ACIL ALLEN

2 June 2021

Report to Energy Estate

Economic impacts of the Broken Hill A-CAES

About ACIL Allen

ACIL Allen is a leading independent economics, policy and strategy advisory firm, dedicated to helping clients solve complex issues.

Our purpose is to help clients make informed decisions about complex economic and public policy issues.

Our vision is to be Australia's most trusted economics, policy and strategy advisory firm. We are committed and passionate about providing rigorous independent advice that contributes to a better world.

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Introduction 1

Hydrostor inc., in conjunction with Energy Estate, are proposing to develop a large-scale, Advanced Compressed Air Energy Storage (A-CAES) project in Broken Hill, New South Wales (the Project). To understand the economic impacts that the development of the Project will provide to the local and state economies, Energy Estate have commissioned ACIL Allen Consulting (ACIL Allen) to conduct an economic impact assessment of the Project. This report sets out the findings of this assessment.

1.1 Data sources

Data describing the costs of the construction and operation phases of the development of the A-CAES project described in this report, and the expected revenues and taxation generated by the Project was sourced from Energy Estate. This includes estimations of the value of the costs and where this spending will occur.

The market modelling component of the analysis has been previously undertaken using ACIL Allen's in-house model PowerMark. Gas market projections and prices are derived from GasMark. The MLF and network curtailment modelling has been undertaken using PowerWorld. The results of this modelling have been used in the modelling in this report.

All other data regarding the description of the economy and key economic variables has been sourced from publicly available sources. The primary source of data is the Australian Government including the Australian Bureau of Statistics and the Department of Employment. Data for this report has been collected for the following statistical areas which have been referred to as:

— **Broken Hill** – as defined by the boundaries of the Broken Hill SA2

— **New South Wales** – as defined by the state of New South Wales.

1.2 Major assumptions

When reading and interpreting this report, a number of key assumptions should be taken into consideration:

— all company data is based on indicative estimates as of December 2020

— all data is presented in real 2021 financial year (FY) Australian dollars

— the term *Project* refers to both the construction and asset operations phases of constructing and operating the A-CAES

— all operations employment figures exclude temporary employees associated with activities such as planned shutdown maintenance and ad hoc scopes of work

— *life of the project* refers to the three years of construction activities beginning in financial year 2020-21 and ending in 2023-24. It also refers to the first 25 years of operations from 2024-25 to 2048-49 inclusive. In total, the life of the project is considered to be 28 years. It should be noted that a 25 year operating life is used for modelling, Energy Estate considers that operating life would be at least 50 years.

1.3 Economic modelling

Economic modelling was undertaken using Computable General Equilibrium (CGE) modelling. For this analysis, the ACIL Allen *Tasman Global* CGE model was used to estimate the impacts of the construction and the operation activities associated with the Project.

Details regarding the *Tasman Global* model is presented in Appendix A.

1.4 Glossary of key economic terms

All economic impact results are presented in terms of the direct and the indirect (or flow on) impact of the proposed activities. This indirect impact is often referred to in other forums as the multiplier effect. This indirect impact embodies the effect of changes in demands from other industries which is caused when the initial impact from the construction and operations of a new project leads to more spending in the economy which creates more income and taxes which leads to further spending and so on.

Direct impacts

Refers to the direct impacts arising from activities directly associated with the A-CAES. For example, the value of the wages paid by Hydrostor during operations constitute the direct income effect.

Interindustry impacts

Refers to economic impacts that arise purely from the purchase of goods and services during construction and/or operations. This includes the impacts arising from the direct purchases made by Hydrostor and those arising from the indirect effects described in Appendix A.

Personal consumption impacts

Refers to the economic impacts that arise from the spending on goods and services of those deriving additional personal income from the construction and/or production activities. This includes the direct effects and the indirect effects described in Appendix A.

Output

A measure of aggregated production of goods and services.

The sum of the value of production of all industries within the economy. Sometimes confused with Gross Domestic Product, output should not be used as an estimate of economic growth as it overestimates growth in the economy by including the production of goods and services for use as intermediate inputs in the production process.

Gross Domestic Product

A measure of the size of the national economy

Gross Domestic Product is a measure of the value of the production of an economy over a period of time (typically a year). It measures the value of final consumption in the economy and thus does not include intermediate use of goods and services in the production process. It also represents the sum of the value added at each stage of the production process. At a state level it is referred to as Gross State Product and at a regional level it is referred to as Gross Regional Product.

Income

A measure of the personal income of residents in an economy arising from the use of their personal labour. Income is accrued through wages and salaries and as mixed income where mixed income is returns to unincorporated enterprises (often small businesses) owned by households

Although changes in real economic output are useful measures for estimating how much the output of the economy may change due to any new economic activities, changes in income are also important as they provide an indication of the change in personal welfare of the residents of a region through their ability to purchase goods and services.

Job years

Job creation over time is measured in job years when jobs are summed over more than one year. A job year is employment of one person for one year. One job existing for three years would be expressed as three job years.

A single year of job creation is referred to as employment.

Real and nominal dollars

Nominal dollars are dollars that are expressed in the actual dollars that are spent or earned in each year, including inflation effects. Real dollars have been adjusted to exclude any inflationary effects and therefore allow better comparison of economic impacts in different years. Over time, price inflation erodes the purchasing power of a dollar thereby making the comparison of a dollar of income in 2040 with a dollar of income in 2021 invalid. Adjusting nominal dollars into real dollars overcomes this problem.

Acronyms

This report uses acronyms. These are presented in **Table 1.1**.

Table 1.1 Glossary of key terms and list of acronyms

Acronym	Definition
$	Australian dollars
%	Per cent
Aboriginal	Aboriginal and Torres Strait Islander people
FTE	Full time equivalent. One FTE is the equivalent of one person working for one year on a full time basis

1.5 Report structure

This report describes the economic impacts of the development of the Project on the economy of the local area of Broken Hill, and New South Wales.

Chapter 2 provides a socio-economic profile of the Broken Hill economy. Chapter 3 describes the proposed project including its spending in construction and operation, its employment, and the generation of taxation revenue. Chapter 4 describes the direct impact and the total economic impact of the project using economic modelling and other economic analysis.

Regional profile 2

2.1 Regional economic profile

The Broken Hill region is where the Project will be constructed and operated. It is the largest regional centre in western half of New South Wales. Land in the region was initially used for grazing with mining operations (including silver, lead and zinc) significantly increasing the population of Broken Hill. Closure and consolidation of mining operations over time has seen the population fall gradually from around 31,000 people in 1950 to about 24,000 in 1986 and to 17,479 in 2019. While mining is still a significant employer in the town, it is also a significant provider of services to the broader region (including retail, health, education and tourism).

CBH Resources[1] undertakes mining at the underground Rasp mine with a surface processing facility, with annual average metal production of 30,000 tonnes of zinc metal in concentrate, 20,000 tonnes of lead metal in concentrate, and over 1.0 million ounces of silver in the lead concentrate. Perilya also undertakes lead, zinc and silver mining in Broken Hill, while mineral processing is performed at the Bemax Mineral Separation Plant.

2.2 Population characteristics

As of 30th June 2019, the estimated resident population (ERP) of Broken Hill was 17,479, or 0.22 per cent of the population of New South Wales.

Table 2.1 shows the population of Broken Hill over the past decade along with the annual growth rates. Since 2009, the population has fallen by 10 per cent. In contrast, the population of New South Wales as a whole increased by 14.7 per cent.

Table 2.2 presents the age profile of the 2019 populations of Broken Hill and New South Wales. As can be seen, the Broken Hill population is noticeably older than the average New South Wales population. The median age of males and females in Broken Hill is 44.2 and 45.8, respectively, compared to 36.7 and 38.4 in New South Wales as a whole.

[1] https://www.cbhresources.com.au/operations/rasp-mine/

Table 2.1 Estimated residential population and annual growth, 2009-2019

Year	Broken Hill	Annual growth	New South Wales	Annual growth	Broken Hill share of New South Wales
June 30	People	YOY % change	People	YOY % change	%
2009	19,421		7,053,755		0.28%
2010	19,267	–0.79	7,144,292	1.28	0.27%
2011	19,151	–0.60	7,218,529	1.04	0.27%
2012	18,985	–0.87	7,308,205	1.24	0.26%
2013	18,802	–0.96	7,409,082	1.38	0.25%
2014	18,627	–0.93	7,517,195	1.46	0.25%
2015	18,360	–1.43	7,627,418	1.47	0.24%
2016	18,114	–1.34	7,732,858	1.38	0.23%
2017	17,883	–1.28	7,867,936	1.75	0.23%
2018	17,715	–0.94	7,980,168	1.43	0.22%
2019	17,479	–1.33	8,089,817	1.37	0.22%

Source: ACIL Allen based on Australian Bureau of Statistics, Regional Population Growth, Australia, catalogue number 3218.0

Table 2.2 Proportion of population by age bracket (percent), 2019

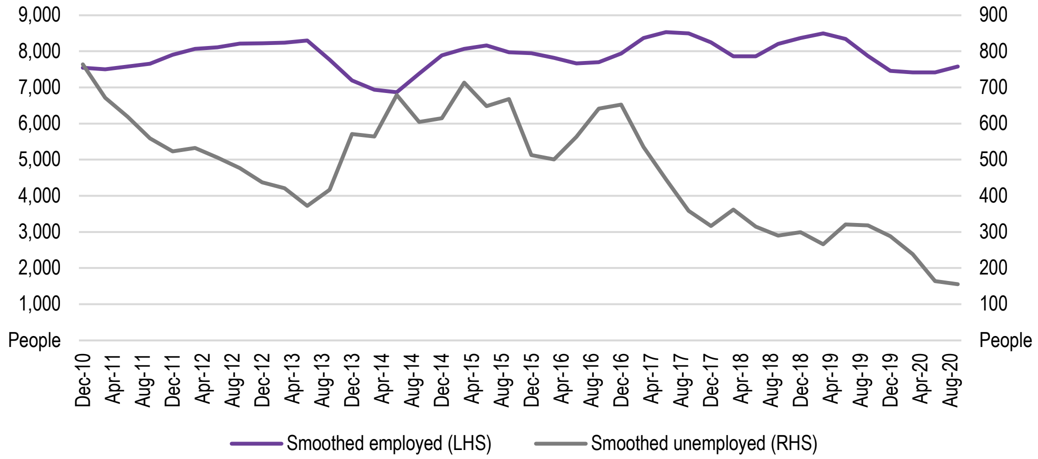
Age group	Broken Hill		New South Wales	
	Males	Females	Males	Females
0-9	11.2	11.3	12.9	12.1
10-19	11.5	10.4	12.4	11.5
20-29	12.0	11.3	14.9	14.1
30-39	11.5	11.4	14.5	14.5
40-49	11.0	10.8	12.7	12.8
50-59	13.9	13.7	11.8	12.2
60-69	14.3	13.4	10.2	10.6
70-79	9.5	10.1	7.0	7.4
80+	5.1	7.6	3.6	4.9
Total	100.0	100.0	100.0	100.0

Source: ACIL Allen based on Australian Bureau of Statistics, Regional Population Growth, Australia, catalogue number 3218.0

2.3 Labour force information

The workforce of the Broken Hill region is small, comprising between 7,500 and 9,000 people over the past decade. As shown in **Figure 2.1**, despite the declining population, the total number of employed people has broadly stayed around an average of 7,900 people over the past decade. This is because the number of unemployed people has fallen considerably from 764 people in December 2010 (a 9.2 per cent unemployment rate), to just 155 people (2.0 per cent) in September 2020. In conjunction with the declining population, this implies that unemployed people and their families have largely left the city over the past decade.

Figure 2.1 Number of employed and unemployed people, Broken Hill



Note:

Source: ACIL Allen based on National Skills, Commission, Small Area Labour Markets (SALM), September Quarter 2020.

For comparison, over the same time period, the total workforce of New South Wales increased from approximately 3.3 million to 4.3 million, with the number of unemployed people increasing from approximately 168,000 people in December 2010 (a 5.2 per cent unemployment rate) to approximately 243,000 people (5.7 per cent) in September 2020.

2.4 Gross Regional Product

In 2019-20, the Gross Domestic Product (GDP) of New South Wales was an estimated $625.3 billion, $1.0 billion of which was generated by the Broken Hill economy (0.17 per cent). On a per capita basis, this implies that the Broken Hill economy generated approximately 20 per cent less economic output compared to New South Wales. However, when put on a per worker basis, it is broadly comparable.

The major industries in these regions in terms of economic value and employment are the agriculture industry, in particular the production of beef cattle, and the mining industry, including copper, silver and gold mining.

2.5 Building approvals

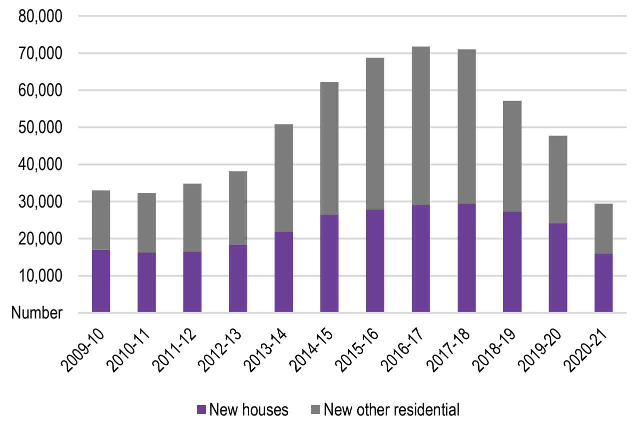
Figure 2.2 presents the number and average value of new building approvals in Broken Hill and New South Wales. As can be seen, there has been a low level of new building approval activity, with less than 50 new houses and five other residential approvals over the past five years. With such low numbers of approvals, the average value is highly volatile, but has been around 20 per cent below the New South Wales average over the past five years.

Table 2.3 and **Figure 2.3** present the value of total building approvals in Broken Hill and New South Wales since 2009-10. Compared to the Broken Hill's share of New South Wales population, its share of the value of building approvals is less than a third. This is most likely driven by the declining population.

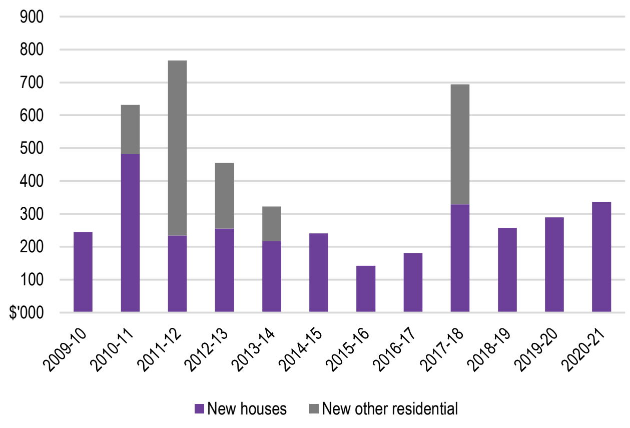
Figure 2.2 Number and average value of new building approvals

A. Number of new approvals: Broken Hill

B. Number of new approvals: New South Wales



C. Average value of new approvals: Broken Hill



D. Average value of new approvals: New South Wales

Note: 2020-21 year to date.

Source: ACIL Allen based on Australian Bureau of Statistics, Building Approvals, Australia, catalogue number 8731.0.

Table 2.3 Value of total building approvals

	Broken Hill			New South Wales			Broken Hill share of New South Wales
	Residential	Non-residential	Total	Non-residential	Residential	Total	
Financial year	$'000	$'000	$'000	$'000	$'000	$'000	%
2009-10	6,432	23,751	30,183	10,185,415	10,762,556	20,947,971	0.14%
2010-11	11,025	8,551	19,576	10,652,464	6,375,261	17,027,725	0.11%
2011-12	8,172	47,597	55,769	11,227,363	7,661,864	18,889,227	0.30%
2012-13	6,832	1,937	8,770	11,886,331	7,811,131	19,697,461	0.04%
2013-14	9,568	9,931	19,499	15,476,473	11,457,974	26,934,447	0.07%
2014-15	4,451	9,111	13,562	19,591,569	9,300,060	28,891,629	0.05%
2015-16	3,378	11,800	15,178	23,307,920	9,979,701	33,287,621	0.05%
2016-17	2,785	4,830	7,614	25,315,800	14,325,899	39,641,699	0.02%
2017-18	8,260	46,747	55,007	26,229,900	13,814,556	40,044,455	0.14%
2018-19	6,971	15,933	22,904	21,913,010	15,882,187	37,795,196	0.06%
2019-20	3,551	15,132	18,683	18,756,156	17,250,242	36,006,398	0.05%
2020-21 YTD	1,216	4,827	6,042	12,060,751	9,686,898	21,747,649	0.03%

Note: 2020-21 year to date.

Source: ACIL Allen based on Australian Bureau of Statistics, Building Approvals, Australia, catalogue number 8731.0.

Figure 2.3 Value of total building approvals

A. Number of new approvals: Broken Hill

B. Number of new approvals: New South Wales

Note: 2020-21 year to date.

Source: ACIL Allen based on Australian Bureau of Statistics, Building Approvals, Australia, catalogue number 8731.0.

The Broken Hill A-CAES project 3

This chapter describes the key ownership, production, workforce, and financial characteristics of the proposed Project.

3.1 Construction and operation spending

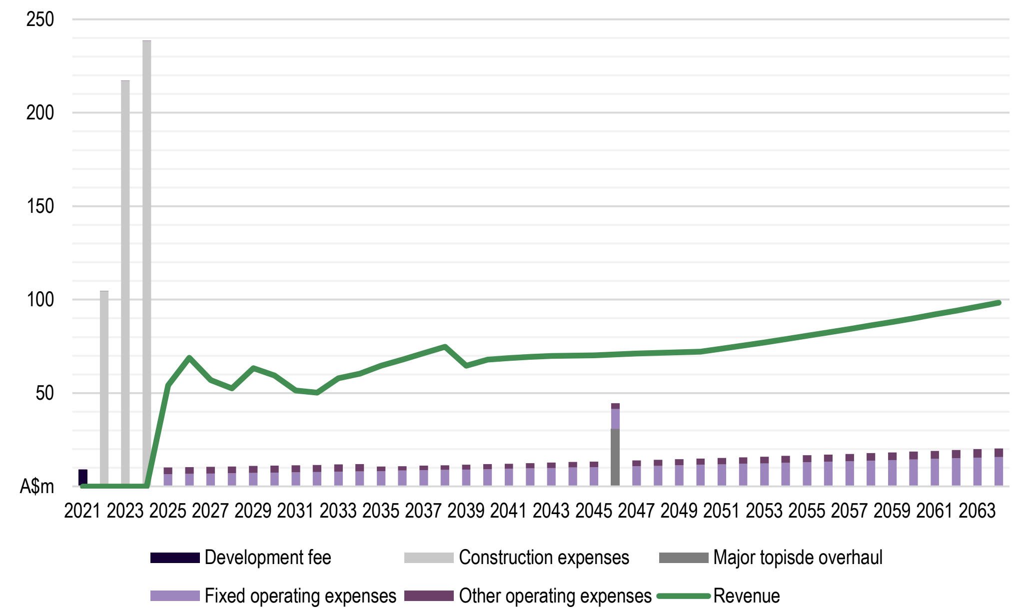
Construction of the Project is expected to take three years beginning in 2021-22 and ending in 2023-24. Operations of the project is expected to commence in 2024-25 and last for 40 years through to 2063-64.

It is estimated that the Project will require around $560 million of capital expenditure (including labour costs and contingency) over the period from 2021-22 to 2023-24. This includes the costs to undertake capital expenditure studies, and initial construction of the Project, but does not include any ongoing capital expenditure to sustain the project, if required. Expenditure in the first year is expected to be approximately $104 million, ramping up to $217 and $239 million in the second and third years, respectively (**Figure 3.1**). Based on current plans, a further $39 million of capital is expected to be expended in 2045-46 for a major topside overhaul. Including a $9 million development fee in 2020-21, the total capital expenditure of the Project is estimated to be $600 million.

The Project has a high Australian content during the three year construction phase. It is estimated that there will be total spending of $562 million in Australia to construct the Project (including labour) which is equivalent to a local content of 93 per cent. It is estimated that $556 million of this expenditure will take place in New South Wales including $239 million (or 40 per cent) in the local Broken Hill region.

Operation of the Project will begin in 2024-25. Not including electricity purchases, over the period to 2050 there will be $314 million of operational spending (or $12 million a year), with a total of $547 million over the full operational life of the Project (or an average of $14 million of spending a year). Just over 40 per cent of the total operational expenditure will be spent on directly on labour with insurances, consumables and parts comprising a further 16 per cent. A further $311 million is expected to be spent on electricity purchases.

Figure 3.1 Broken Hill A-CAES project: construction and operation costs ($ million)



Note: Excludes electricity purchases.
Source: ACIL Allen from Verdant data

There will be purchases of goods and services from the local Broken Hill city to operate the Project. Besides labour, examples of local purchases include maintenance activities, and third party transport and logistics services. In total, it is expected that 53 per cent of all operations expenditure (excluding taxes) over the operational life of the project will be purchases from the local Broken Hill region. This is equivalent to a total of $457 million over 40 years or $11.4 million a year as illustrated in **Table 3.1**.

The Project currently projects that nearly $826 million or 96 per cent of the total operational expenditure (excluding taxes) over the life of the Project will be spent on goods and services purchased from New South Wales. This is equivalent to an annual average of around $20.7 million a year.

An average of $20.8 million a year will be spent in Australia on goods and services. Over the 40 operational life of the Project, this is equivalent to total spending of over $830 million and represents an Australian content share of 97 per cent.

Table 3.1 Local content spending: Broken Hill A-CAES Project: $ million and %

	Local Broken Hill region	New South Wales	Australia	Overseas
Construction total ($M)	238.7	556.2	562.4	37.5
Local content share (%)	39.8	92.7	93.7	6.3
Operation total ($M)	457.1	826.2	830.0	27.2
Operation a year ($M)	11.4	20.7	20.8	0.7
Local content share (%)	53.3	96.4	96.8	3.2

Source: ACIL Allen from Energy Estate data

3.2 Project workforce profile

The Project will require 780 full time equivalent job years over three years or an average of 260 full time equivalent workers a year. The peak construction employment will occur in the second year of construction when 350 full time equivalent workers will be employed on the site.

Many of the workers employed to construct the Project will be sourced from the local Broken Hill region or from the broader New South Wales workforce. In particular, it is estimated that 30 per cent of the construction workforce will be sourced from the local region, with a further 53 per cent of employees being either fly-in, fly-out (FIFO) or drive-in, drive-out (DIDO) from elsewhere in New South Wales. In total, it is expected that 234 full time equivalent job years will be sourced from the local Broken Hill region and a total of 650 full time equivalent job years from New South Wales as a whole.

Economic impacts 4

4.1 Measures of macro-economic impacts

One of the most commonly quoted macroeconomic variables at a national level is real GDP, which is a measure of the aggregate output generated by an economy over a given period of time (typically a year). GDP may be calculated in different ways:

— On the expenditure side by adding together total private and government consumption, investment and net trade.

— On the income side as the sum of returns to the primary factors of production (labour, capital and natural resources) employed in the national economy plus indirect tax revenue.

The regional level equivalent to GDP is GRP – at the state or territory level it is called GSP or GTP, respectively. 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 chapter.

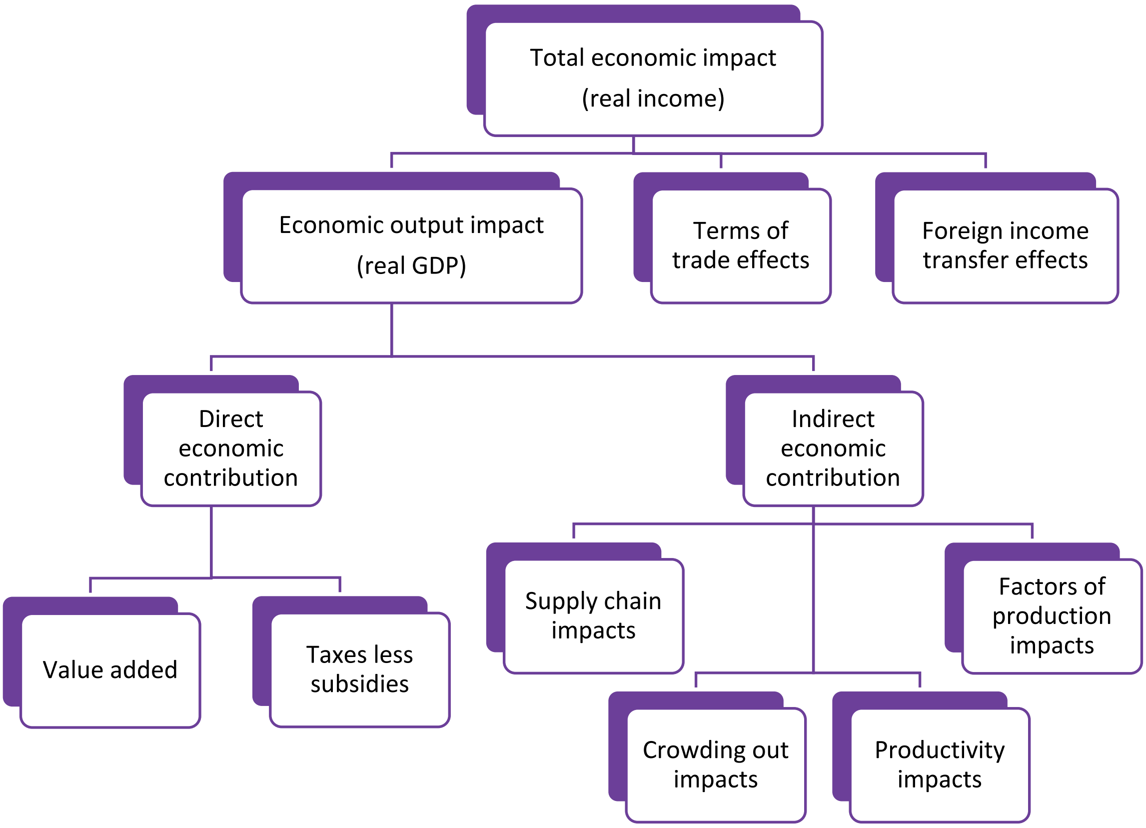
These measures of the real economic output of an economy should be distinguished from measures of the economy's real income, which provide a better indication of the economic welfare of the residents of a region. It is possible for real economic output to increase (that is, for GDP to rise) while at the same time real income (economic welfare) declines. In such circumstances, people and households would be worse off despite economic growth.

In *Tasman Global*, the relevant measure of real income at the national level is real gross national disposable income or RGNDI as reported by the Australian Bureau of Statistics (ABS).

As shown in **Figure 4.1**, the change in a region's real income as a result of a new project is the change in real economic output plus the change in net external income transfers plus the change in the region's terms of trade (which measure the change in the purchasing power of the region's exports relative to its imports). As Australians have experienced first-hand in recent years, changes in the terms of trade can have a substantial impact on residents' welfare independently of changes in real economic output.

In global CGE models such as *Tasman Global*, the change in real income is equivalent to the change in consumer welfare using the equivalent variation measure of welfare change resulting from exogenous shocks. Hence, it is valid to say that the projected change in real income (from *Tasman Global*) is also the projected change in consumer welfare.

Figure 4.1 Estimating the macroeconomic effects of a project or policy



Note: In *Tasman Global*, the change in real income is equivalent to the change in equivalent variation – a standard economic measure of the change in consumer welfare resulting from exogenous shocks.
Source: ACIL Allen

4.2 Economic modelling results

4.2.1 Real Economic Output and Real Income

As discussed in section 4.1, real economic output is the sum of value added by all producers in the relevant region/state, plus any product taxes (minus subsidies) not included in output. When calculated at a national level, this is referred to as GDP, and as GSP/GRP at the state/regional level.

In contrast, the change in real income is:

— the change in real economic output
— plus the change in net foreign income transfers
— plus the change in terms of trade.

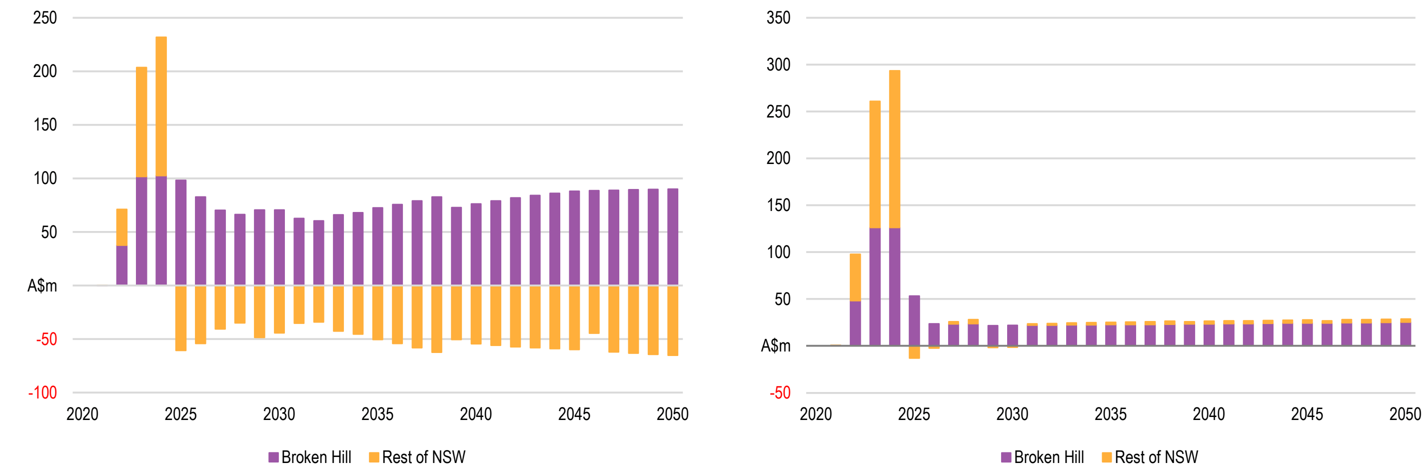
While real output is a useful indicator, real income provides a better measure of the welfare impact that changes in these aggregates have on people living in a region.[2]

[2] In CGE models with the same framework as *Tasman Global*, it can be shown that the change in real income is equal to the 'equivalent variation' measure of welfare change. Hence, it is valid to say that the projected change in state or national real income is the projected change in consumer welfare at the state or national level.

Figure 4.2 shows the estimated change in both real economic output and real income in each region of New South Wales due to the construction and operations of the Project. A summary of the projected impacts is presented in Table 4.1.

Figure 4.2 Change in New South Wales real economic output and real income as a result of the A-CAES Project, relative to the Reference Case (in 2020 terms)

A. Real economic output (GRP/GSP) B. Real income



Note: All years are financial years ending June 30.
Source: ACIL Allen Consulting

The macroeconomic effects of the Project are driven by three broad elements:

1. The effect of the construction and operation of the Project. Parts of which either stimulate or crowd-out economic activity in the rest of New South Wales (principally driven by the relative movement of scarce factors of production from interstate and within New South Wales).
2. The underlying productivity improvement in the generation sector driven by the reduction in the MLF (albeit an effect which we only conservatively assumed for the first four years of the operations).
3. A reduction in the expected amount of unserved energy.

The construction and operations of the Project, which, at $560 million, is nominally large, is primarily increasing demand for scarce factors of production, and so has a smaller effect on economic output compared to the size of the investment. However, the additional construction activity associated with the Project has a noticeably higher impact on the real income of residents in throughout New South Wales, as there is increased demand for labour and goods and services and this boosts local incomes.

As shown in Table 4.1, the Broken Hill economy is projected to benefit, while there is a small projected decrease in real economic output in the Rest of New South Wales due to the movement of scarce primary factors (i.e. labour and capital) into the Broken Hill region. As shown in Table 4.1, however, the real income generated by the increase in output is not kept within the Broken Hill region, and is instead repatriated to other Australian and overseas residents through the payment of New South Wales and Commonwealth Government taxes and through the payment of dividends to shareholders. For residents in the Rest of New South Wales, the increase in real income is positive in almost all years in the projection period, and more than compensates for any negative effects on real GSP. Similarly, over the whole modelling time frame, there is a clear, strong aggregate benefit to the real income of New South Wales.

Table 4.1 Projected cumulative change in real economic output and real income in New South Wales as a result of the Project, relative to the Reference Case (in 2020 terms)

	Total (2020 to 2050)	NPV (3% real discount rate)	NPV (7% real discount rate)	NPV (10% real discount rate)
	2020 $Am	2020 $Am	2020 $Am	2020 $Am
Real economic output				
Broken Hill	2,286	1,451	885	654
Rest of NSW	-1,095	-571	-237	-114
New South Wales (GSP)	**1,191**	**880**	**648**	**541**
Real income				
Broken Hill	940	669	472	384
Rest of NSW	401	342	289	259
New South Wales	**1,341**	**1,011**	**761**	**643**

Note: NPV = net present value.
Source: ACIL Allen Consulting

Real Economic Output

Over the period to 2050, the Project is projected to increase the real economic output of:

— Broken Hill by a cumulative total of $2.3 billion relative to the Reference Case (with a net present value of $1.5 billion, using a 3 per cent real discount rate)

— New South Wales as a whole (i.e. real GSP) by a cumulative total of $1.2 billion relative to the Reference Case (with a net present value of $648 million, using a 3 per cent real discount rate).

To place the projected changes in economic output estimates in perspective, the discounted present value (using a 3 per cent real discount rate) is equivalent to approximately 0.14 per cent of New South Wales' current GSP.

Real Income

Real income is a measure of the ability to purchase goods and services, adjusted for inflation. A rise in real income indicates a rise in the capacity for current consumption, but also an increased ability to accumulate wealth in the form of financial and other assets. The change in real income from a development is a measure of the change in welfare of an economy.

The extent to which local residents will benefit from the additional economic output depends on the level of ownership of the capital (including the natural resources) utilised in the business as well as any wealth transfers undertaken by Australian governments as a result of the taxation revenues generated by the Project.

The New South Wales Government will receive some additional taxes (such as payroll taxes) because of the Project, while the Australian Government will receive higher taxes through higher personal income and company tax receipts. Where this additional income will be spent is unknown, but for this study we have assumed that it will be spent proportionately to the population in each region of Australia.

Over the period 2021 to 2050, the Project is projected to increase the real income of:

— Broken Hill by a cumulative total of $940 million relative to the Reference Case (with a net present value of $669 million, using a 3 per cent real discount rate)

— New South Wales as a whole by a cumulative total of $1.3 billion relative to the Reference Case (with a net present value of $1.0 billion, using a 3 per cent real discount rate).

To place these projected changes in income in perspective, the discounted present values (using a 3 per cent real discount rate) are equivalent to a one-off increase in the average real income of all current residents of New South Wales by approximately $125 per person (or approximately $300 per household).

4.2.2 Employment

As well as generating short-term jobs related to the construction of the A-CAES, the Project will also create additional employment in the Broken Hill economy. In addition to the direct jobs generated on-site, the construction and installation, and production phases will require additional quantities of New South Wales sourced goods and services. Production of these inputs will further increase the demand for labour across the New South Wales economy.

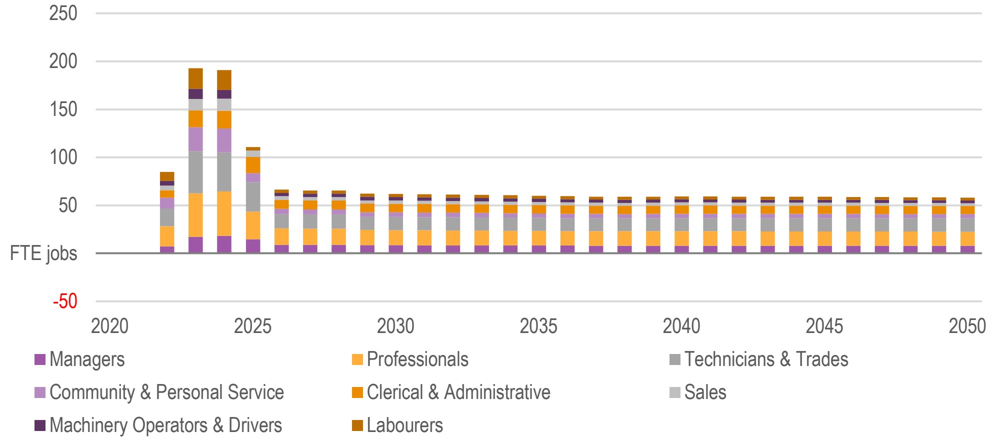
A key issue when estimating the impact of a project is determining how the labour market will clear.[3] As discussed in Section A.2, for this analysis, increases in the demand for labour in the Broken Hill region can be met by three mechanisms: increasing migration from the Rest of New South Wales and Rest of Australia; increasing participation rates and/or average hours worked; and by reducing the unemployment rate. In the model framework, the first two mechanisms are driven by changes in the real wages paid to workers in the Broken Hill 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 forecast period, changes in the real wage rate accounts for the majority of the additional labour supply in the policy scenarios relative to the Reference case.

It should be noted that this analysis does not assume any change in net foreign migration as a result of the Project.

A range of different skills will be impacted by the additional economic activity stimulated by the Project. Figure 4.3 shows the broad classifications and numbers of employees stimulated in the Broken Hill region by the Project over its life. The data reflect the high proportion of technicians and trades workers, skilled machinery operators and drivers as well as professional personnel required to construct a project of this type. Other jobs are stimulated in response to consumer's consumption patterns and their higher incomes, relative to the Reference case.

[3] As with other CGE models, the standard assumption within *Tasman Global* is that all markets clear (ie. demand equals supply) at the start and end of each time period, including the labour market. CGE models place explicit limits on the availability of factors 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. Consequently, these tools tend to overestimate the impacts of a project or policy.

Figure 4.3 Projected additional Broken Hill employment by occupation, relative to the Reference Case (Full-time equivalent jobs)



Note: FTE = full-time equivalent.
Source: ACIL Allen

Employment creation by region

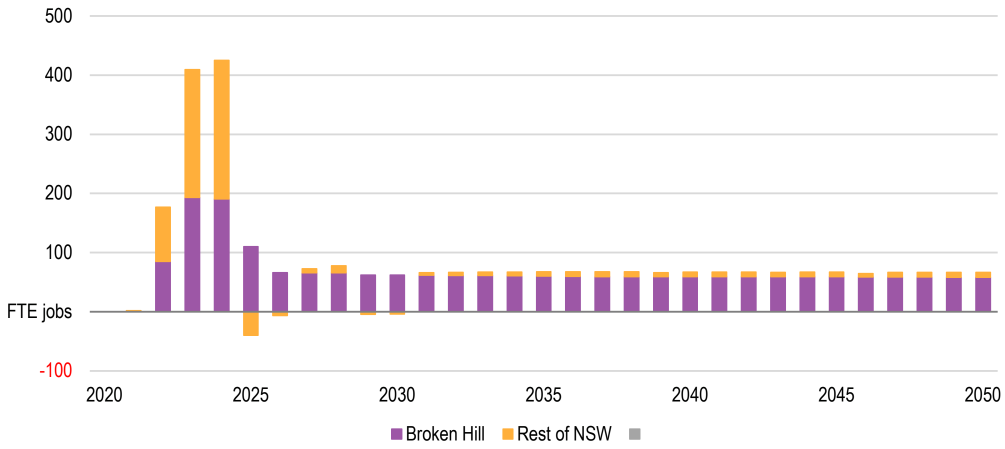
Over the modelled life of the Project to 2050, it is projected that employment is expect to increase:

— In the local Broken Hill region by 2,088 employee years (average annual increase of 70 FTE jobs)

— New South Wales as a whole by 2,748 employee years (average annual increase of 92 FTE jobs).

As illustrated in Figure 4.4, the total additional employment from about 2025 is projected to be broadly constant throughout the projection period at approximately 66 FTE jobs, but will experience some variation by region year to year.

Figure 4.4 Projected change in employment by region, NEM connected case relative to BAU Case (full time equivalent jobs)



Note: All years are financial years ending June 30. FTE = full-time equivalent.
Source: ACIL Allen Consulting

Appendices

Overview of Tasman Global

A

Tasman Global is a dynamic, global computable general equilibrium (CGE) model that has been developed by ACIL Allen for the purpose of undertaking economic impact analysis at the regional, state, national and global level.

A CGE model captures the interlinkages between the markets of all commodities and factors, taking into account resource constraints, to find a simultaneous equilibrium in all markets. A global CGE model extends this interdependence of the markets across world regions and finds simultaneous equilibrium globally. A dynamic model adds onto this the interconnection of equilibrium economies across time periods. For example, investments made today are going to determine the capital stocks of tomorrow and hence future equilibrium outcomes depend on today's equilibrium outcome, and so on.

A dynamic global CGE model, such as *Tasman Global*, has the capability of addressing total, sectoral, spatial and temporal efficiency of resource allocation as it connects markets globally and over time. Being a recursively dynamic model, however, its ability to address temporal issues is limited. In particular, *Tasman Global* cannot typically address issues requiring partial or perfect foresight. However, as documented in Jakeman et al (2001), it is possible to introduce partial or perfect foresight in certain markets using algorithmic approaches. Notwithstanding this, the model does have the capability to project the economic impacts over time of given changes in policies, tastes and technologies in any region of the world economy on all sectors and agents of all regions of the world economy.

Tasman Global was developed from the 2001 version of the Global Trade and Environment Model (GTEM) developed by ABARE (Pant 2001) and has been evolving ever since. In turn, GTEM was developed out of the MEGABARE model (ABARE 1996), which contained significant advancements over the GTAP model of that time (Hertel 1997).

A.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 an economic disturbance and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues for which both the timing of and the adjustment path that economies follow are relevant in the analysis.

A.2 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 Global Trade Analysis Project (GTAP) database (Aguiar et al. 2019). 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. It is the most detailed database of its type in the world.

Tasman Global builds on the GTAP database by adding the following important features:

— a detailed population and labour market database
— 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
— explicit representation of the states and territories of Australia
— the capacity to represent multiple regions within states and territories of Australia explicitly.

Nominally, version 10.1 of the *Tasman Global* database divides the world economy into 153 regions (145 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian or international projects or policies at the regional level including at the or at the state/territory/provincial level for various countries.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 76 industries (Table A.1). 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, transport 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 has its 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 A.1 Standard sectors in the Tasman Global model

no	Name	no	Name
1	Paddy rice	39	Diesel (incl. nonconventional diesel)
2	Wheat	40	Other petroleum, coal products
3	Cereal grains nec	41	Chemical, rubber, plastic products
4	Vegetables, fruit, nuts	42	Iron ore
5	Oil seeds	43	Bauxite
6	Sugar cane, sugar beet	44	Mineral products nec
7	Plant- based fibres	45	Ferrous metals
8	Crops nec	46	Alumina
9	Bovine cattle, sheep, goats, horses	47	Primary aluminium
10	Pigs	48	Metals nec
11	Animal products nec	49	Metal products
12	Raw milk	50	Motor vehicle and parts
13	Wool, silk worm cocoons	51	Transport equipment nec
14	Forestry	52	Electronic equipment
15	Fishing	53	Machinery and equipment nec
16	Brown coal	54	Manufactures nec
17	Black coal	55	Electricity generation
18	Oil	56	Electricity transmission and distribution
19	Liquefied natural gas (LNG)	57	Gas manufacture, distribution
20	Other natural gas	58	Water
21	Minerals nec	59	Construction
22	Bovine meat products	60	Trade
23	Pig meat products	61	Road transport
24	Meat products nec	62	Rail and pipeline transport
25	Vegetables oils and fats	63	Water transport
26	Dairy products	64	Air transport
27	Processed rice	65	Transport nec
28	Sugar	66	Warehousing and support activities
29	Food products nec	67	
30	Wine	68	Communication
31	Beer	69	Financial services nec
32	Spirits and RTDs	70	Insurance
33	Other beverages and tobacco products	71	Business services nec
34	Textiles	72	Recreational and other services
35	Wearing apparel	73	Public Administration and Defence
36	Leather products	74	Education
37	Wood products	75	Human health and social work activities
38	Paper products, publishing	76	Dwellings

Note: nec = not elsewhere classified.

Source: ACIL Allen

A.3 Model Structure

Given its heritage, the structure of the *Tasman Global* model closely follows that of the GTAP and GTEM models and interested readers are encouraged to refer to the documentation of these models for more detail (namely Hertel 1997 and Pant 2001, respectively). In summary:

— The model divides the world into a variety of regions and international waters.

  - Each region is fully represented with its own 'bottom-up' social accounting matrix and could be a local community, an LGA, state, country or a group of countries. The number of regions in a given simulation depends on the database aggregation. Each region consists of households, a government with a tax system, production sectors, investors, traders and finance brokers.
  - 'International waters' are a hypothetical region in which global traders operate and use international shipping services to ship goods from one region to the other. It also houses an international finance 'clearing house' that pools global savings and allocates the fund to investors located in every region.
  - Each region has a 'regional household'[4] that collects all factor payments, taxes, net foreign borrowings, net repatriation of factor incomes due to foreign ownership and any net income from trading of emission permits.
- The income of the regional household is allocated across private consumption, government consumption and savings according to a Cobb-Douglas utility function, which, in practice, means that the share of income going to each component is assumed to remain constant in nominal terms.
- Private consumption of each commodity is determined by maximising utility subject to a Constant Difference of Elasticities (CDE) function which includes both price and income elasticities.
- Government consumption of each commodity is determined by maximising utility subject to a Cobb-Douglas utility function.
- Each region has *n* production sectors, each producing single products using various production functions where they aim to maximise profits (or minimise costs) and take all prices as given. The nature of the production functions chosen in the model means that producers exhibit constant returns to scale.
  - In general, each producer supplies consumption goods by combining an aggregate energy-primary factor bundle with other intermediate inputs and according to a Leontief production function (which in practice means that the quantity shares remain in fixed proportions). Within the aggregate energy-primary factor bundle, the individual energy commodities and primary factors are combined using a nested-CES (Constant Elasticity of Substitution) production function, in which energy and primary factor aggregates substitute according to a CES function with the individual energy commodities and individual primary factors substituting with their respective aggregates according to further CES production functions.
  - Exceptions to the above include the electricity generation, iron and steel and road transport sectors. These sectors employ the 'technology bundle' approach developed by ABARE (1996) in which non-homogenous technologies are employed to produce a homogenous output with the choice of technology governed by minimising costs according to a modified-CRESH production function. For example, electricity may be generated from a variety of technologies (including brown coal, black coal, gas, nuclear, hydro, solar etc.), iron and steel may be produced from blast furnace or electric arc technologies while road transport services may be supplied using a range of different vehicle technologies. The 'modified-CRESH' function differs from the traditional CRESH function by also imposing the condition that the quantity units are homogenous.
- There are four primary factors (land, labour, mobile capital and fixed capital). While labour and mobile capital are used by all production sectors, land is only used by agricultural sectors while fixed capital is typically employed in industries with natural resources (such as fishing, forestry and mining) or in selected industries built by ACIL Allen.

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[4] The term "regional household" was devised for the GTAP model. In essence it is an agent that aggregates all incomes attributable to the residents of a given region before distributing the funds to the various types of regional consumption (including savings).

- Land supply in each region is typically assumed to remain fixed through time with the allocation of land between sectors occurring to maximise returns subject to a Constant Elasticity of Transformation (CET) utility function.
- Mobile capital accumulates as a result of net investment. It is implicitly assumed in *Tasman Global* that it takes one year for capital to be installed. Hence, supply of capital in the current period depends on the last year's capital stock and investments made during the previous year.
- Labour supply in each year is determined by endogenous changes in population, given participation rates and a given unemployment rate. In policy scenarios, the supply of labour is positively influenced by movements in the real wage rate governed by the elasticity of supply. For countries where sub-regions have been specified (such as Australia), migration between regions is induced by changes in relative real wages with the constraint that net interregional migration equals zero. For regions where the labour market has been disaggregated to include occupations, there is limited substitution allowed between occupations by individuals supplying labour (according to a CET utility function) and by firms demanding labour (according to a CES production function) based on movements in relative real wages.
- The supply of fixed capital is given for each sector in each region.

The model has the option for these assumptions to be changed at the time of model application if alternative factor supply behaviours are considered more relevant.

- It is assumed that labour (by occupation) and mobile capital are fully mobile across production sectors implying that, in equilibrium, wage rates (by occupation) and rental rates on capital are equalised across all sectors within each region. To a lesser extent, labour and capital are mobile between regions through international financial investment and migration, but this sort of mobility is sluggish and does not equalise rates of return across regions.
- For most international regions, for each consumer (private, government, industries and the local investment sector), consumption goods can be sourced either from domestic or imported sources. In any country that has disaggregated regions (such as Australia), consumption goods can also be sourced from other intrastate or interstate regions. In all cases, the source of non-domestically produced consumption goods is determined by minimising costs subject to a Constant Ratios of Elasticities of Substitution, Homothetic (CRESH) utility function. Like most other CGE models, a CES demand function is used to model the relative demand for domestically-produced commodities versus non-domestically produced commodities. The elasticities chosen for the CES and CRESH demand functions mean that consumers in each region have a higher preference for domestically-produced commodities than non-domestic commodities and a higher preference for intrastate- or interstate-produced commodities than foreign commodities.
- The capital account in *Tasman Global* is open. Domestic savers in each region purchase 'bonds' in the global financial market through local 'brokers' while investors in each region sell bonds to the global financial market to raise investible funds. A flexible global interest rate clears the global financial market.
- It is assumed that regions may differ in their risk characteristics and policy configurations. As a result, rates of return on money invested in physical capital may differ between regions and therefore may be different from the global cost of funds. Any difference between the local rates of return on capital and the global cost of borrowing is treated as the result of the existence of a risk premium and policy imperfections in the international capital market. It is maintained that the equilibrium allocation of investment requires the equalisation of changes in (as opposed to the absolute levels of) rates of return over the base year rates of return.
- Any excess of investment over domestic savings in a given region causes an increase in the net debt of that region. It is assumed that debtors service the debt at the interest rate that

clears the global financial market. Similarly, regions that are net savers gives rise to interest receipts from the global financial market at the same interest rate.

— Investment in each region is used by the regional investor to purchase a suite of intermediate goods according to a Leontief production function to construct capital stock with the regional investor cost minimising by choosing between domestic, interstate and imported sources of each intermediate good via the CRESH production function. The regional cost of creating new capital stock versus the local rates of return on mobile capital is what determines the regional rate of return on new investment.

— In equilibrium, exports of a good from one region to the rest of world are equal to the import demand for that good in the remaining regions. Together with the merchandise trade balance, the net payments on foreign debt add up to the current account balance. *Tasman Global* does not require that the current account be in balance every year. It allows the capital account to move in a compensatory direction to maintain the balance of payments. The exchange rate provides the flexibility to keep the balance of payments in balance.

— Detailed bilateral transport margins for every commodity are specified in the starting database. By default, the bilateral transport mode shares are assumed to be constant, with the supply of international transportation services by each region solved by a cost-minimising international trader according to a Cobb-Douglas demand function.

— Emissions of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6) associated with economic activity are tracked in the model. 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 externally. Prices can be applied to emissions which are converted to industry-specific production taxes or commodity-specific sales taxes that impact on demand. Abatement technologies similar to those adopted in a report released by the Australian Government (2008) are available and emission quotas can be set globally or by region along with allocation schemes that enable emissions to be traded between regions.

More detail regarding specific elements of the model structure are discussed in the following sections.

A.4 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 each region represented in the *Tasman Global* database is projected using ACIL Allen'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 projected period.

For each of region, 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 regional participation rates by age by gender. Over the projected period labour supply in most developed economies is projected to grow slower than total population because of ageing population effects.

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

A.4.1 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 and regions within each state.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms that 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 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 which are presented in Table A.2.

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).

Table A.2 Occupations in the *Tasman Global* database, ANZSCO 3-digit level (minor groups)

ANZSCO code, Description
1. MANAGERS
111 Chief Executives, General Managers and Legislators
121 Farmers and Farm Managers
131 Advertising and Sales Managers
132 Business Administration Managers
133 Construction, Distribution and Production Managers
134 Education, Health and Welfare Services Managers
135 ICT Managers
139 Miscellaneous Specialist Managers
141 Accommodation and Hospitality Managers
142 Retail Managers
149 Miscellaneous Hospitality, Retail and Service Managers
2. PROFESSIONALS
211 Arts Professionals
212 Media Professionals
221 Accountants, Auditors and Company Secretaries
222 Financial Brokers and Dealers, and Investment Advisers
223 Human Resource and Training Professionals
224 Information and Organisation Professionals
225 Sales, Marketing and Public Relations Professionals
231 Air and Marine Transport Professionals
232 Architects, Designers, Planners and Surveyors
233 Engineering Professionals
234 Natural and Physical Science Professionals
241 School Teachers
242 Tertiary Education Teachers
249 Miscellaneous Education Professionals
251 Health Diagnostic and Promotion Professionals
252 Health Therapy Professionals
253 Medical Practitioners
254 Midwifery and Nursing Professionals
261 Business and Systems Analysts, and Programmers
262 Database and Systems Administrators, and ICT Security Specialists
263 ICT Network and Support Professionals
271 Legal Professionals
272 Social and Welfare Professionals
3. TECHNICIANS & TRADES WORKERS
311 Agricultural, Medical and Science Technicians
312 Building and Engineering Technicians
313 ICT and Telecommunications Technicians
321 Automotive Electricians and Mechanics
322 Fabrication Engineering Trades Workers
323 Mechanical Engineering Trades Workers
324 Panel beaters, and Vehicle Body Builders, Trimmers and Painters
331 Bricklayers, and Carpenters and Joiners
332 Floor Finishers and Painting Trades Workers
333 Glaziers, Plasterers and Tilers
334 Plumbers
341 Electricians
342 Electronics and Telecommunications Trades Workers
351 Food Trades Workers
361 Animal Attendants and Trainers, and Shearers
362 Horticultural Trades Workers
391 Hairdressers
392 Printing Trades Workers
393 Textile, Clothing and Footwear Trades Workers
394 Wood Trades Workers
399 Miscellaneous Technicians and Trades Workers
4. COMMUNITY & PERSONAL SERVICE
411 Health and Welfare Support Workers
421 Child Carers
422 Education Aides
423 Personal Carers and Assistants
431 Hospitality Workers
441 Defence Force Members, Fire Fighters and Police
442 Prison and Security Officers
451 Personal Service and Travel Workers
452 Sports and Fitness Workers
5. CLERICAL & ADMINISTRATIVE
511 Contract, Program and Project Administrators
512 Office and Practice Managers
521 Personal Assistants and Secretaries
531 General Clerks
532 Keyboard Operators
541 Call or Contact Centre Information Clerks
542 Receptionists
551 Accounting Clerks and Bookkeepers
552 Financial and Insurance Clerks
561 Clerical and Office Support Workers
591 Logistics Clerks
599 Miscellaneous Clerical and Administrative Workers
6. SALES WORKERS
611 Insurance Agents and Sales Representatives
612 Real Estate Sales Agents
621 Sales Assistants and Salespersons
631 Checkout Operators and Office Cashiers
639 Miscellaneous Sales Support Workers
7. MACHINERY OPERATORS & DRIVERS
711 Machine Operators
712 Stationary Plant Operators
721 Mobile Plant Operators
731 Automobile, Bus and Rail Drivers
732 Delivery Drivers
733 Truck Drivers
741 Storepersons
8. LABOURERS
811 Cleaners and Laundry Workers
821 Construction and Mining Labourers
831 Food Process Workers
832 Packers and Product Assemblers
839 Miscellaneous Factory Process Workers
841 Farm, Forestry and Garden Workers
851 Food Preparation Assistants
891 Freight Handlers and Shelf Fillers
899 Miscellaneous Labourers

Source: ABS (2009), ANZSCO – Australian and New Zealand Standard Classifications of Occupations, First edition, Revision 1, ABS Catalogue No. 1220.0.

A.4.2 Labour Market Database

The *Tasman Global* database includes a detailed representation of the Australian labour market that has been designed to capture the supply and demand for different skills and occupations by industry. To achieve this, the Australian workforce is characterised by detailed supply and demand matrices.

On the supply side, the Australian population is characterised by a five-dimensional matrix consisting of:

- 7 post-school qualification levels
- 12 main qualification fields of highest educational attainment
- 97 occupations
- 101 age groups (namely 0 to 99 and 100+)
- 2 genders.

The data for this matrix is measured in persons and was sourced from the ABS 2011 Census. As the skills elements of the database and model structure have not been used for this project, it will be ignored in this discussion.

The 97 occupations are those specified at the 3-digit level (or Minor Groups) under the Australian New Zealand Standard Classification of Occupations (ANZSCO) (see Table A.2).

On the demand side, each industry demands a particular mix of occupations. This matrix is specified in units of full-time equivalent (FTE) jobs where an FTE employee works an average of 37.5 hours per week. Consistent with the labour supply matrix, the data for FTE jobs by occupation by industry was also sourced from the ABS 2011 Census and updated using the latest labour force statistics.

Matching the demand and supply side matrices means that there is the implicit assumption that the average hours per worker are constant, but it is noted that mathematically changes in participation rates have the same effect as changes in average hours worked.

A.4.3 Labour Market Model Structure

In the model, the underlying growth of each industry in the Australian economy results in a growth in demand for a particular set of skills and occupations. In contrast, the supply of each set of skills and occupations in a given year is primarily driven by the underlying demographics of the resident population. This creates a market for each skill by occupation that (unless specified otherwise) needs to clear at the start and end of each time period.[5] The labour markets clear by a combination of different prices (i.e. wages) for each labour type and by allowing a range of demand and supply substitution possibilities, including:

- changes in firms' demand for labour driven by changes in the underlying production technology
  - for technology bundle industries (electricity, iron and steel and road transportation) this occurs due to changes between explicitly identified alternative technologies
  - for non-technology bundle industries this includes substitution between factors (such as labour for capital) or energy for factors
- changes to participation rates (or average hours worked) due to changes in real wages
- changes in the occupations of a person due to changes in relative real wages

[5] For example, at the start and end of each week for this analysis. *Tasman Global* can be run with different steps in time, such as quarterly or bi-annually in which case the markets would clear at the start and end of these time points.

— substitution between occupations by the firms demanding labour due to changes in the relative costs
— changes to unemployment rates due to changes in labour demand, and
— limited labour mobility between states due to changes in relative real wages.

All of the labour supply substitution functions are modified-CET functions in which people supply their skills, occupation and rates of participation as a positive function of relative wages. However, unlike a standard CET (or CES) function, the functions are 'modified' to enforce an additional constraint that the number of people is maintained before and after substitution.[6]

Although technically solved simultaneously, the labour market in *Tasman Global* can be thought of as a five-stage process:

— labour makes itself available to the workforce based on movements in the real wage (that is, it actively participates with a certain number of average hours worked per week)
— the age, gender and occupations of the underlying population combined with the participation rate by gender by age implies a given supply of labour (the potentially available workforce)
— a portion of the potentially available workforce is unemployed, implying a given available labour force
— labour chooses to move between occupations based on relative real wages
— industries alter their demands for labour as a whole and for specific occupations based on the relative cost of labour to other inputs and the relative cost of each occupation.

By default, *Tasman Global*, like all CGE models, assumes that markets clear at the start and end of each period. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model). In principle, (subject to zero starting values) people of any age and gender can move between any of the 97 occupations while industries can produce their output with any mix of occupations. However, in practice the combination of the initial database, the functional forms, low elasticities and moderate changes in relative prices for skills, occupations etc. means that there is only low to moderate change induced by these functions. The changes are sufficient to clear the markets, but not enough to radically change the structure of the workforce in the timeframe of this analysis.

Factor-factor substitution elasticities in non-technology bundle industries are industry specific and are the same as those specified in the GTAP database[7], while the fuel-factor and technology bundle elasticities are the same as those specified in GTEM.[8] The detailed labour market elasticities are ACIL Allen assumptions, previously calibrated in the context of the model framework to replicate the historical change in the observed Australian labour market over a five year period[9]. The unemployment rate function in the policy scenarios is a non-linear function of the change in the labour demand relative to the reference case with the elasticity being a function of the

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[6] As discussed in Dixon et al (1997), a standard CES/CET function is defined in terms of *effective units*. Quantitatively this means that, when substituting between, say, X_1 and X_2 to form a total quantity X using a CET function a simple summation generally does not actually equal X. Use of these functions is common practice in CGE models when substituting between substantially different units (such as labour versus capital or imported versus domestic services) but was not deemed appropriate when tracking the physical number of people. Such 'modified' functions have long been employed in the technology bundles of *Tasman Global* and GTEM. The Productivity Commission have proposed alternatives to the standard CES to overcome similar and other weaknesses when applied to internationally traded commodities.

[7] Narayanan et al. (2012).

[8] Pant (2007).

[9] This method is a common way of calibrating the economic relationships assumed in CGE models to those observed in the economy. See for example Dixon and Rimmer (2002).

unemployment rate (that is, the lower the unemployment rate the lower the elasticity and the higher the unemployment rate the higher the elasticity).

A.5 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 Allen'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 up to twelve different electricity generation technologies:

— brown coal (with and without carbon capture and storage)
— black coal (with and without carbon capture and storage)
— petroleum
— base load gas (with and without carbon capture and storage)
— peak load gas
— hydro
— geothermal
— nuclear
— biomass
— wind
— solar
— 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. Fuel use and emissions factors by each technology are also matched to those projected in *PowerMark*. This representation enables the highly detailed market based projections from *PowerMark* to be incorporated as accurately as possible into *Tasman Global*.

A.6 References

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