EQUITIES

BRN-AU		Not rated
Stock price as of 14/04/2022	A$	0.91
GICS sector		Information Technology
Market cap	US$m	1,157
Avg Value Traded (3m)	US$m	29.2
12m high/low	A$	2.13/0.37
EV/Sales FY21	x	741.4
P/BV FY21	x	61.2

Historical financials

YE Dec (US$m)	2019A	2020A	2021A
Revenue	0.08	0.12	1.59
% growth	-92%	60%	1,215%
EBITDA	(10.0)	(10.2)	(18.9)
% growth	30%	-2%	-86%
EPS (US$)	(0.01)	(0.02)	(0.01)
% growth	42%	-84%	30%
EBIT Margin	-13,219%	-8,443%	-1,191%

Source: Company data, FactSet,March 2022

Historical business risk/reward*

*Relative to the market.
Source: Macquarie Research, March 2022

Style

Thematic
Growth
Value
Event

Source: Macquarie Research, March 2022

The subject Company discussed in this report is not under Macquarie Research's coverage. This report is not an initiation of coverage on the Company and does not intend to provide any rating or recommendation on the Company.

MacVisit: Brainchip Inc

Brainchip Inc

Key points

- BRN is a pure-play AI company, producing a neuromorphic processor called Akida.
- Akida has utility across consumer and industrial applications, including autonomous vehicles, IoT devices, medical diagnosis.
- Neuromorphic chip market is still nascent in a commercial sense, there is high competition & new technology risk from major players (e.g Intel & IBM).

BRN is a semiconductor company that designs neuromorphic chips. BRN's AKD1000 relies on spiking neural networks (SNN) which enables high performance, real-time inference at ultra-low power. This is significantly less than the traditional AI chips relying on convolutional neural network (CNN) technology. BRN transitioned from R&D to commercialisation in H2 2021. BRN states it is the world's first commercial producer of neuromorphic chips.

Advantages of the Akida chip

- **Independence from cloud:** Akida manages AI tasks at the Edge of the network instead of sending data to the cloud. Without needing an ongoing internet connection, Akida provides reduced system latency and faster response times.
- **One shot learning:** Reduces resources required to train models due to efficiency in accommodating new data inputs. Learns from very small set of samples and expands knowledge as more data is absorbed.
- **Low power consumption:** Uses 100 microwatts to a few hundred milliwatts of power depending on the workload. It generates minimal heat from consuming low power, so the chip should outlive the product it has been installed into.
- **On-chip fast learning and convolution:** Traditional software-based neural networks (e.g CNN) can be efficiently run on BRN's SNN by leveraging TensorFlow for industry standard neural network development. In April 2021, BRN introduced MetaTF as a versatile ML framework which allows people working in the CNN space to easily switch to neuromorphic computing without having to learn a new language.
- **Small and lightweight:** 28nm chip can be designed into wearable devices and flying machines (e.g drones, aircraft, spacecraft).

Financials and risks

- FY21 revenue of US$1.59M was a significant increase from US$120,829 in FY20, but still loss-making on EBITDA level.
- Risks: IP, Reliance on key personnel, competition and new technologies, future funding requirements

Akida has a broad range of applications with low power use

Source: BrainChip, Tech Brief, May 2020

Ownership

Substantial shareholders in BRN include:

- **Peter Van Der Made (9.35%):** Co-founder & CTO.
- **Anil Shamrao Mankar (5.87%):** Co-founder & CDO.
- **Louis Dinardo (0.69%):** Former CEO.
- **Steven Liebeskind (0.68%):** Former Non-Executive Director.
- **LDA Capital (0.58%):** US investment group, provides BRN with equity financing via a put option agreement.
- **Adam Osseiran (0.54%):** Former Chair of the Scientific Advisory Board and former Non-Executive Director.
- **Rebecca Osseiran Moisson (0.40%):** Wife of Adam Osseiran.

History and corporate governance

- Founded in 2013 by Peter Van der Made & Anil Shamrao Mankar, BrainChip Inc was acquired by Aziana Limited, a former mining company, and joined the ASX via a reverse listing in 2015.
- Aziana Limited merged with BrainChip Inc, divesting its existing mineral assets and the two were reinstated on the ASX as one entity BrainChip Holdings in September 2015.
- BRN is incorporated and domiciled in Australia. Apart from trading on ASX, BRN also trades under BCHPY (ADR) and BRCHF on the OTCQX.
- Employs a Scientific Advisory Board (SAB) consisting of three cognitive scientists and industry experts, including Nobel Prize Laureate Professor Barry J. Marshall, who joined in July 2020.
- In 2016, BRN acquired SpikeNet, a French company focusing on computer vision systems.

Balance sheet data and refinancing (As of Dec 2021)

- Net cash outflow of US$14.2M from operations in FY21.
- Net loss after income tax in FY21 of US$21.0M, includes non-cash losses of US$1.4M from fair valuation of LDA Capital financial liabilities, recognised from put option premium and agreed pricing mechanism.

Latest results highlights (4QFY21, Dec year-end)

- Finished quarter with US$19.4M in cash. Increase of 1% YoY but decrease of 19% QoQ.
- Net operating cash outflows of US$3.4M lower by 15% QoQ, with 83% increase in receipts from customers at US$1.1M (US$0.1M in Q3-21).

Directors' background

- **Sean Hehir (CEO & Executive Director):** Joined in November 2021, a seasoned technology executive and board member of Silicon Valley Executive Network. Responsible for driving explosive revenue growth for HP, Compaq and Fusion-io.
- **Peter van der Made (CTO & Executive Director):** Co-founder of BrainChip. Previously CTO, founder and Chief Scientist of vCIS Technology, later Chief Scientist when acquired by Internet Security Systems and IBM. Also founded PolyGraphics Systems.
- **Antonio Viana:** On the board of Arteris, a leading provider of NoC interconnect. Previously Executive Chairman at QuantalRF, former ARM President and EVP of Commercial and Global Development.
- **Geoffrey Carrick:** On the board of Global Study Partners and VCF Capital Partners. Previously Head of Equity Capital Markets at CBA, Director of Equity Capital Markets at Macquarie Group and Head of Finance of Shaw & Partners.
- **Pia Turcinov**: Manages a portfolio career with qualifications in business management and law.

Management background

- **Kenneth W. Scarince (CFO):** Joined in 2019. Previously held senior management positions as Finance Director of Midwest Connect, Controller of Virgin Galactic, VP and Controller of Virgin America, VP Finance of Chicago Express Airlines.
- **Anil Shamrao Mankar (CDO):** Co-founder of BrainChip, previously CDO for Conexant Systems LLC, VP Business Development at T2M and Senior VP-VLSI Engineering at Mindspeed Technologies.
- **Jerome Nadel (CMO):** Joined in January 2022 from Rambus, a NASDAQ-listed semiconductor technology company. Previously held senior positions at Sagem, Thales, wireless and IoT solutions provider Option NV, Unisys and IBM. Board member of Silicon Valley Executive Network and President of Silicon Valley chapter of CMO club, a global community of marketing executives.

Fig 1 Board has average tenure of ~1.7 years

Title	Name	Gender	Tenure (years)
Exec Director, Co-founder & CTO	Peter van der Made	M	6.5
Exec Director & CEO	Sean Hehir	M	0.3
Independent Non-Exec Director	Pia Turcinov	F	0.3
Independent Non-Exec Director	Geoffrey Carrick	M	1.3
Independent Non-Exec Chair	Antonio J Vianna	M	0.1
Independence: 60%		**Female (%): 20%**	**Average: 1.7**

Source: Company data, April 2022

What is Neuromorphic computing (aka Cognitive computing)

Neuromorphic computing hardwires AI and ML algorithms into an integrated circuit (printed circuit board) that closely reproduces the behaviour of the human brain. In devices with these types of circuits, each function is allowed as much time needed to complete its task. To allow for greater complexity and use less energy, all these functions work asynchronously and in parallel — like how neuroscientists believe the brain operates. The neurons of a neuromorphic computer work in parallel with each other, each doing what it needs to do to complete a task. They communicate via bursts of electric current, known as spikes.

Spiking neural network (SNN): Instead of manipulating signals, the chip sends spikes along to activate synapses. Connections are asynchronous and highly timed-based. Neuromorphic cores containing many neurons are interlinked and receive spikes from elsewhere in the network. When received spikes accumulate for a certain period and reach a set threshold, the core will fire off its own spikes to its connected neurons. Preceding spikes reinforce each other and the neuron connections while spikes that follow will inhibit the connection, declining the connectivity until all activities are halted.

Vs. modern conventional computer: Asynchronous systems' roots go back to the earliest versions of the modern computer. The blueprint of the modern computer ("Von Neumann" machine) from the 1940s explains that asynchronous computation is advantageous. Many early machines were built this way, but computer architecture soon grew in complexity and included a lot more wires. Ensuring that a signal was sent and received correctly within the machine got trickier. An internal timekeeper was needed to make sure things ran properly, and synchronous circuits became the preferred platform.

Competition

BRN states it has a competitive advantage over rivals in the commercialisation process as other neuromorphic chips are still in the R&D stage.

IBM TrueNorth

- Produced in 2014, a single processor consists of 5.4 billion transistors, 1 million neurons, 256 million synapses using 4,096 cores. Although it only uses milliwatts of power, each synapse needs to be programmed, which restricts the chip's learning capabilities in real-time. Does not have backward compatibility with previous technology (e.g C++ compilers) and has vendor lock-in risks. ML workflow requires learning Corelet.

Intel Loihi

- Introduced Loihi in January 2018 and its successor Loihi 2 in 2021, which provides 10x faster processing, 15x resource density and improved energy efficiency with a 7nm chip. Loihi 2 consists of 1 million neurons and 120 million synapses but lacks on-chip convolution and requires learning NEF for ML workflow. In 2019, Intel said they're 5 years away from commercialisation.

Google Coral TPU

- Introduced in 2019, Google Coral TPU is a ML application-specific integrated circuit (ASIC) designed to run AI at the edge. Provides high performance ML inferencing for low-power devices but only supports TensorFlow Lite. An individual Edge TPU performs 4 trillion (fixed-point) operations per second and consumes 2-5W of power.

DLAs (e.g Nvidia)

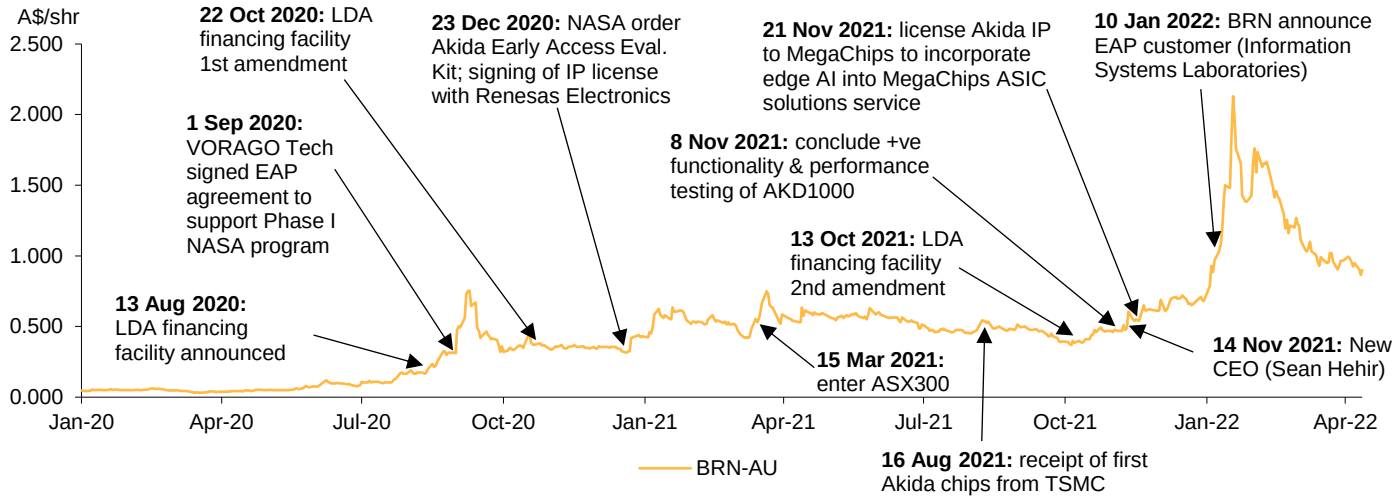
- Launched in 2017, Nvidia produced an open-source hardware neural network AI accelerator written in Verilog. It is configurable and scalable to meet a range of architecture needs. However, as an accelerator, any process must be scheduled and arbitered by an outside entity (e.g CPU). Available for product development as a part of Nvidia's Jetsen Xavier NX.

Fig 2 Competitive Space

	Micro to MW Power Use	Standard ML Workflow	Standalone Possible (No CPU)	On-Chip Convolution
BrainChip Akida™ AKD1000	✔	✔	✔	✔
IBM TrueNorth	✔	Learn Corel	✘	✘
Intel Loihi	✔	Learn NEF	✔	✘
Google Coral TPU	2-5W	✔	✘	✘
Deep Learning Accelerator (e.g Nvidia)	✘	✔	✘	✘

Source: BrainChip, BrainChip Introduction presentation, April 2022

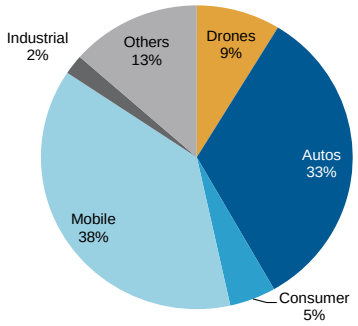
Fig 3 BRN operational highlights



Source: Company data, April 2022

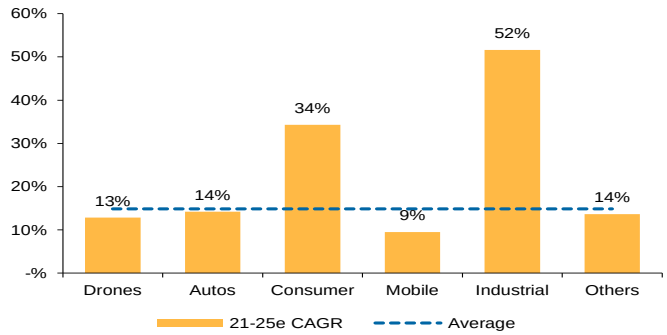
Estimates from various sources suggest edge computing will see a CAGR of between 19-49% over the coming 5-10 years (consensus average of 33% CAGR).

Fig 4 Edge based devices requiring AI 2021e breakdown



Source: BrainChip, Share Café Podcast presentation, June 2021

Fig 5 Edge based devices 21-25e growth CAGR

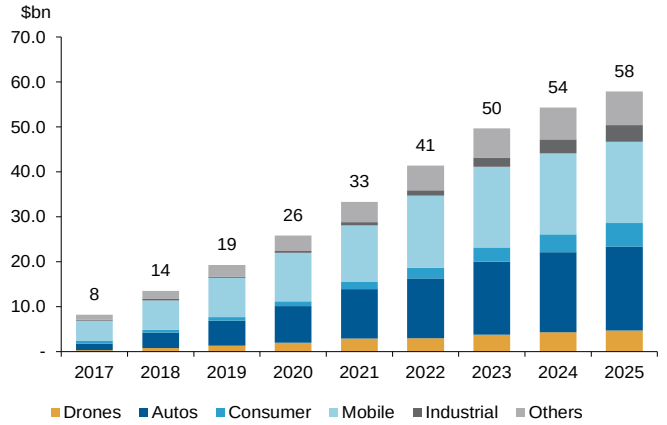


Source: BrainChip, Share Café Podcast presentation, June 2021

Fig 6 BRN market traction

Source: BrainChip Investor presentation, April 2022

Fig 7 Edge based devices requiring AI by 2025



Source: BrainChip, Share Café Podcast presentation, June 2021

The growth proposition

- **Strong demand for AI enabled IoT and edge devices**
- **Independence from cloud:** Akida's capabilities are suited to address the sustainability concerns raised by extreme power consumption and emissions from data centres, allowing a shift from traditional cloud data centres to processing on the device. Akida is ~97% more energy efficient compared to processing the same task at a data centre.
- **International growth:** New sales partnerships with technology solutions provider SalesLink and high-tech distributor Eastronics to expand Akida's commercial reach in Europe and Israel.
- **Future products:** BRN intends to evolve the Akida technology overtime. Chips currently in development include AKD2000, AKD3000 and the AKD500.

The business model

- **Chips and board sales:** Revenue from sales of Akida chips manufactured by third parties (i.e TSMC in Taiwan). PCIe Boards and Akida Development Kits (ARM-based Raspberry Pi & x86 Shuttle PC) are also available for order on their website.
- **IP licensing fees:** From single product to multi-product use, customers can use the Akida IP by purchasing IP licenses.
- **Non-recurring engineering (NRE):** One-off fees related to adapting Akida technology to specific integration needs.
- **Royalties:** Recurring royalties from each product sold that includes Akida IP by customers.

The value proposition

- **Early Access Program (EAP**): BRN receives market validation for Akida technology by signing multiple agreements, including with Ford Motor Company, Valeo and NASA. In January 2022, BRN announced that Information Systems Laboratories is developing an AI-based radar solution for the Air Force Research Laboratory based on Akida.
- **Easy adoption:** BRN's MetaTF software automates conversion from traditional networks into immediately usable and efficient spiking networks.

The main risks

- **IP risk:** Current portfolio has 8 US and 1 Chinese granted patent, but BRN should continue expanding international patent filings to maintain global competitive advantage. They have 21 pending applications in the US, Europe, Canada, Japan, Korea, Australia, Mexico, Brazil and Israel.
- **Reliance on key personnel:** If one or more key management personnel (BoD, CTO, CDO, CFO, sales VP) leave, it could weaken company management and strategy.
- **Competition and new technologies:** Some existing and/or potential competitors (e.g Intel, IBM) are more well-resourced than BRN which could risk future growth and development.
- **Future funding requirements:** Operations are largely loss-making to date, so BRN should secure additional funding to support development activities. Option agreement with LDA Capital allows BRN to access A$65M funding when necessary until December 2023.

Strengths

- **Crossed threshold from R&D into commercialisation:** BRN evolved its operations to become the world's first and only commercial producer of neuromorphic AI chips in FY21.
- **Strong partnerships:** BRN has IP licensing agreements with Japan-based ASIC leader MegaChips and global semiconductor manufacturer Renesas.
- **Board composition:** Seasoned and highly qualified management team. Short average tenure of board members at 1.7 years could bring new strategic direction for BRN.

Weaknesses

- **Volatile share price:** ASX has conducted both an aware and price query for BRN in October 2021 and January 2022.
- **Cash burn:** Net operating cash flows in FY21 were US$14.2M and are expected to grow for FY22 from increased Akida production.
- **Market uncertainty:** SNN technologies are at an early stage so there isn't a clear dominant technology in the market.

Opportunities

- **Large and fast-growing addressable market:** Akida architecture is flexible to address requirements for the increasing number of IoT and edge devices in consumer and industrial applications (e.g automotive, healthcare).
- **Expansion outside of North America:** North America is BRN's primary target market but through IP partners Renesas and MegaChips, BRN looks to enter the Japanese market and access the consumer electronics industry.

Threats

- **Competition**: Intel and IBM are bigger companies with more resources to potentially develop neuromorphic chips with higher performance and utility, which could render Akida obsolete.
- **Share overhang**: LDA Capital can sell the shares it owns in BRN (other than collateral shares) on the market at any time which would create sudden adverse share price movements.
- **Low adoption rate of Akida:** Customers' unfamiliarity with neuromorphic chips inhibits BRN's foray into foreign markets.

Fig 8 BrainChip Financial Summary

BrainChip (BRN)						Market Price:				A$1.00
Interim		**1H20**	**2H20**	**1H21**	**2H21**	**Full year**		**FY18**	**FY19**	**FY20**	**FY21**
Revenue	**US$m**	**0.0**	**0.1**	**0.8**	**0.8**	**Revenue**	**US$m**	**0.9**	**0.1**	**0.1**	**1.6**
Cost of revenue	US$m	-	(0.0)	(0.1)	(0.1)	Cost of revenue	US$m	-	-	(0.0)	(0.3)
Gross profit	**US$m**	**0.0**	**0.1**	**0.6**	**0.7**	**Gross Profit**	**US$m**	**0.9**	**0.1**	**0.1**	**1.3**
Other Income	US$m	-	-	0.4	-	Other Income	US$m	-	-	-	0.4
OPEX, net (incl. D&A)	US$m	(6.2)	(5.0)	(9.5)	(11.8)	OPEX, net (incl. D&A)	US$m	(17.6)	(11.0)	(11.2)	(21.2)
Operating loss	**US$m**	**(6.2)**	**(5.0)**	**(8.4)**	**(11.1)**	**Operating loss**	**US$m**	**(16.7)**	**(10.9)**	**(11.2)**	**(19.5)**
EBITDA	**US$m**	**(5.9)**	**(4.4)**	**(9.1)**	**(9.8)**	**EBITDA**	**US$m**	**(14.4)**	**(10.0)**	**(10.2)**	**(18.9)**
Total other income/(expense)	US$m	(0.7)	(15.0)	(0.7)	(0.6)	Total other income/(expense)	US$m	0.1	(0.4)	(15.7)	(1.3)
Loss before income taxes	**US$m**	**(6.9)**	**(20.0)**	**(9.1)**	**(11.7)**	**Loss before income taxes**	**US$m**	**(16.5)**	**(11.3)**	**(26.8)**	**(20.8)**
Tax (expense)/benefit	US$m	-	-	(0.1)	(0.0)	Tax (expense)/benefit	US$m	-	-	-	(0.2)
Net loss	**US$m**	**(6.9)**	**(20.0)**	**(9.3)**	**(11.7)**	**Net loss**	**US$m**	**(16.5)**	**(11.3)**	**(26.8)**	**(21.0)**
EPS/(LPS)	cps	(0.5)	(1.3)	(0.5)	(0.7)	EPS/(LPS)	cps	(1.6)	(1.0)	(1.8)	(1.2)
PER (reported)	x	nmf	nmf	nmf	nmf	PER (reported)	x	nmf	nmf	nmf	nmf
Profit and Loss Ratios		**FY18**	**FY19**	**FY20**	**FY21**	**Cashflow Analysis**		**FY18**	**FY19**	**FY20**	**FY21**
Revenue growth	%	252%	(92%)	60%	1215%	**EBITDA**	**US$m**	**(14.4)**	**(10.0)**	**(10.2)**	**(18.9)**
EBITDA growth	%	(16%)	30%	(2%)	(86%)	Change in working capital	US$m	7.2	1.0	0.2	4.8
EV/Sales	x	1386.3	17390.1	10876.8	827.4	**Operating cash flows**	**US$m**	**(7.2)**	**(9.0)**	**(10.0)**	**(14.2)**
EV/EBIT	x	-78.9	-120.3	-117.7	-67.3	Capex	US$m	(1.2)	(0.2)	(0.0)	(0.3)
						Other	US$m	-	-	-	-
Balance Sheet Ratios		**FY18**	**FY19**	**FY20**	**FY21**	**Investing cashflows**	**US$m**	**(1.2)**	**(0.2)**	**(0.0)**	**(0.3)**
						Receipts from the issue of shares	US$m	-	7.4	2.0	-
Net Debt/(Net Cash)	US$m	(7.3)	(6.7)	(15.5)	(19.2)	Receipts from the exercise of unlisted o	US$m	-	-	3.4	10.2
Net Debt/Equity	x	(0.8)	(0.7)	(0.9)	(1.0)	Other	US$m	(0.0)	1.8	16.1	4.5
Net Debt/EBITDA	x	0.5	0.7	1.5	1.0	**Financing cash flows**	**US$m**	**(0.0)**	**9.2**	**21.5**	**14.7**
Interest cover (EBIT)	x	-	(20.6)	(39.4)	(675.0)						
EFPOWA	m	1,006.9	1,187.2	1,527.5	1,719.2	**Net Cashflow**	**US$m**	**(8.5)**	**0.1**	**11.4**	**0.3**
KPIs		**FY18**	**FY19**	**FY20**	**FY21**	**Balance Sheet**		**FY18**	**FY19**	**FY20**	**FY21**
Product revenue	US$m	0.108	0.010	0.030	0.196	Cash	US$m	8	8	19	19
License revenue	US$m	0.327	0.002	0.000	0.825	Receivables	US$m	0	1	1	1
Development service revenue	US$m	0.513	0.063	0.091	0.567	Financial asset	US$m	-	-	1	-
						PP&E	US$m	0	0	0	0
Revenue from NA	US$m	0.7	0.0	0.1	1.4	Intangibles	US$m	2	2	1	2
Revenue from Oceania	US$m	-	-	-	0.0	Other	US$m	0	0	0	1
Revenue from EMEA	US$m	0.2	0.1	0.0	0.2	**Total Assets**	**US$m**	**10**	**11**	**23**	**24**
						Payables	US$m	1	0	1	1
						Deferred revenue	US$m	-	-	0	1
						Debt	US$m	0	1	4	0
						Defined benefit plan	US$m	0	0	0	0
						Other	US$m	0	0	1	2
Current price	A$	1.00				**Total Liabilities**	**US$m**	**1**	**2**	**6**	**5**
Market cap	US$m	1287				Shareholders Funds	US$m	9	9	17	19
Enterprise value	US$m	1314				Other	US$m	-	-	-	-
						Shareholder Equity	**US$m**	**9**	**9**	**17**	**19**

Source: Company data, April 2022

Important disclosures:

Recommendation definitions

Macquarie – Asia and USA
Outperform – expected return >10%
Neutral – expected return from -10% to +10%
Underperform – expected return <-10%

Macquarie – Australia/New Zealand
Outperform – expected return >10%
Neutral – expected return from 0% to 10%
Underperform – expected return <0%

Note: expected return is reflective of a Medium Volatility stock and should be assumed to adjust proportionately with volatility risk

Volatility index definition*

This is calculated from the volatility of historical price movements.

Very high–highest risk – Stock should be expected to move up or down 60–100% in a year – investors should be aware this stock is highly speculative.

High – stock should be expected to move up or down at least 40–60% in a year – investors should be aware this stock could be speculative.

Medium – stock should be expected to move up or down at least 30–40% in a year.

Low–medium – stock should be expected to move up or down at least 25–30% in a year.

Low – stock should be expected to move up or down at least 15–25% in a year.
* Applicable to select stocks in Asia/Australia/NZ

Recommendations – 12 months
Note: Quant recommendations may differ from Fundamental Analyst recommendations

Financial definitions

All "Adjusted" data items have had the following adjustments made:
Added back: goodwill amortisation, provision for catastrophe reserves, IFRS derivatives & hedging, IFRS impairments & IFRS interest expense
Excluded: non recurring items, asset revals, property revals, appraisal value uplift, preference dividends & minority interests

EPS = adjusted net profit / efpowa*
ROA = adjusted ebit / average total assets
ROA Banks/Insurance = adjusted net profit /average total assets
ROE = adjusted net profit / average shareholders funds
Gross cashflow = adjusted net profit + depreciation
*equivalent fully paid ordinary weighted average number of shares

All Reported numbers for Australian/NZ listed stocks are modelled under IFRS (International Financial Reporting Standards).

Recommendation proportions – For quarter ending 31 Mar 2022

	AU/NZ	Asia	USA	
Outperform	63.27%	69.10%	79.79%	(for global coverage by Macquarie, 6.23% of stocks followed are investment banking clients)
Neutral	30.61%	20.65%	18.09%	(for global coverage by Macquarie, 3.33% of stocks followed are investment banking clients)
Underperform	6.12%	10.25%	2.13%	(for global coverage by Macquarie, 1.16% of stocks followed are investment banking clients)

Company-specific disclosures:

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