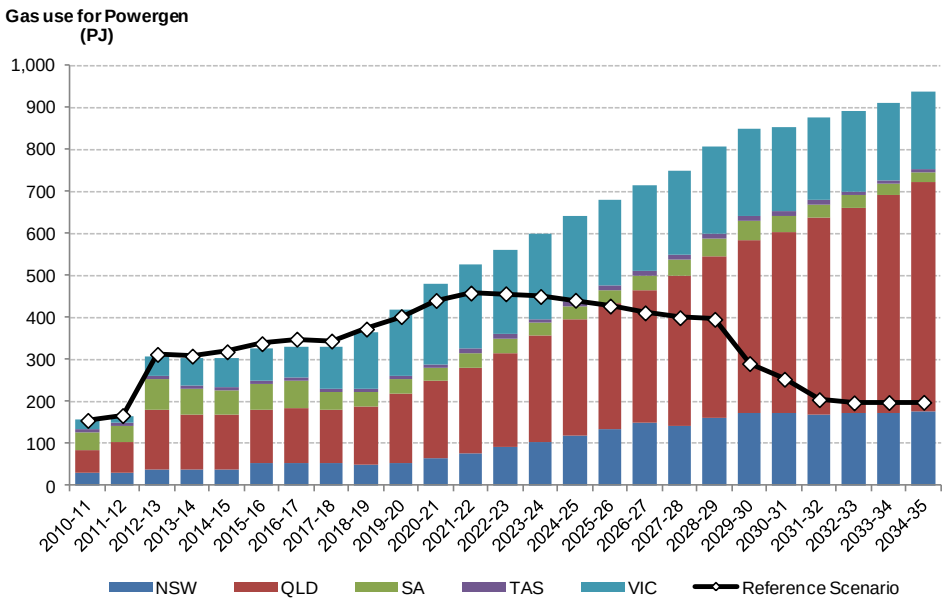
Figure 65 **10-train Expansion Case: Queensland generated electricity, by fuel type**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 66 summarises the modelled consumption of gas for electricity generation in the NEM, by State, over the period to 2034-35 under the 10-train Expansion Case. Total gas-for-power generation consumption is projected to grow very strongly, from 156 PJ in 2010-11 to 936 PJ/a in 2034-35 (Base Case 1,250 PJ/a; Reference Scenario 199 PJ/a). The largest increases in gas consumption for electricity generation occur in Queensland, New South Wales and Victoria.

Figure 66 **10-train Expansion Case: modelled gas consumption for electricity generation, by state**



Source: ACIL Tasman *PowerMark LT* modelling

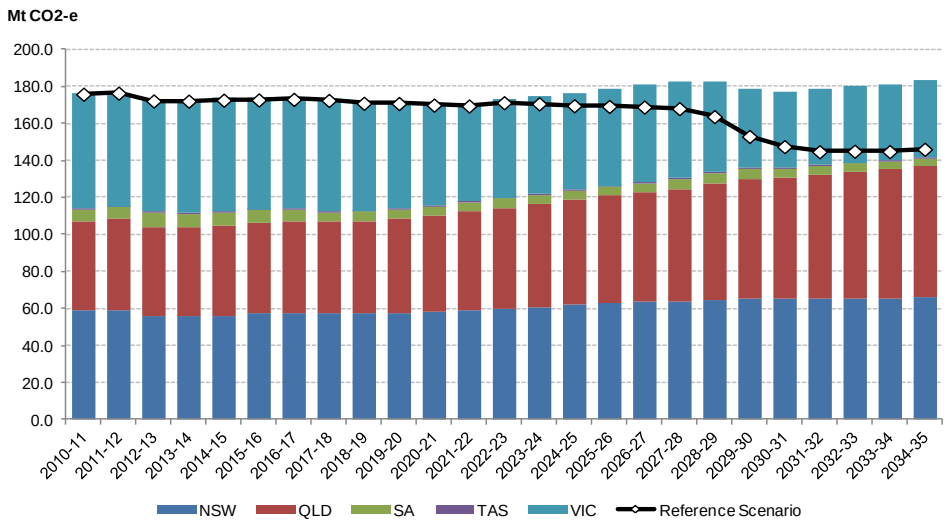
CO_2 emissions

The changing fuel mix under the 10-train Expansion Case is projected to produce a progressive reduction in emission intensity across the NEM, from 0.92 tCO_2e/MWh (sent out) to around 0.54 tCO_2e/MWh (sent out) by 2034-35. However, our modelling shows that under the 10-train Expansion Case assumptions NEM-wide emissions will increase by around 4% from 176 to 183 Mt-CO_2e between 2010-11 and 2034-35 (Figure 67).

The corresponding projected change in Queensland is a 47% increase in emissions from about 48 to 71 Mt-CO_2e driven by the very strong growth of gas-fired generation in the State.

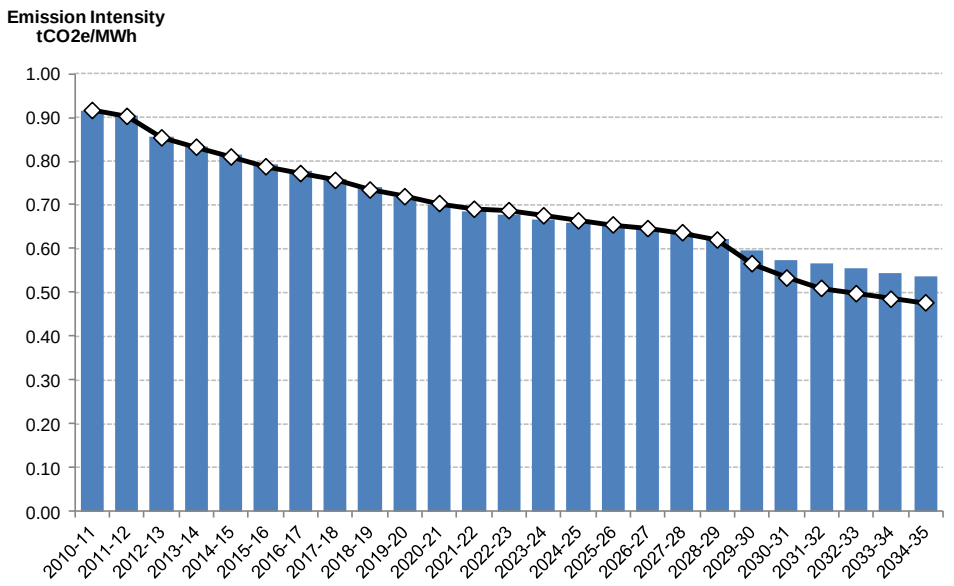
The NEM-wide CO_2 emission intensity trend under the 10-train Expansion Case assumptions is shown in Figure 68. Emission intensity under the 10-train Expansion Case is virtually identical to that under the Reference Scenario until 2028–29. After this time, emission intensity under the Reference Scenario falls relative to the 10-train Expansion Case because of the entry of large scale low-emission clean coal generating plant with CCS.

Figure 67 **10-train Expansion Case: modelled CO_2 emissions from electricity generation**



Source: ACIL Tasman *PowerMark LT* modelling

Figure 68 **10-train Expansion Case: NEM-wide CO_2 emission intensity**



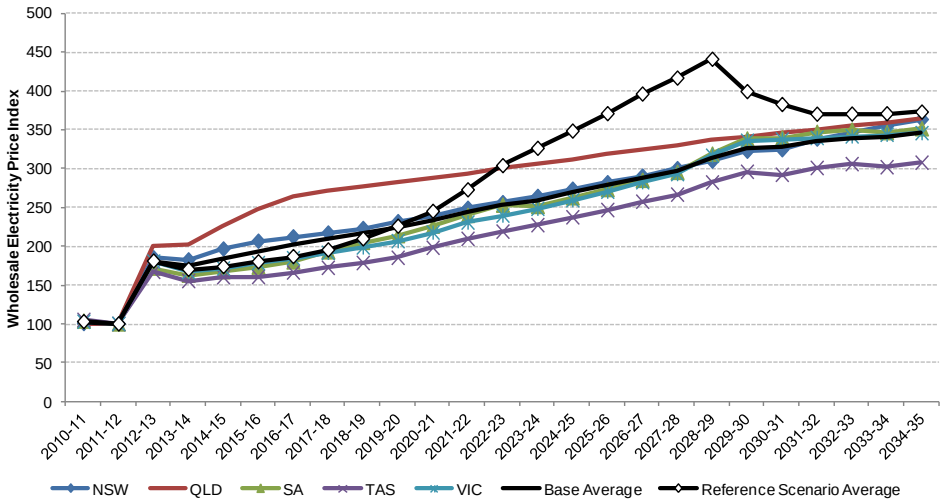
Source: ACIL Tasman *PowerMark LT* modelling

Wholesale electricity prices

Wholesale electricity prices across the NEM are projected to see a step-change increase in the 2012-13 financial year with the introduction of carbon pricing, declining reserve margins and upward pressure on fuel prices. Subsequently, prices under the 10-train Expansion Case assumptions are projected to rise steadily in real terms over the remainder of the modelling period. Wholesale

electricity prices in Queensland are projected initially to rise more quickly than in the southern states immediately following the commissioning of the LNG production facilities. However Queensland electricity prices fall relative to prices in the other NEM regions so that during the later years of the projection period they come back fairly well in line with the other mainland NEM states (Figure 69).

Figure 69 **10-train Expansion Case: modelled wholesale electricity prices**



Note: Wholesale price indices based on time-weighted regional reference prices expressed in real 2011-12 $/MWh; base year 2011-12 index = 100

Source: ACIL Tasman *PowerMark LT* modelling

Compared to the Reference Scenario, average electricity prices[19] in the NEM under the 10-train Expansion Case over the period 2014-15 to 2034-35 will be 10% lower.

6.4 Economic Impacts Modelling Results—10-train Expansion Case

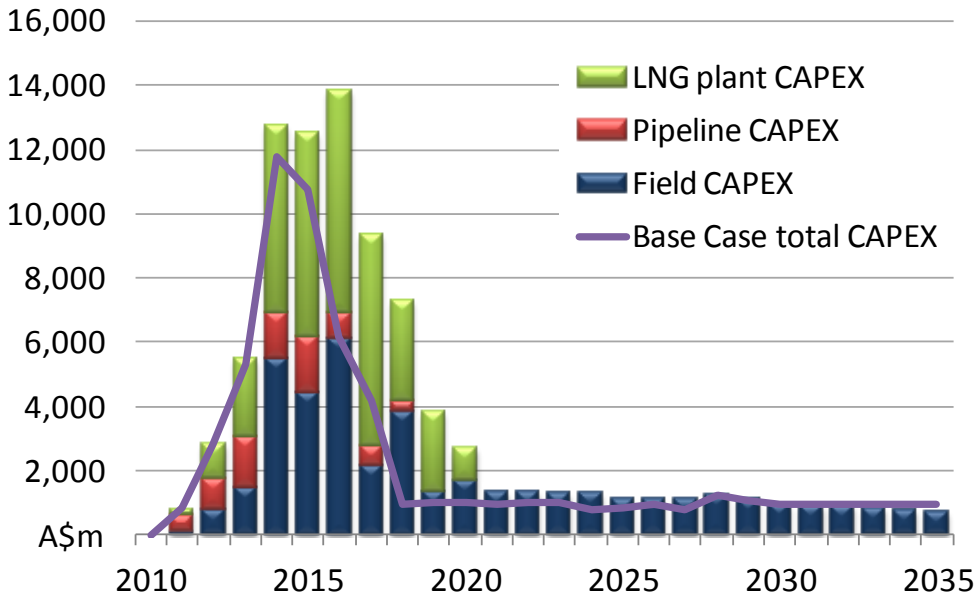
In this section, we compare the results of the *Tasman Global* CGE modelling of the economic impacts of under the 10-train Expansion Case assumptions with the corresponding modelling results for the Reference Scenario. These results incorporate the projected CSG revenue effects from *GasMark* as well as the projected detailed changes in electricity generation by technology and state and projected dispatch weighted prices and investment implications from *PowerMark LT*.

[19] Average prices calculated as the simple arithmetic average of time-weighted regional reference prices.

6.4.1 Annual investment

Over the period to 2034-35, total additional investment related to Queensland CSG and LNG production activities is projected to be $87.4 billion higher under the 10-train Expansion Case, relative to the Reference Scenario (Figure 70). Although total investment under the 10-train Expansion Case is nearly 50 per cent higher than the Base Case, additional Australian content is projected to be only 40 per cent higher based on the assumption that there will be an increased use of foreign pre-assembled modules.

Figure 70 **10-train Expansion Case: Projected annual investment related to Queensland CSG production activities (in 2010-11 terms)**

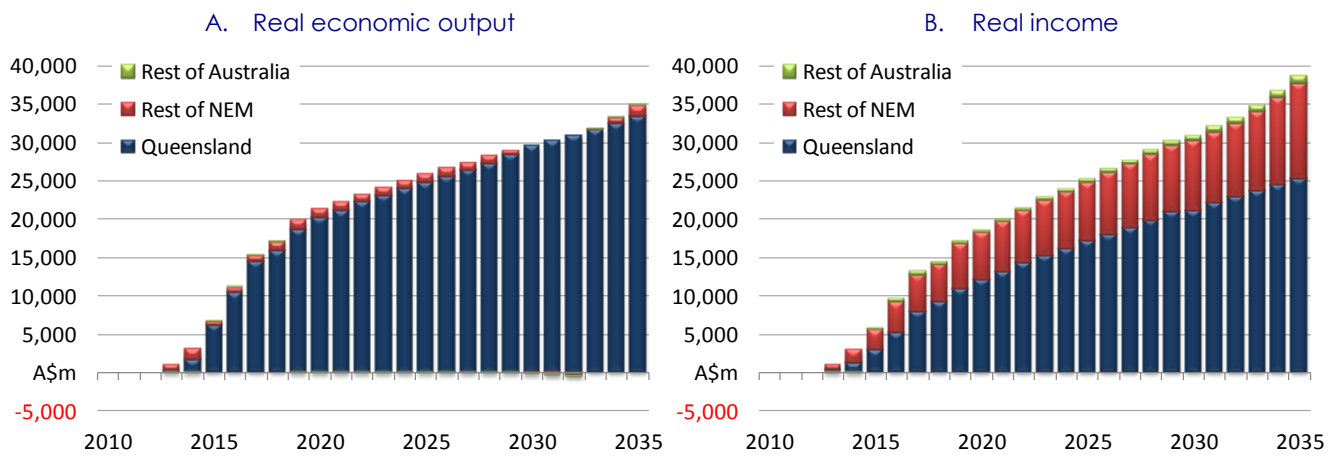


Source: ACIL Tasman

6.4.2 Real economic output and real income

Figure 71 shows the change in real economic output and real income in each region for each year of the projection period (2010-11 to 2034-35) under the 10-train Expansion Case relative to the Reference Scenario.

Figure 71 **Change in real economic output and real income – 10-train Expansion Case relative to the Reference Scenario (in 2010-11 terms)**



Source: ACIL Tasman

Table 9 shows the cumulative impacts of the 10-train Expansion Case relative to the Reference Scenario for each region while Table 10 presents a decomposition of the changes in Queensland real economic output and real income.

Table 9 **Projected changes in real economic output and real income by region – 10-train Expansion Case, relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
REAL ECONOMIC OUTPUT			
Queensland	497,701	286,321	197,931
Other NEM regions	18,408	12,602	9,876
Rest of Australia	–456	–291	–215
Australia (Real GDP)	**515,654**	**298,632**	**207,592**
REAL INCOME			
Queensland	342,686	192,965	131,192
Other NEM regions	162,000	93,838	65,421
Rest of Australia	11,025	6,172	4,195
Australia (Real income)	**515,711**	**292,975**	**200,808**

Note: For the purposes of this modelling Other NEM regions includes New South Wales, Victoria, Tasmania, South Australia and the ACT. NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the 10-train Expansion scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Table 10 **Decomposition of changes in Queensland real economic output and real income – 10-train Expansion Case, relative to the Reference Scenario**

	Total (2011-12 to 2034-35	NPV 4% real discount rate	NPV 7% real discount rate
	2010-11 A$m	2010-11 A$m	2010-11 A$m
Private consumption	168,561	95,803	65,565
Government consumption	31,134	17,663	12,071
Investment	102,191	59,733	41,755
Net foreign and interstate trade	150,003	89,298	63,333
Real QLD economic output (GSP)	**497,701**	**286,321**	**197,931**
Terms of trade	160,794	89,106	60,019
Net foreign income transfers	–268,963	–153,546	–105,794
Real QLD income	**342,686**	**192,965**	**131,192**

Note: NPV = Net present value. It should be noted that the NPV calculation only includes impacts through to 2034-35 even though the 10-train Expansion Scenario will likely to continue to have a significant impact beyond this artificial time horizon.

Data source: ACIL Tasman

Real economic output

Over the period 2011-12 to 2034-35, the 10-train Expansion Case is projected to change the real economic output of

- Queensland (i.e. real GSP) by a cumulative total of +$497.7 billion relative to the Reference Scenario (with a net present value of +$197.9 billion, using a 7 per cent real discount rate)
- Rest of NEM regions by a cumulative total of +$18.4 billion relative to the Reference Scenario (with a net present value of +$9.8 billion, using a 7 per cent real discount rate)
- Australia (i.e. real GDP) a cumulative total of +$515.6billion relative to the Reference Scenario (with a net present value of +$207.5 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value of the gain in real economic output is equivalent an increase of approximately 74 per cent in the level of Queensland's 2010-11 GSP and 15 per cent of Australia's 2010-11 GDP. This is a very substantial change in the level of economic activity as a result of production changes from a single industry.

Real income

The real income of Queensland is projected to be boosted significantly as a result of the development of CSG production and LNG exports under the Base Case. As presented in Table 9, the 10-train Expansion Case is projected to change the real economic output of:

- Queensland by a cumulative total of +$342.6 billion relative to the Reference Scenario (with a net present value of +$131.2 billion, using a 7 per cent real discount rate)
- Rest of NEM regions by a cumulative total of +$162.0 billion relative to the Reference Scenario (with a net present value of +$65.4 billion, using a 7 per cent real discount rate)
- Australia (i.e. RGNDI) a cumulative total of +$515.7 billion relative to the Reference Scenario (with a net present value of +$200.8 billion, using a 7 per cent real discount rate).

To place this in perspective, the discounted present value of the gain in real income (7% real discount rate) is approximately equivalent to a one-off increase in the average real income of all current Queensland residents of approximately $28,300 per person.

Employment

The projected changes in employment in Queensland and Australia are summarised in Table 11 and Figure 72.

Total employment across Queensland is projected rise strongly under the 10-train Expansion Case. Specifically, over the projection period under the 10-train Expansion Case:

- Queensland employment rises by a cumulative total of 464,801 employee years compared to the Reference Scenario – equivalent to an average gain of 21,106 FTE jobs each year
- Rest of Australia employment decreases by a cumulative total of 18,157employee years compared to the Reference Scenario – equivalent to an average decrease of 1,686 FTE jobs each year
- Australian employment rises by a cumulative total of 446,645 employee years compared to the Reference Scenario – equivalent to an average gain of 19,420 FTE jobs each year.

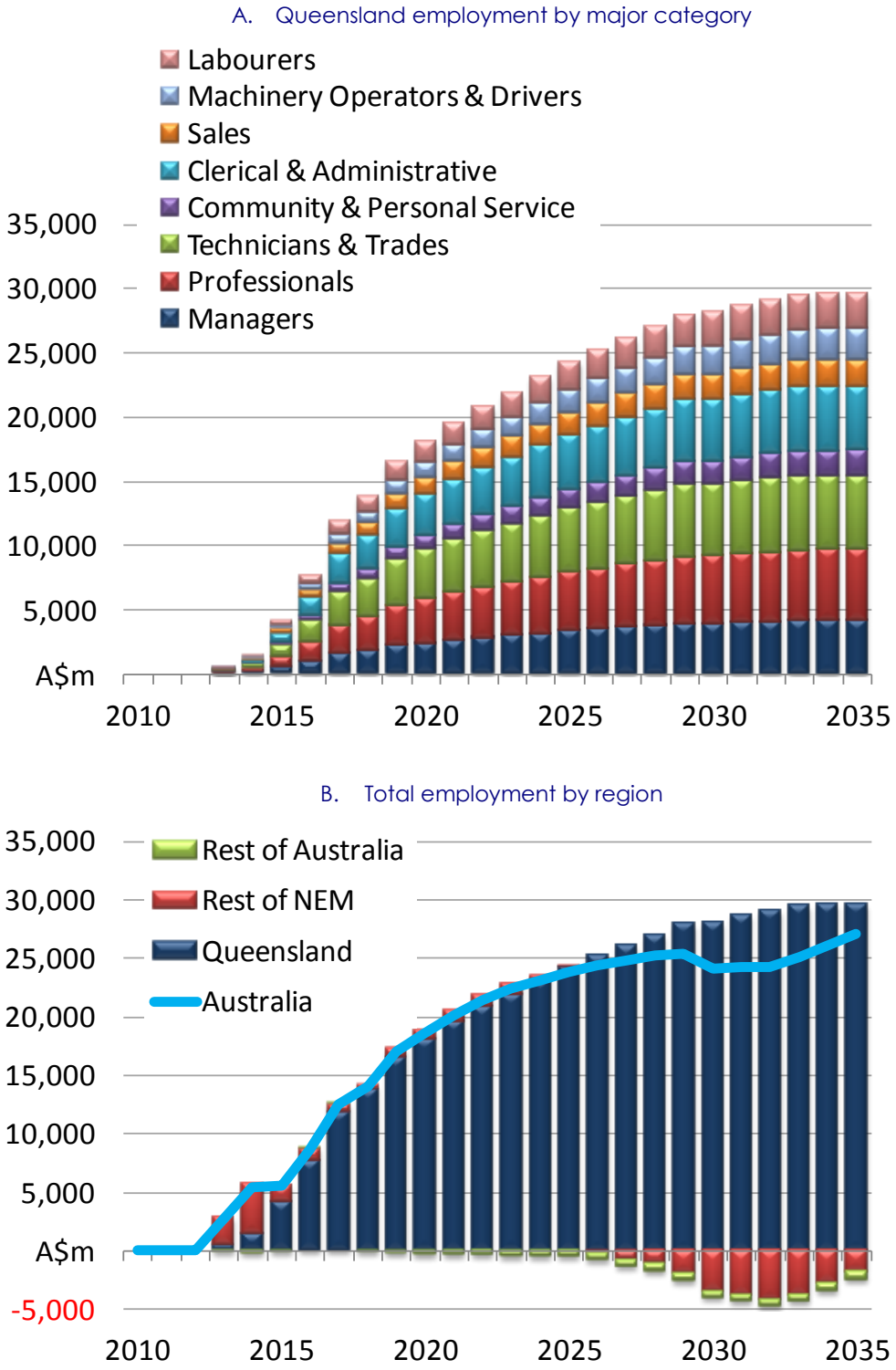
Table 11 **Projected change in employment by main occupation, relative to the Reference Scenario**

	Queensland		Australia	
	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)	Cumulative total (2011-12 to 2034-35)	Annual average (2011-12 to 2034-35)
	Employee years	Employee years	Employee years	Employee years
Managers	63,986	2,782	61,496	2,674
Professionals	87,482	3,804	97,623	4,244
Technicians & Trades	94,634	4,115	78,623	3,418
Community & Personal Service	28,850	1,254	35,233	1,532
Clerical & Administrative	80,401	3,496	77,094	3,352
Sales	33,049	1,437	36,615	1,592
Machinery Operators & Drivers	34,071	1,481	23,535	1,023
Labourers	42,352	1,841	36,434	1,584
Total	**464,825**	**20,210**	**446,654**	**19,420**

Notes: FTE = full time equivalent. An employee year is equivalent to one full time job held for a year or, for example, 0.5 of a full time job held for two years equals one FTE.

Source: ACIL Tasman modelling

Figure 72 **Projected annual change in employment – 10-train Expansion Case relative to the Reference Scenario**



Source: ACIL Tasman

Real wages

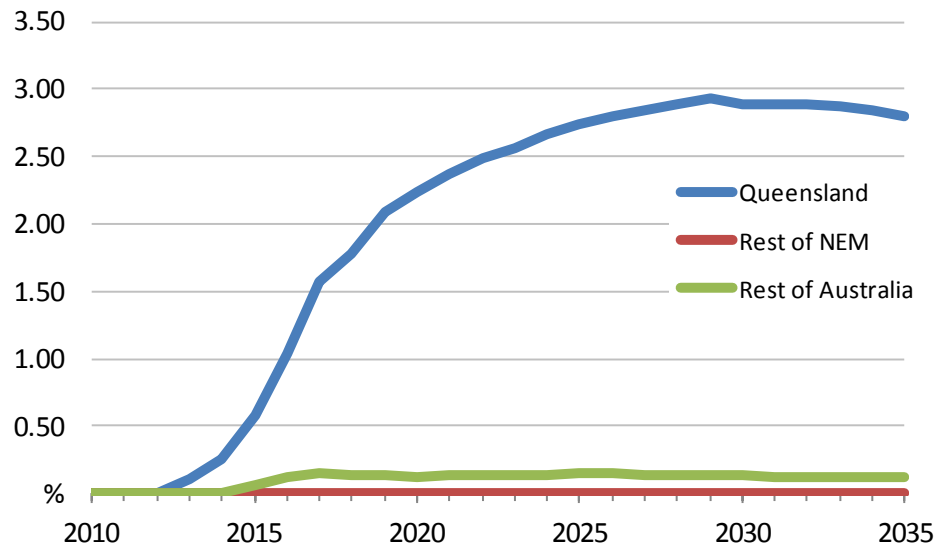
Figure 73 shows the projected changes in real wages under the 10-train Expansion Case relative to the Reference Scenario.

Over the projection period, relative to the Reference Scenario, average real wages across Queensland under the 10-train Expansion Case increase by an average of:

- 1.1 per cent, over the period 2012-13 to 2019-20
- 2.7 per cent, over the period 2020-21 to 2034-35
- 2.1 per cent, over the entire projection period 2012-13 to 2034-35

These are sizeable changes in the context of the size of the additional labour demand relative to the size of the entire Queensland economy.

Figure 73 **Change in average real wages by region – 10-train Expansion Case relative to the Reference Scenario**



Source: ACIL Tasman

6.5 Government revenues

Government revenues will rise significantly as a result of the additional CSG and LNG activities occurring in the 10-train Expansion Case relative to the Reference Scenario. As discussed in Section 4.5, it is likely that at least some of the additional revenue will be returned to private households through slightly lower effective tax rates compared to the Reference Scenario, while the rest will be used to provide public goods and services. Table 4 provides a summary of the anticipated total additional tax revenues generated under the 10-train Expansion Case relative to the Reference Scenario, while Figure 34 shows the changes in different revenue streams through time.

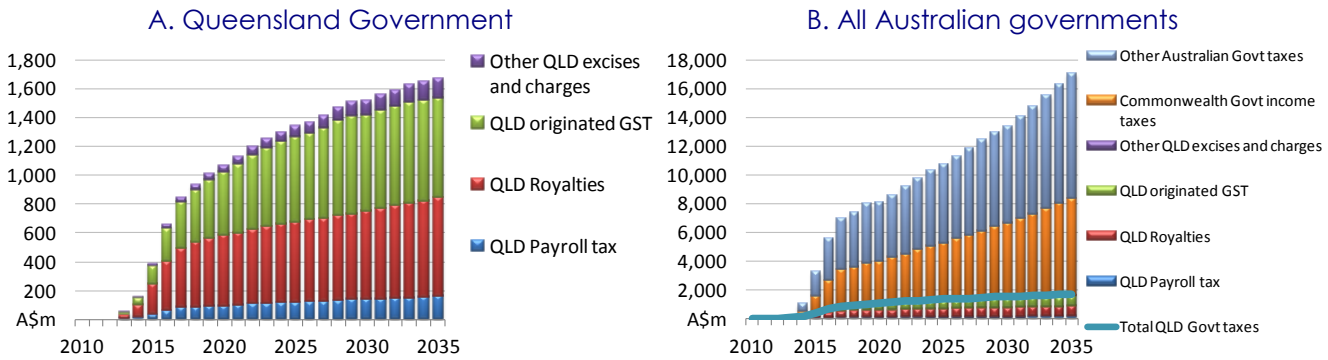
Table 12 **Cumulative change in real government tax revenues – 10-train Expansion Case, relative to the Reference Scenario (2010-11 to 2034-35)**

	Total (2011-12 to 2034-35)	NPV (4% discount rate)	NPV (7% discount rate)
	2010-11$m	2010-11$m	2010-11$m
QLD Payroll tax	3,034	1,755	1,219
QLD Royalties	13,371	7,880	5,550
QLD originated GST	13,655	7,831	5,393
Other QLD excises and charges (not including taxes on property and motor vehicles)	1,893	1,042	698
Total Queensland	**31,952**	**18,508**	**12,859**
Commonwealth Government income taxes	102,954	57,907	39,415
Other Australian Government taxes	140,042	79,410	54,392
Total Australian Government taxes	**274,948**	**155,824**	**106,666**

[a] Note that GST revenues generated within the Queensland economy may not all be transferred back to Queensland. Similarly, a portion of other tax revenues may actually be transferred to Queensland (either directly or indirectly). Other tax revenues do not include the cost of emission permits (even though some or all may add to consolidated revenues), nor does it include stamp duties or other transfer taxes and taxes on motor vehicles.

Source: ACIL Tasman

Figure 74 **Changes in annual real government revenues – 10-train Expansion Case, relative to the Reference Scenario (in 2010-11 terms)**



Note: All years are Australian financial years ending June 30.

Source: ACIL Tasman modelling

The Queensland Government is projected to benefit from higher tax revenues of around $32 billion as a result of the additional CSG and LNG activities in the 10-train Expansion Case relative to the Reference Scenario, including:

- $3.0 billion of additional payroll taxes
- $13.4 billion of additional royalties

- $13.7 billion of additional Queensland-originated GST revenues, which may or may not be distributed in full back to Queensland[20]
- $1.9 billion of other revenues from a range of Queensland excises and charges.

The Australian Government will be the major beneficiary through higher collections of company tax and personal income tax, which are projected to increase by a cumulative total of $103 billion over the forecast period under the 10-train Expansion Case relative to the Reference Scenario.

Cumulatively, government revenues throughout Australia are projected to increase by $274.9 billion, relative to the Reference Scenario (with a discounted value of $106.7 billion using a 7 per cent discount rate).

As discussed in Section 4.5, these estimates do not include any additional revenues that may be raised from transfer taxes, motor vehicle taxes or greenhouse gas emission taxation or permit sales.

[20] Distribution of Commonwealth GST between States in not hypothecated back to States based on their contribution of gross revenue, but rather is distributed based on a complex formula calculated by the Commonwealth Grants Commission taking into account revenue-raising capacity, 'disabilities' and expenditure needs.

A The GMG Australia GasMark model

The *GasMark® Global* (GMG) model is a generic gas modelling platform, developed by ACIL Tasman, which has the flexibility to represent the unique characteristics of gas markets across the globe. Its potential applications cover a broad scope — from global LNG trade, through to intra-country and regional market analysis. The Eastern Australian version of the model is known as *GMG Australia*.

A.1 Data inputs

The user can establish the level of detail by defining a set of supply regions, customers, demand regions, pipelines and LNG facilities. These sets of basic entities in the model can be very detailed or aggregated as best suits the objectives of the user. A 'pipeline' could represent an actual pipeline or a pipeline corridor between a supply and a demand region. A supplier could be a whole gas production basin aggregating the output of many individual fields, or could be a specific producer in a smaller region. Similarly a demand point could be a single industrial user or an aggregation of small consumers such as the residential and commercial users typically serviced by energy utility companies.

The inputs to *GMG Australia* can be categorised as follows:

- **Existing and potential new sources of gas supply**: these are characterised by assumptions about available reserves, production rates, production decline characteristics, and minimum price expectations of the producer. These price expectations may be based on long-run marginal costs of production or on market expectations, including producer's understandings of substitute prices.
- **Existing and potential new gas demand**: demand may relate to a specific load such as a power station, or fertiliser plant. Alternatively it may relate to a group or aggregation of customers, such as the residential or commercial utility load in a particular region or location. Loads are defined in terms of their location, annual gas demand, price tolerance and price elasticity of demand (that is, the amount by which demand will increase or decrease depending on the price at which gas can be delivered), and load factor (defined as the ratio between average and maximum daily quantity requirements).
- **Existing, new and expanded transmission pipeline capacity**: pipelines are represented in terms of their geographic location, physical capacity, system average load factor (which is relevant to determination of the effective annual throughput capability given assumptions regarding short-term [daily] capacity limits) and tariffs.

- **Existing and potential new LNG facilities**: LNG facilities include liquefaction plants, regasification (receiving) terminals and assumptions regarding shipping costs and routes. LNG facilities play a similar role to pipelines in that they link supply sources with demand. LNG plants and terminals are defined at the plant level and require assumptions with regard to annual throughput capacity and tariffs for conversion.

A.2 Solving the model: the market settlement process

At its core, GMG is a partial spatial equilibrium model. The market is represented by a collection of spatially related nodal objects (supply sources, demand points, LNG liquefaction and receiving facilities), connected via a network of pipeline or LNG shipping elements.

The equilibrium solution of the model is found through application of linear programming techniques which seek to maximise the sum of producer and consumer surplus across the entire market simultaneously. The objective function of this solution, which is well established in economic theory[21], consists of three terms:

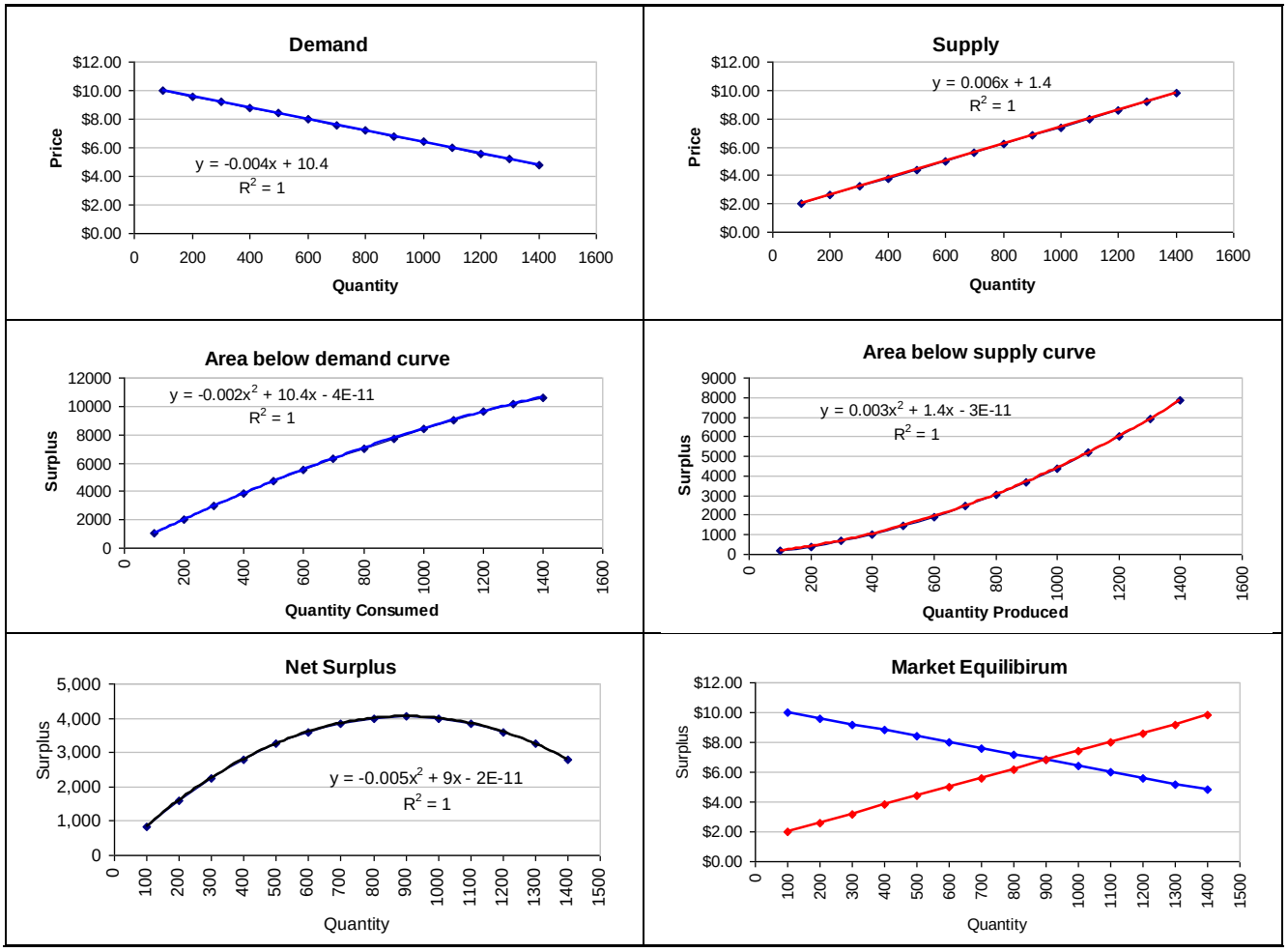
- the integral of the demand price function over demand; minus
- the integral of the supply price function over supply; minus
- the sum of the transportation, conversion and storage costs.

The solution results in an economically efficient system where lower cost sources of supply are utilised before more expensive sources and end-users who have higher willingness to pay are served before those who are less willing to pay. Through the process of maximising producer and consumer surplus, transportation costs are minimised and spatial arbitrage opportunities are eliminated. Each market is cleared with a single competitive price.

Figure A1 seeks to explain diagrammatically a simplified example of the optimisation process. The two charts at the top of Figure A1 show simple linear demand and supply functions for a particular market. The figures in the middle of Figure A1 show the integrals of these demand and supply functions, which represent the areas under the demand and supply curves. These are equivalent to the consumer and producer surpluses at each price point along the curve. The figure on the bottom left shows the summation of the consumer and producer surplus, with a maximum clearly evident at a quantity of 900 units. This is equivalent to the equilibrium quantity when demand and supply curves are overlayed as shown in the bottom right figure.

[21] The theoretical framework for the market solution used in GMG is attributed to Nobel Prize winning economist Paul Samuelson.

Figure A1 **Simplified example of market equilibrium and settlement process**



Data source: ACIL Tasman

The distinguishing characteristic of spatial price equilibrium models lies in their recognition of the importance of space and transportation costs associated with transporting a commodity from a supply source to a demand centre. Since gas markets are interlinked by a complex series of transportation paths (pipelines, shipping paths) with distinct pricing structures (fixed, zonal or distance based), GMG also includes a detailed network model with these features.

Spatial price equilibrium models have been used to study problems in a number of fields including agriculture, energy markets, mineral economics, as well as in finance. These perfectly competitive partial equilibrium models assume that there are many producers and consumers involved in the production and consumption, respectively, of one or more commodities and that as a result the market settles in an economically efficient fashion. Similar

approaches are used within gas market models across the world. Examples include:

- Gas Pipeline Competition Model (GPCM®) developed by RBAC Inc energy industry forecasting systems in the USA.
- Market Builder from Altos Partners, another US-based energy market analysis company.

B PowerMark LT

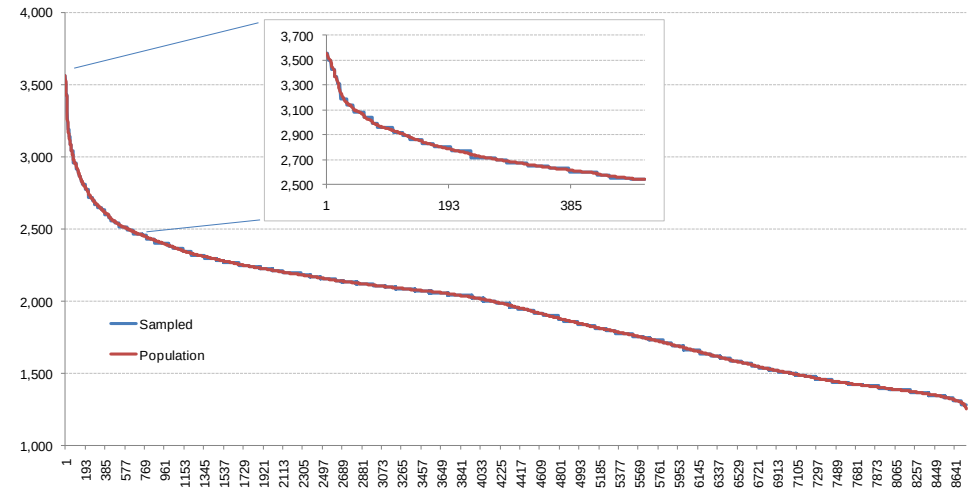
PowerMark LT is a dynamic least cost model, which optimises existing and new generation operation and new investments over the period 2010 to 2050, given a range of input assumptions regarding demand growth, incumbent plant costs, interconnectors, new development costs and government policy settings (CPRS, expanded RET etc.). *PowerMark LT* utilises a large scale commercial LP solver. *PowerMark LT* solves efficiently providing the solution for a single long term scenario (technology, policy settings etc.) within a few minutes. This means that multiple scenario comparisons (for example to compare the effect of different technology futures) are practical within a single set of model runs with the full comparison suite available quickly.

B.1 Demand representation

Unlike a detailed simulation model, *PowerMark LT* utilises a sampled 50 or 100 point sequential representation of demand in each year, with each point weighted such that it provides a realistic representation of the demand population. The sampling utilises a tree clustering process with a weighted pair-group centroid distance measure.

Figure B1 shows the fit between a 100 point sampled Load Duration Curve (LDC) with an hourly load trace. The sampled series exhibits an extremely close fit with the population LDC. In this example, the average sampling error was only 0.36 MW (max 57 MW, min -53 MW).

Figure B1 **Comparison of 100 point sampled LDC with hourly trace (MW)**



Data source: PowerMark LT

B.2 Supply representation

The supply side is modelled at station level. Inputs for each station include:

- sent-out capacity
- planned and unplanned outage rates
- fuel costs
- thermal efficiency
- emission intensity.

The model is not strictly a least cost Short-Run Marginal Cost (SRMC) model, in that each plant is represented by two offer bands – one at SRMC and another at a defined multiple of SRMC. This is a crude approximation of the complex bidding behaviour observed in the NEM and simulated within ACIL Tasman's detailed *PowerMark* model. The SRMC offer band represents a proxy for the plant's level of contract cover, which owners are incentivised to offer to the market at its marginal cost of generation. The second, higher offer band reflects the uncontracted portion of the station's output.

B.3 Network and new entry

The NEM is modelled on a regional basis with interconnectors represented as bidirectional linkages between regions with defined capacity limits and linear (as opposed to quadratic) loss equations.

PowerMark LT provides an optimal expansion program which takes into account all generation costs, including carbon costs and constructs new generation facilities under the assumption of perfect foresight of future costs.

A range of new entrant technologies are available for deployment in each region, with defined fixed and variable costs. Fixed costs are in the form of an annual charge (specified in $/kW/year), covering capital, fixed O&M and tax. Variable costs (specified in $/MWh), represent fuel, variable O&M and carbon costs. For each technology constraints may be applied to construction limits in any one year or in aggregate.

Wherever possible the model is calibrated against the more detailed *PowerMark* simulation model for the initial 10-15 year period.

B.4 Outputs

PowerMark LT provides a range of outputs including:

- dispatch and capacity factor for incumbent generators
- new entrant plant schedule (timing, technology and size)
- interconnector flows (energy flows, constraint times)

- market equilibrium price (efficient dispatch price or price require to justify new entry)
- unserved energy
- fuel use by technology and region
- CO_2-e emissions released to the atmosphere and those captured and stored from CCS plant.

C The *Tasman Global* model

ACIL Tasman's computable general equilibrium (CGE) model *Tasman Global* is a powerful tool for undertaking economic impact analysis at the regional, state, national and global level.

There are various types of economic models and modelling techniques. Many of these are based on partial equilibrium analysis that usually considers a single market. However, in economic analysis, linkages between markets and how these linkages develop and change over time can be critical. *Tasman Global* has been developed to meet this need.

Tasman Global is an analytical tool that can capture these linkages on a regional, state, national and global scale. *Tasman Global* is a large-scale computable general equilibrium model which is designed to account for all sectors within an economy and all economies across the world. ACIL Tasman uses this modelling platform to undertake industry, project, scenario and policy analyses. The model is able to analyse issues at the industry, global, national, state and regional levels and to determine the impacts of various economic changes on production, consumption and trade at the macroeconomic and industry levels.

C.1 A dynamic model

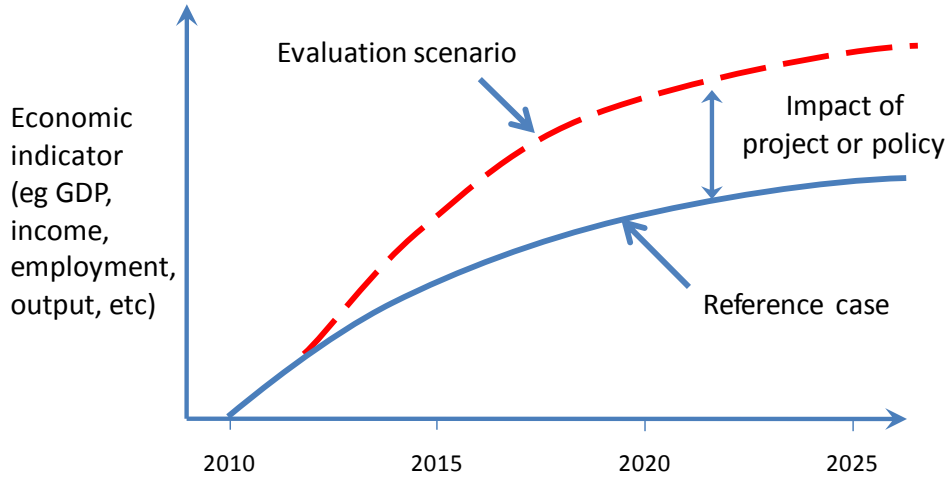
Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

In applications of the *Tasman Global* model, a reference case simulation forms a 'business-as-usual' basis with which to compare the results of various simulations. The reference case provides projections of growth in the absence of the changes to be examined. The impact of the change to be examined is then simulated and the results interpreted as deviations from the reference case. (See Figure C1).

The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the latest Global Trade Analysis Project (GTAP) database which was released in 2008. This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities.

Figure C1 **Illustrative scenario analysis using Tasman Global**



Source: ACIL Tasman

The GTAP model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

Tasman Global builds on the GTAP model's equation structure and database by adding the following important features:

- dynamics (including detailed population and labour market dynamics)
- detailed technology representation within key industries (such as electricity generation and iron and steel production)
- disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG
- the ability to repatriate labour and capital income
- a detailed emissions accounting abatement framework
- explicit representation of the states and territories of Australia
- the capacity to explicitly represent multiple regions within states and territories of Australia.

Nominally the *Tasman Global* database divides the world economy into 120 regions (112 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Tasman regularly models projects or policies at the statistical division (SD) level, as defined by the ABS, but finer regional detail has been modelled when warranted.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 70 industries (Table C1). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final

demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, diesel and iron and steel sectors are modelled using a 'technology bundle' approach. With this approach, different known production methods are used to generate a homogeneous output for the 'technology bundle' industry. For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which have their own cost structure.

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

Table C1 **Sectors in the *Tasman Global* database**

	Sector		Sector
1	Paddy rice	36	Paper products, publishing
2	Wheat	37	Diesel (incl. nonconventional diesel)
3	Cereal grains nec	38	Other petroleum, coal products
4	Vegetables, fruit, nuts	39	Chemical, rubber, plastic products
5	Oil seeds	40	Iron ore
6	Sugar cane, sugar beef	41	Bauxite
7	Plant- based fibres	42	Mineral products nec
8	Crops nec	43	Ferrous metals
9	Bovine cattle, sheep, goats, horses	44	Alumina
10	Animal products nec	45	Primary aluminium
11	Raw milk	46	Metals nec
12	Wool, silk worm cocoons	47	Metal products
13	Forestry	48	Motor vehicle and parts
14	Fishing	49	Transport equipment nec
15	Brown coal	50	Electronic equipment
16	Black coal	51	Machinery and equipment nec
17	Oil	52	Manufactures nec
18	Liquefied natural gas (LNG)	53	Electricity generation
19	Other natural gas	54	Electricity transmission and distribution
20	Minerals nec	55	Gas manufacture, distribution
21	Bovine meat products	56	Water
22	Meat products nec	57	Construction
23	Vegetables oils and fats	58	Trade
24	Dairy products	59	Road transport
25	Processed rice	60	Rail and pipeline transport
26	Sugar	61	Water transport
27	Food products nec	62	Air transport
28	Wine **a**	63	Transport nec
29	Beer **a**	64	Communication
30	Spirits and RTDs **a**	65	Financial services nec
31	Other beverages and tobacco products **a**	66	Insurance
32	Textiles	67	Business services nec
33	Wearing apparel	68	Recreational and other services
34	Leather products	69	Public Administration, Defence, Education, Health
35	Wood products	70	Dwellings

a A detailed beverage database and model structure covering 52+ alcoholic and non-alcoholic sub-categories and alternative sales channels is also available.
Note: nec = not elsewhere classified

Detailed energy sector and linkage to *PowerMark* and *GasMark*

Tasman Global contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to bottom-up models such as ACIL Tasman's *GasMark* and *PowerMark* models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies twelve different electricity generation technologies:

5. brown coal (with and without carbon capture and storage)
6. black coal (with and without carbon capture and storage)
7. petroleum
8. base load gas (with and without carbon capture and storage)
9. peak load gas
10. hydro
11. geothermal
12. nuclear
13. biomass
14. wind
15. solar
16. other renewables.

To enable more accurate linking to *PowerMark* the generation cost of each technology is assumed to be equal to their long run marginal cost (LRMC) while the sales price in each region is matched to the average annual dispatch weighted prices projected by *PowerMark* – with any difference being returned as an economic rent to electricity generators. This representation enables the highly detailed market based projections from *PowerMark* to be incorporated as accurately as possible into *Tasman Global*.

Factors of production

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates through investment (less depreciation) in each period. Land is used only in agriculture industries and is fixed in each region. *Tasman Global* explicitly models natural resource inputs as a sector specific factor of production in resource based sectors (coal mining, oil and gas extraction, other mining, forestry and fishing).

Population growth and labour supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for the 112 international regions and for the 8 states and territories of Australia represented in the *Tasman Global* database is projected using ACIL Tasman's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.

For each of the 120 regions in *Tasman Global*, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Tasman's demographics module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

The Australian labour market

Tasman Global has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations
- changes to participation rates (or average hours worked) due to changes in real wages
- changes to unemployment rates due to changes in labour demand
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour; and

- limited labour mobility between states.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms who hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state rise relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three stage process:

1. labour makes itself available to the workforce based on movements in the real wage and the unemployment rate
2. labour chooses between occupations in a state based on relative real wages within the state; and
3. labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

Greenhouse gas emissions

The model has a detailed greenhouse gas emissions accounting, trading and abatement framework that tracks the status of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6). Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled but can be accounted for in policy analysis.

The greenhouse modelling framework not only allows accounting of changes in greenhouse gas emissions, but also allows various policy responses such as carbon taxes or emissions trading to be employed and assessed within a consistent framework. For example, the model can be used to measure the economic and emission impacts of a fixed emissions penalty in single or multiple regions whether trading is allowed or not. Or, it can used to model the

emissions penalty required to achieve a desired cut in emissions based on various trading and taxation criteria.

Model results

Tasman Global solves equations covering industry sales and consumption, private consumption, government consumption, investment and trade. The model therefore produces detailed microeconomic results, such as:

- output by industry
- employment by industry; and
- industry imports and exports.

Tasman Global also produces a full range of macroeconomic results, for each Australian and international region including:

- total economic output – i.e. gross domestic product (GDP), gross state product (GSP) and gross regional product (GRP)
- total employment
- gross national product (GNP)
- private consumption
- public consumption
- investment and savings
- imports; and
- exports.

D Reference Scenario assumptions

As was outlined in section C.1, the modelling for this project involved the development of a number of alternative scenarios simulated in *Tasman Global*. The Reference or Business As Usual (BAU) Scenario attempts to establish a scenario where no further CSG development drilling is undertaken in Queensland and NSW.

This Chapter discusses a range of key macro- and micro-economic assumptions that underlie the Reference Scenario.

D.1.1 Macroeconomic growth

Projections for a range of key variables underlie the future growth of Australia's economy in *Tasman Global*. These include assumptions relating to projections of:

- changes in population – including changes in the number of people of working age (15 years old and over)
- changes in workforce participation rates
- changes in the unemployment rate
- changes in average hours worked
- growth in labour productivity – defined here as the average output per hour worked.

These factors underlie the projected change in Australian real GDP for the scenarios. The projection of each of these elements for the Base Case scenario is discussed in the following sections.

It is these base case projections that form the basis for the other policy scenarios.

D.1.2 Population growth

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for 114 international regions and Australia represented in the *Tasman Global* database has been projected using ACIL Tasman's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time. It is an important tool for determining the changes in regional labour supply and total population over the projection period.

For each of the 120 regions, the demographic model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in

participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc). Participation rates are a function of life expectancy as well expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Global population growth

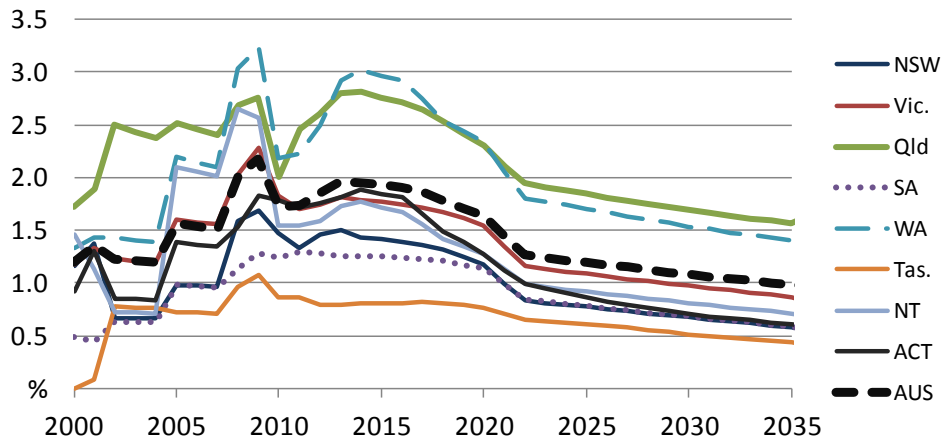
For this analysis, the global population is projected to increase over the projection period by 0.83 per cent a year, increasing the global population from around 6.7 billion in 2008 to 8.03 billion in 2030. Most of this growth occurs in the next decade, with the average annual growth projected to be 0.95 per cent a year to 2020, falling to 0.67 per cent a year between 2020 and 2030.

The slowing rate of growth is due to continuing declines in fertility rates across developing countries coupled with ageing population effects across developed economies and some developing economies such as China. For example, Japan's population began declining in the 2009 calendar year while the population of the European Union over the period is at first projected to increase moderately before falling back to current levels around 2022.

Australian population growth

The total Australian population is projected to grow to 31.8 million by 2034-35 with Queensland reaching 7.6 million. The annual population growth rates by state are presented in Figure D1. Key factors underlying the Australian population projection are summarised in Table D1.

Figure D1 **Reference Scenario projected regional population growth (per cent, year on year)**



Note: All years are financial years ending June 30.

Source: ACIL Tasman projections

Table D1 **Key Australian demographic projections and assumptions, all scenarios**

	Units	2007-08	2009-10	2014-15	2029-30	2034-35
Australia						
Population	Million	21.50	22.34	24.53	30.18	31.75
Working age population (aged 15+)	Million	17.37	18.12	19.99	24.78	26.27
Workforce	Million	11.38	11.90	13.19	15.99	16.78
Average participation rate (people aged 15+)	%	65.5	65.7	66.0	64.5	63.9
Life expectancy at birth						
– Males	Years	79.0	80.1	81.5	84.5	85.4
– Females	Years	83.5	84.4	85.5	87.8	88.6
Average fertility rate	Children per female	1.88	1.93	1.91	1.90	1.90
Net overseas migration	Thousand	277.3	215.6	281.7	152.0	152.0

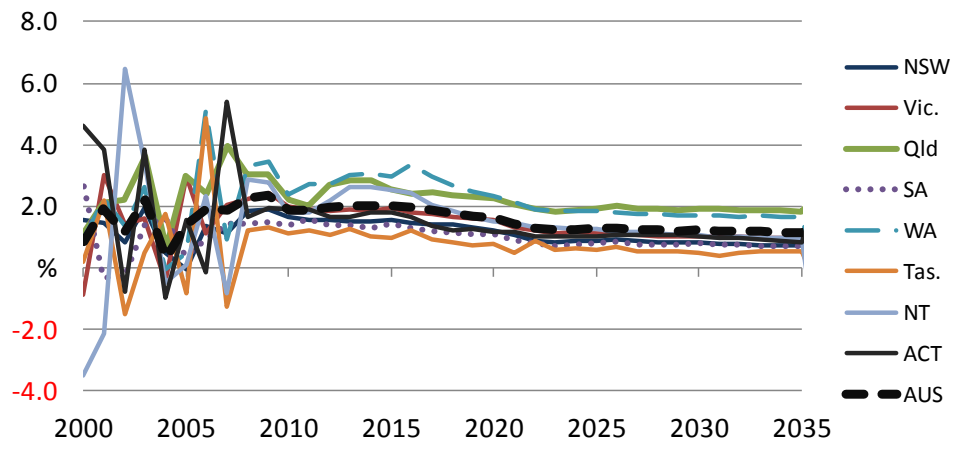
Note: All years are financial years ending June 30.

Data source: ACIL Tasman

D.1.3 Labour supply

Labour supply is derived from the combination of the projected population by age by gender and the projected participation rates by age by gender. Over the projection period labour supply in most regions is projected to grow more slowly than total population as a result of the ageing population. The working age population growth projections for Australian regions used for this analysis are shown in Figure D2 with the projected average annual participation rates presented in Figure D3.

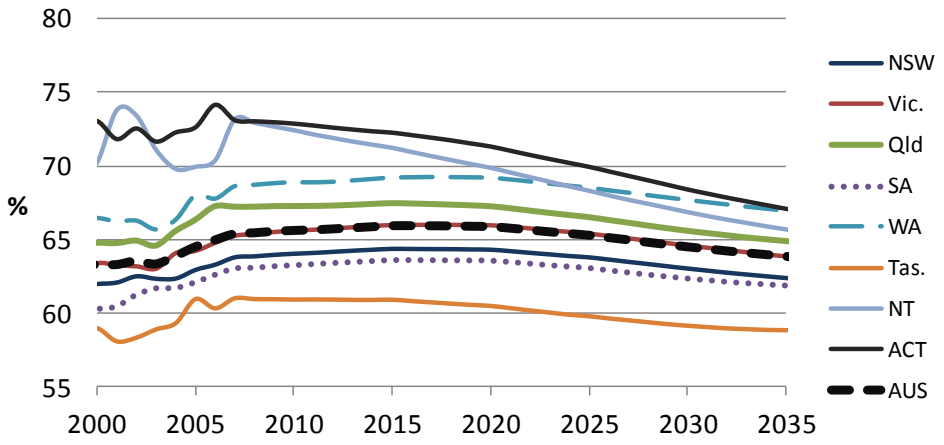
Figure D2 **Reference Scenario projected growth in Australia's regional working age population, (per cent, year on year)**



Notes: All years are financial years ending June 30. Working age population is defined as people aged 15+. The effect of retirement on the available workforce (or labour supply) is captured through the age specific participation rates.

Source: ACIL Tasman projections.

Figure D3 **Reference Scenario projected average participation rates by Australian region**



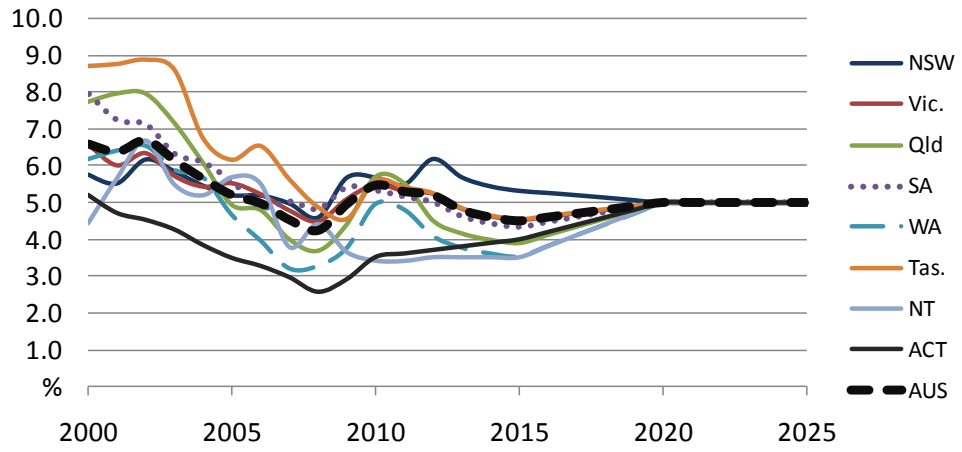
Source: Tasman Global projections

D.1.4 Unemployment

In addition to tracking the available workforce through the changes in population demographics and participation rates, *Tasman Global* also tracks unemployment rates. Unemployment and participation rates are largely interchangeable in affecting the number of people available for work in the model. The components are separately identified to allow a better representation of the labour market. In general, when unemployment is high, increases in labour demand can largely be supplied by reducing the unemployment rate but when unemployment is low, increases in labour demand will largely be met by increasing participation rates (and/or hours worked). Changes in participation rates in *Tasman Global* are driven by changes in the real wages offered by employers.

Figure D4 presents the assumed Australia wide unemployment rates used in this analysis. Near term assumptions are taken from the Treasury 2011-12 Budget Papers with the unemployment rate across Australia assumed to average 4.5 per cent by 2014-5, then trending toward an average of 5.0 per cent by 2019-20.

Figure D4 **Reference Scenario Historical and assumed average unemployment rates**



Note: All years are financial years ending June 30.

Source: ACIL Tasman projections.

D.1.5 Labour productivity growth

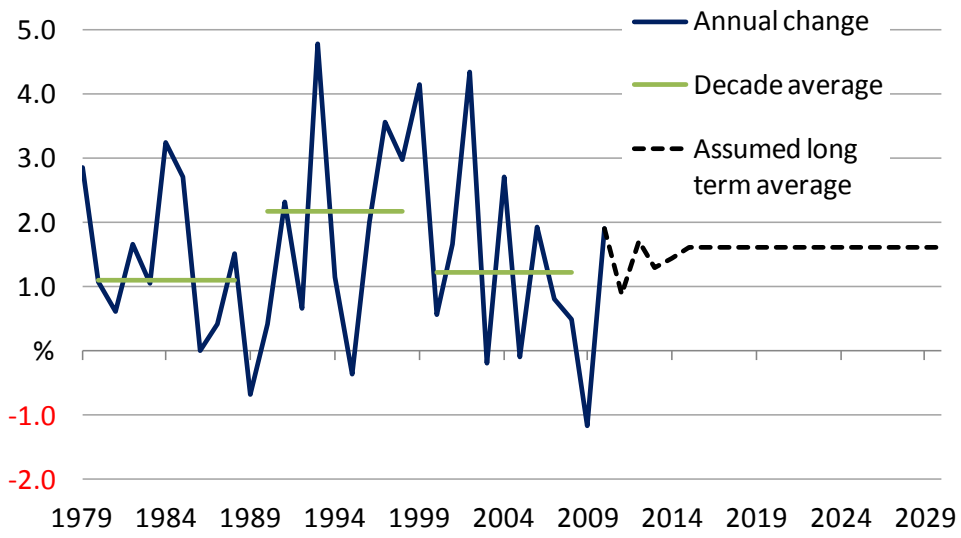
Labour productivity is a measure of the quantity of goods and services per unit of time worked. Growth in labour productivity is highly variable on a year to year basis and is influenced by many developments in the economy, including changes in capital intensity and the composition of the work force.[22]

Over the past 30 years Australian labour productivity growth has averaged 1.75 per cent a year and 1.8 per cent over the past 40 years.[23] Near term labour productivity growth is based on projections of labour supply and real GDP. The annual growth in Australian labour productivity is assumed to average 1.6 per cent a year in the Reference Scenario (Figure D5).

[22] Treasury (2008), *Australia's Low Pollution Future: The Economics of Climate Change Mitigation*, www.climatechange.gov.au.

[23] Treasury. (2010). *Intergenerational Report 2010: Australia to 2050: future challenges.* Canberra: Commonwealth of Australia.

Figure D5 **Reference Scenario historical and assumed Australian average labour productivity growth (per cent change, year on year)**



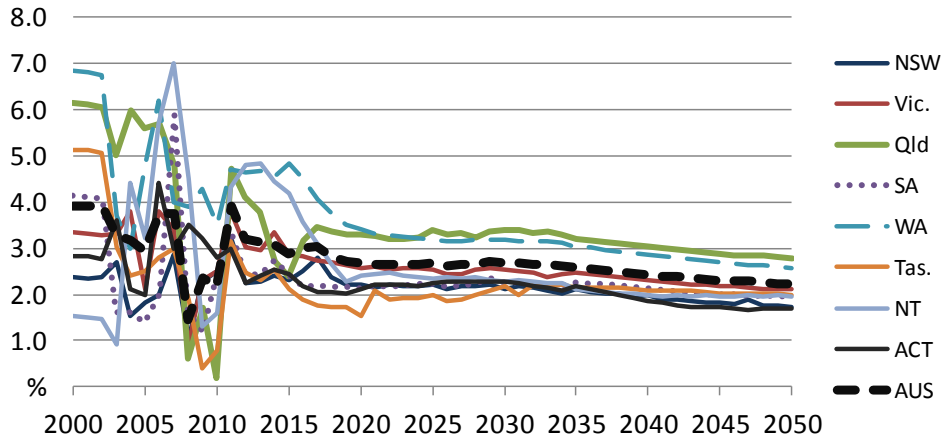
Note: All years are financial years ending June 30.

Source: ABS catalogue number 5206.0 and ACIL Tasman projections.

D.1.6 Real economic output growth

In *Tasman Global*, the Reference Scenario growth in economic output nationally (GDP) is based on a mixture of historical data, near-term projections by the Commonwealth Treasury and medium-long run projections. Australian historical GDP growth to 2010-11 is sourced from the ABS national accounts, while historical growth for the rest of the World is sourced from the IMF World Economic Outlook. Near term projections for Australia as a whole are sourced from the latest Commonwealth Budget papers. The projections for the rest of the World (to 2016) are sourced from the IMF World Economic Outlook (November 2011). Projections for economic growth past these points are determined using the previously discussed projections of labour supply and labour productivity. The projected real economic growth used for the Reference Scenario in this analysis is shown in Figure D6.

Figure D6 **Reference Scenario Australian real GDP growth, (per cent, year on year)**



Note: All years are financial years ending June 30.

Source: ACIL Tasman projections.

Based on these economic growth assumptions, the level of Australia's real GDP is projected to rise from $1.40 trillion[24] in 2010-11 to $2.74 trillion in 2034-35 under the Reference Scenario, with Queensland's real GSP rising from $266.6 billion in 2010-11 to $588.7 billion in 2034-35.

D.1.7 Sectoral efficiency assumptions

The macroeconomic assumptions presented in Section D.1.1 imply an average annual change in productivity. Assumptions need to be made about the way these productivity changes are distributed across inputs and across industries. A range of specific assumptions were made with respect to certain inputs in certain industries with the remaining productivity changes distributed using the relative sectoral productivity growth rates presented in Treasury (2008).

More specifically:

- The own-use of gas by LNG facilities was taken from ACIL Tasman estimates and are consistent with the *GasMark* assumptions in this analysis.
- The annual average use of fossil fuels by electricity generation technology by state and the annual average dispatch weighted price by technology by state have been taken from *PowerMark* and *PowerMark LT* and are consistent with the forecasts in this analysis across all scenarios.
- Efficiencies of certain physical transformation activities were taken to be fixed (which in some cases may be an oversimplification of the underlying chemical processes). These include the amount of bauxite per unit of

[24] Where trillion is defined as $1x10^{12}$ as per the US convention. Billion is defined as $1x10^{9}$.

alumina; alumina per unit of primary aluminium; iron ore per unit of iron and steel; and oil per unit of petroleum products.

- An autonomous energy efficiency improvement (AEEI) of 0.5 per cent per year was imposed for all other energy demand. This rate is consistent with many other projection exercises including those commissioned by the AGO and DCCEE over the past decade or so.
- All remaining productivity improvements required to meet the assumed growth in real GDP were solved endogenously and distributed across all (non-specified) intermediate inputs based on the relative[25] sectoral labour growth assumptions presented in Treasury (2008) and reproduced in Table D2. The relative efficiency of capital by sector was assumed to be the same as labour. Land was assumed to have twice the relative efficiency of labour while all other intermediates (primarily non-energy given the AEEI assumption) were assumed to have half the relative productivity improvements compared to labour.

Table D2 **Sectoral labour productivity distribution**

Industry	US	EU25	China	FSU	Japan	India	Canada	Australia	Indonesia	Southern Africa	Other SE Asia	OPEC	Rest of world
Coal mining	1	1	1.3	0.5	0.5	1.5	1	1	1.4	1	1	1	1
Oil mining	1	1	0.75	0.5	0.5	1	1	1	0.75	1	0.75	1	1
Gas mining	1	1	0.75	0.5	0.5	1	1	1.4	0.75	1	0.75	1	1
Petroleum and coal	1	1	0.75	0.5	0.5	1	1	1.4	0.75	1	0.75	1	1
Electricity	1.25	1	0.75	0.5	0.5	0.5	1.25	1.4	0.75	1	0.75	1	1
Mining and chemicals	1.25	1	1	1	1.5	1	1.25	0.8	1	1	1	1	1
Manufacturing	1.25	1.5	1	1	1.5	1	1.25	1	1	1	1	1	1
Road transport	1.5	2	2	1	2	2	1.5	2	2	2	2	2	2
Water and air transport	0.75	1	0.5	0.5	1	0.5	0.75	1.4	0.5	1	0.5	1	1
Crops	0.75	1.5	1	1	0.5	0.5	0.75	1	0.75	1	0.5	1	1
Livestock	0.75	1.5	1	1	0.5	0.5	0.75	1	0.5	1	0.5	1	1
Fishing and forestry	0.75	1.5	1	1	0.5	0.5	0.75	2	0.5	1	0.5	1	1
Food	1.4	1.5	1	1	1	1	1.4	1	0.5	1	0.5	1	1
Services	1	1	0.75	0.75	1	0.75	1	1	0.75	1	0.75	1	1

Data source: Treasury (2008) section B.5.3.

[25] In *Tasman Global*, as in the Treasury (2008) modelling, the 'relative' productivity is distributed according to a power function. If we let a_{ij} be the relative distribution across input i and industry j of the efficiency improvement e, then it is distributed according to $e^{a_{ij}}$.

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