PITT STREET RESEARCH

Weebit Nano

One step away from commercialisation

Share Price: $3.05

ASX: WBT

Sector: Technology Hardware and Equipment

10 November 2022

The next generation of electronic applications requires Non-Volatile Memory (NVM) to offer superior performance at smaller process geometries. Flash technology, which has served the needs of the NVM market for decades, cannot adequately meet the growing performance needs and is too expensive to scale down below 40nm. ReRAM, an emerging NVM technology, offers significant advantages over Flash across all key metrics and, hence, can capture a share of the NVM market currently served by Flash.

WBT targets a fast-growing market opportunities

Weebit Nano (ASX:WBT) is poised to enter the embedded NVM segment and is likely to find applications for its ReRAM technology in several growing end-user markets, such as Analogue and Power ICs, IoT devices, Edge AI, Automotive, Industrial, Aerospace and Defence within the embedded NVM segment. At the same time, it is also pushing to enter the discrete, or stand-alone, NVM segment in the medium term. Together, these two segments are expected to grow into a US$5.6b market by 2027 of which US$935m is expected to be initially addressed by ReRAM technology. The longer-term opportunity is substantially larger, in our view, while the immediate term embedded opportunity is far more profitable (gross margins).

On track to enter embedded NVM market in 2023

In the last year, Weebit Nano has covered a lot of ground in the development and commercialisation of its technology. Since finalising its first commercial agreement with SkyWater Technology (a US-based foundry), it has demonstrated the capabilities of its technology at 28nm. WBT has also - as an NVM block embedded on an SoC (System-on-chip) - completed the tape out of its technology to SkyWater's fab and reported positive results from the qualification process it performed on wafers manufactured at CEA-Leti's facility.

In talks with multiple tier-1 fabs

These milestones bring WBT closer to commercialisation and provide market validation, which will help advance current discussions with tier-1 fabs. We expect some of these to come to fruition in the near term. WBT continues to work on scaling down its technology to 22nm and will look to move into volume production at SkyWater in 2023.

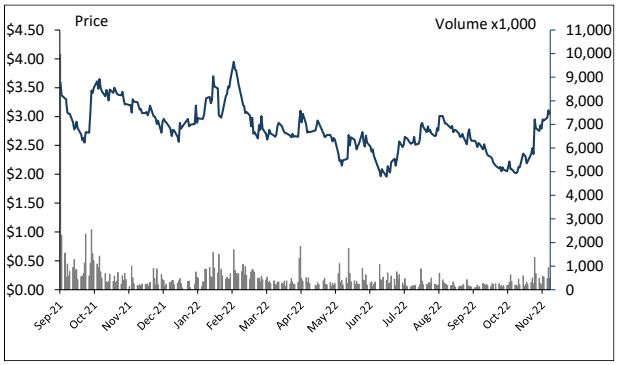
Valuation of A$4.75 per share

We reiterate our valuation for WBT of A$4.75 per share (see full valuation here). This represents an enterprise value of ~$750m, which is in line with past industry M&A deals and based on the expectation of additional commercial deals in the near to medium term. We are anticipating more deals helped, in part, by the tape out at SkyWater. Such deals should serve as catalysts for the share price and may, in turn, attract other prospects. See page 15 for key investment risks.

Market Cap. (A$ m)	525.6
# Shares outstanding (m)	172.3
# Share fully diluted (m)	189.9
Market Cap Full. Dil. (A$m)	579.1
Free Float	100%
12-month high/low (A$)	4.01/1.92
Avg. daily volume ('1000)	403
Website	www.weebit-nano.com

Source: Company, Pitt Street Research

Share price (A$) and avg. daily volume (k, r.h.s.)



Source: Thomson Reuters, Pitt Street Research

Valuation metrics	
Valuation per share (A$)	4.75

Source: Pitt Street Research

Analyst: Marc Kennis

Tel: +61 (0)434 838 134

marc.kennis@pittstreetresearch.com

Disclosure: Pitt Street Research directors own shares in Weebit Nano Ltd.

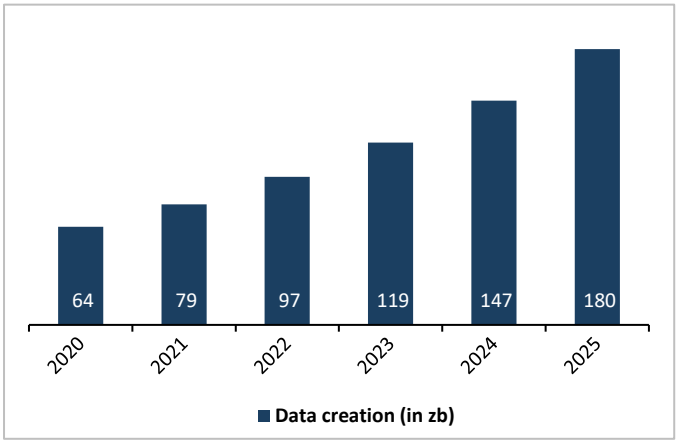
Table of Contents

The NVM market is expected to grow significantly

The growth in the number of connected devices and data will drive growth in the NVM market

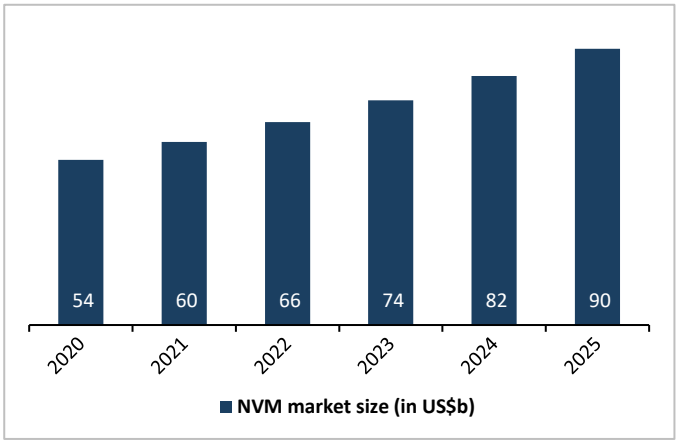
In 2020, 64.1zb (zettabyte, equivalent to 10^{21} bytes) of data was created and consumed globally through inter-connected electronic devices and network systems. As the adoption rate of IoT devices increases further at the government, enterprise and individual level, the number of connected devices in the world is expected to reach 80bn by 2025. These devices are likely to drive the proliferation of data and generate 180zb of data each year (Figure 1). Gathering, storing and processing the data generated by these devices is expected to drive the demand for NVM (non-volatile memory), which is at the heart of data storage and processing functions, to US$90bn by 2025 (Figure 2).

Figure 1: Forecast for global annual data created (2020-2025)



Source: Investor Presentation - April 2022, Investors, Company website

Figure 2: NVM market - Growth forecast (2020-2025)



Source: Investor Presentation - April 2022, Investors, Company website

Flash memory has reached its limits

Flash technology, which represents a US$67bn market, is not commercially viable to use in several segments of next-generation devices

The NVM market has traditionally been led by Flash memory technology, representing a US$67bn market on its own. As the quantum of data grows, the demands from NVM chips are also evolving. A next generation of devices and applications requires NVM chips to perform faster and consume lower power reliably and cost-effectively. Flash memory technology has already had several advancements and has either reached its limit or is close to reaching it in several key NVM segments. Additionally, since flash memory technology uses electrical charges to store data, it reduces the chip's tolerance to radiation, making it difficult to incorporate in designs for application in medical, industrial and aerospace industries. Most importantly, Flash memory technology has reached its scaling limits and achieving smaller process geometries would be highly cost-prohibitive, necessitating the exploration of new options to meet the needs of the current generation of devices.

ReRAM the most promising alternative technology

The complexities around the scalability of Flash memory have brought alternative technologies, such as Phase Change Memory (PCM), Magneto resistive random-access memory (MRAM) and Resistive Random Access Memory (ReRAM) to the forefront in recent years. Each of these could help address the shortcomings of Flash in the embedded and discrete NVM market. The alternatives, however, are not without their flaws. Production of the three alternatives, in general, would entail procurement of rare earth materials, would not fit in the fabs' standard manufacturing flow and would generally require substantial capital investment.

ReRAM has an edge over MRAM and PCM

PCM and MRAM have been around for more than a decade, but have gained momentum for the embedded NVM segment only in the past several years in a bid to replace Flash. The potential of embedded PCM remains a question owing to technical and cost challenges. MRAM, which has received backing from prominent names such as Samsung and UMC on its potential, has been the leading contender for the embedded market. However, questions remain around its reliability, cost effectiveness and tolerance to electromagnetic fields, limiting its application to only a niche segment of the overall market.

ReRAM, a newer technology, has lagged behind MRAM in terms of R&D until recently. However, it is the most balanced technology in terms of specifications and cost and is now emerging as the most promising alternative to displace Flash memory.

Weebit Nano's ReRAM technology offers significant benefits

Weebit Nano's proprietary ReRAM technology, developed in collaboration with CEA-Leti, is expected to outperform Flash memory and alternative technologies across key metrics:

Figure 3: Advantages of Weebit's ReRAM

Metric	Advantages of Weebit's ReRAM
Endurance	Weebit's ReRAM can handle 100k-1m read/write cycles, as compared to 1-10k for today's embedded Flash applications, thus performing 10-100x better.
Data Retention	Weebit's ReRAM can store data for 10 years at 175°C or 20 years at 125°C, substantially superior to other NVM alternatives, which often have a data retention capacity of just 10 years at 85-105°C.
Power Consumption	Weebit's ReRAM has lower power consumption levels and lower voltage requirements compared to Flash technology and thus enables longer battery life.
Access time	Weebit's ReRAM has a 100x faster access time than Flash. It is also faster than most other alternatives.
Environmental tolerance	Weebit's ReRAM can withstand up to 350x more radiation than Flash, is tolerant to electromagnetic interference (unlike MRAM) and is thermally very stable (unlike PCM).
Cost	Weebit's ReRAM adds 5-7% to the wafer cost as compared to 10-20% for flash and 30%, or even 40%, for MRAM.
Manufacturing and Capex	Weebit's ReRAM can be produced using fab-friendly materials and does not require special equipment, as compared to other NVMs, which are more complicated and Capex-heavy to manufacture. This is especially true with regards to MRAM which uses very unconventional materials and tools.
Security	Weebit's ReRAM does not use a floating gate charge (unlike Flash), making it difficult to change its internal state. It can also withstand magnetic attacks (unlike MRAM) and optical attacks.

Sources: ReRAM Advantages, Technology, Company website

Addressing three main target markets

Weebit Nano is aiming to address three main markets with its ReRAM technology; embedded memory, discrete memory and neuromorphic processing.

The Embedded NVM market is ripe for disruption

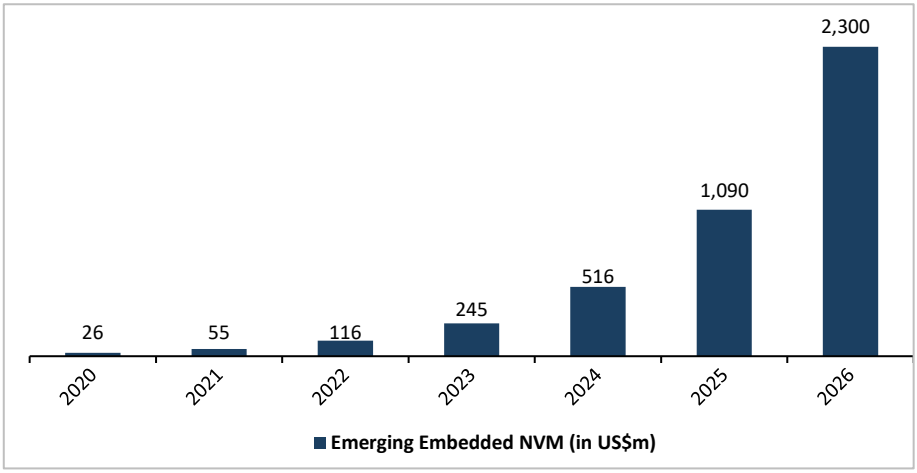
Systems on a Chip (SoCs) need memory to perform code and data storage, security key storage, device configuration and device identification functions. Therefore, having embedded memory take up valuable chip real estate comes at a premium. The growth of smart connected devices in segments such as IoT, wearables, medical, industrial, automotive and mobile computing, is increasing the performance demands of SoCs, which are now required to integrate more capabilities and memory. This has increased the burden on embedded NVMs to pack superior performance at smaller process geometries.

However, embedded Flash memory, the dominant embedded NVM technology today, has reached its scaling limits. SoCs with embedded Flash at 40nm are common and have served well for years, but the new generation of applications need embedded memory modules at resolutions of 28nm or below. With Flash memory, process geometries of 28nm or lower would lead to leakage of current between adjacent memory cells, which would be too expensive to overcome, rendering the scaling down commercially unviable.

ReRAM may capture 22% of the US$2.3bn market for emerging embedded NVM technologies by 2026

This issue has created a gap in the market, representing an initial opportunity of US$2.3bn by 2026 (Figure 4) for a new, easily scalable alternative. According to i-MicroNews estimates, ReRAM is expected to capture 22% of this market. But we believe that, based on successful commercialisation and market uptake, it could command a substantially higher market share.

Figure 4: Emerging Embedded NVM market – Growth forecast (2020-2026)



Source: 'Emerging Non-Volatile Memory 2021', i-MicroNews

ReRAM fits well in several embedded NVM end-user segments

ReRAM's road to commercialisation would entail entering into 1 or 2 niche segments in the initial years and growing to new segments in each subsequent year (Figure 5). Weebit's ReRAM technology could enter the market as early as next year, targeting the following lucrative segments:

Weebit Nano could enter the market for Analog and Power ICs in 2023

- **Mixed Signal, Analog and Power ICs**: Analog and Power ICs used across a range of electronic devices need MCUs (Micro Controller Units) to provide analytical and processing capabilities to store program code and enable program updates. MCUs, in turn, need embedded NVM to perform these tasks. The use of embedded Flash at geometries smaller than 40nm would compromise the performance of MCUs and lead to high costs. And Flash below 40nm would need to be external, which is slow, less secure and expensive. Flash is also a FEOL (front-end-of-line) technology and therefore affects the overall design of the chip. ReRAM, integrated in the back end of the manufacturing line (BEOL), ensures that performance is not compromised and simplifies the manufacturing process for fabs.
- **IoT devices**: IoT devices are sensor-rich and need to store data locally (on the device) for which they require NVMs that can combine high performance with low energy requirements and low costs. This can be achieved by reducing the size of NVMs. Embedded Flash cannot scale below 40nm and so must be used in conjunction with external memory to fulfil the requirements of these devices. ReRAM, on the other hand, offers many benefits over Flash in these respects as it can improve speed, provide better security and has a lot lower power consumption, which extends battery life.

Weebit's ReRAM technology can be used in diverse settings in numerous end-user segments

- **Edge AI:** Edge AI applications are required to store weights for artificial neural networks, which need a storage capacity of anywhere between 10 – 100 MB. SRAM and DRAM are volatile, costly and require an off-chip NVM if smaller than 40nm. Flash is non-volatile, but scalability issues mandate the use of external memory. ReRAM, however, meets the performance requirements, is 4x smaller than SRAM, is non-volatile and can scale to smaller process geometries, making it ideal for use in Edge-IA applications. While ReRAM technology with the storage capacity needs of Edge AI applications has not been developed yet, it could reach that mark and possibly enter this segment in a few years' time.

Figure 5: Tentative timeline and Market Size of End-user segments for Weebit's ReRAM

End-user segment	Timeline for entry (years)	Market size forecast (US$)
Mixed Signal, Analog and Power ICs	1	83b (2022)
IoT devices	1	80b (2025)
Edge AI	2+	28b (2028)
Automotive/Industrial	4-5 (mostly due to regulation)	78b (2026)
Aerospace and Defence	1	8.6b (2027)

Sources: Investor Presentation – April 2022, Investors, Company website; 'The Future of Memory - The Time for ReRAM', Circuit Cellar

- **Automotive/Industrial**: Vehicles and Industrial Applications are now fitted with multiple chips that need NVM to perform various functions, such as storing code and collected data in demanding environmental conditions. Electric vehicles, for example, need NVMs that are immune to electromagnetic fields (a limitation of MRAM). Weebit's ReRAM can

deliver superior performance and better endurance at high temperatures (175°C) compared to Flash and other alternatives. It is much better scalable and less costly to implement, making it a suitable alternative for the Automotive/Industrial market.

– **Aerospace and Defence**: Applications used in the Aerospace and Defence industries remain operational for a long time without maintenance in harsh conditions. As a result, NVMs used in these applications should have high endurance and reliability. Weebit's ReRAM beats Flash in terms of endurance and immunity to radiation and electromagnetic fields (mostly relevant in space). Therefore, ReRAM is ideal for Aerospace and Defence applications.

SkyWater manufactured first wafers with WBT's embedded ReRAM module

On 8 November 2022, WBT announced that it received the first batch of wafers from SkyWater that incorporate WBT's embedded ReRAM modules. This is the first time WBT's ReRAM has been manufactured in a commercial fab, which is very significant as it demonstrates the technology can be incorporated into existing designs and can be manufactured on industry standard manufacturing tools.

The chips were manufactured using SkyWater's 130nm CMOS (Complementary Metal Oxide Semiconductor) manufacturing process. CMOS is the most-used chip manufacturing process in the industry.

Qualification expected in first half of 2023

We believe WBT's conversations with current and future prospective customers will be a lot easier now that SkyWater has manufactured these demonstration chips in a commercial fab.

The next step is for WBT to qualify these chips, i.e. after they have been diced, packaged and tested. Once qualification is complete, expected in first half of 2023, WBT and SkyWater will be ready for mass production. Both companies have already started to engage with prospective customers, which leads us to believe that volume production could ramp up within a year post-qualification. For instance, a customer deal could be finalised ahead of final qualification, but conditional on actual successful qualification.

Leti-manufactured ReRAM modules successfully qualified

As a testament to the company's progress in embedded ReRAM, on 27 October 2022 WBT announced that it successfully qualified its ReRAM module as manufactured by CEA-Leti, its French development partner. The qualification was performed based on JEDEC standards, used in non-volatile memories. JEDEC (Joint Electron Device Engineering Council) is the global leader in developing open standards for the microelectronics industry, based in Virginia, USA.

Qualification of Leti-manufactured modules expedites commercial discussions

The qualification confirmed endurance of 10,000 read/write cycles, similar to Flash memory, and a retention rate of 10 years at 85°C, which is considered "industrial grade". Additionally, it confirmed 3 Surface Mount Technology reflow cycles. SMT is where the chip is soldered onto a carrier so it can be placed on a printed circuit board. If this can be done 3 times at temperatures of up to 260 degrees C for 15 minutes, it confirms the chip's robustness.

The qualification of the Leti-manufactured chips is separate from the aforementioned qualification that is currently being performed on the

SkyWater-manufactured chips and should expedite discussions with prospects. These prospects will still want to do their own evaluation and, if they move forward with WBT on commercial terms, their own qualification. But the fact that Leti-manufactured chips have been JEDEC qualified is a big tick for WBT in engaging with these prospects.

At the Flash Memory Summit in August 2022, the company demonstrated their Leti-manufactured chip, which was subsequently fully qualified, as an embedded NVM block. The demo showed how the memory block would keep the data retained also when the power was turned off. Additionally, it only stored modified data and rightfully ignores unchanged data, thereby saving on memory access time and power consumption. A video of that demonstration is available here: https://www.youtube.com/watch?v=-PH7jhq4J0k

Displacing NAND Flash in the discrete NVM segment

Discrete NVMs are stand-alone non-volatile memory chips that have a high storage capacity. Discrete memory chips are used in low-cost, high-density on-device data storage applications, such as mobile phones, PCs, tablets, USB drives and SSDs. Similar to the market for embedded NVMs, the market for discrete NVMs is dominated by a particular type of Flash memory, notably NAND Flash.

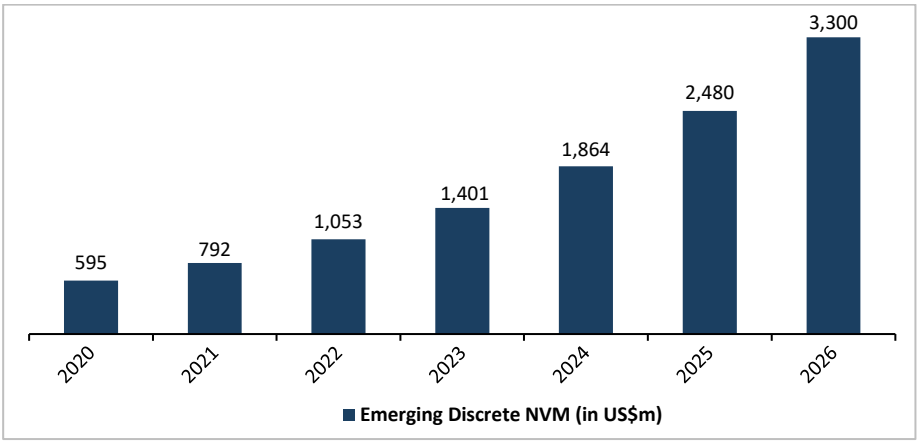
3D NAND Flash technology will stop scaling beyond a certain point

NAND flash hit its scaling limits in 2007, which prompted the players in the market to move from a 2D structure to a 3D structure in which NAND cells could be stacked vertically as layers on top of each other. This has allowed NAND flash to remain the dominant technology in the market and meet unprecedented power, performance and capacity requirements.

ReRAM could capture 13% of the US$3.3bn market for Emerging Discrete NVM technologies

3D NAND Flash was introduced in 2013 with 24-layer NAND Flash which has now expanded to 232 vertical layers (announced by Micron in July 2022). However, while 3D NAND Flash has prolonged the useful life of Flash memory in the last decade, the addition of layers adds to the complexities of the manufacturing process. It requires high capex investments, which will make it unfeasible beyond a certain number of layers. This will open up a market opportunity of US$3.3bn by 2026 (Figure 6) for emerging NVM technologies in the discrete NVM market, 13% of which is expected to be captured by ReRAM technology.

Figure 6: Emerging Discrete NVM market – Growth forecast (2020-2026)



Source: 'Emerging Non-Volatile Memory 2021', i-MicroNews

ReRAM to fill the gap between DRAM and Flash

A computer system primarily consists of two types of memory, i.e. DRAM, which has low latency, lower storage capacity and higher costs and is used for temporary storage; and NAND flash, which has high latency, high storage capacity and is relatively inexpensive and is used for permanent storage.

Traditionally, applications requiring high performance levels have utilised DRAM, which has latencies of nanoseconds. As data storage requirements have grown over the years, the use of Flash memory has increased to complement DRAM. However, NAND Flash operates at latencies of microseconds rather than nanoseconds, but offer higher storage capacities.

Enter ReRAM

ReRAM would be a perfect fit for the newly emerging Storage Class Memory segment

The need for low latency and non-volatile storage of data has driven the push for ReRAM, which acts as a bridge between DRAM and NAND Flash and fits in the middle of the two, providing performance that is superior to NAND Flash, but at a significantly lower cost and power than DRAM. It is ideal for computing environments that need to process big datasets and cannot afford to lose in-memory data. It could see applications in cyber threat analysis, fraud detection and stock market trading – all of which need to store and process large volumes of data.

We believe Weebit's ReRAM is ideally positioned to bridge the gap between DRAM and Flash once Weebit gets its discrete ReRAM into production in the coming years.

Weebit Nano's positioning in the discrete NVM segment

Weebit Nano has already made some progress in its pursuit of the discrete NVM segment by developing a BEOL selector and demonstrating its integration with ReRAM cells. The BEOL selector will be ideal for scaling and achieving high memory densities and opening up opportunities in several end-user segments. It is still early days for Weebit Nano in the discrete NVM segment, but it aims to enter this market in the medium term. The selector will also work in embedded memory, which means the embedded memory module can scale even smaller than previously thought.

Several other players are also attempting to capture market share in the discrete NVM segment, including Everspin Technologies (with Global Foundries) and Avalanche Technology (with UMC), which have ventured into the development of MRAM.

In contrast, Intel and Micron have launched, and subsequently terminated, their joint 3D XPoint technology (a type of PCM technology) with limited success. ReRAM's superior specifications and ability to scale at lower cost should enable Weebit Nano to successfully take on this type of competition.

Neuromorphic Computing presents a long-term opportunity

What is Neuromorphic Computing?

A neuromorphic computing system analyses and processes information by mimicking how a human brain works. In other words, the basic idea behind neuromorphic computing is to use a microchip to leverage neuroscience concepts and knowledge in computing architecture. Please see our report on BrainChip (ASX:BRN) for more background on neuromorphic processing.

In normal applications, memory and processing form two different elements. To process data, it must be sent back and forth between the two units. But the human brain is much more efficient and processes data while collecting and storing it. Neuromorphic computing (or processing) aims to emulate the efficient processing engine of the human brain in a computer processor.

On-board and real-time processing of data collected by sensors has a very wide range of application areas, including ADAS and autonomous vehicles, any basically any Edge devices that has offline and real-time processing requirements.

So, while currently at an early stage, neuromorphic processing capabilities, once fully developed, will serve many end-user industries. Considered the future of AI, neuromorphic processing has piqued the interest of several established companies, such as Intel and IBM, who are investing in R&D teams and capabilities to gain an edge.

Weebit Nano has high potential in Neuromorphic Computing

Since conventional computing systems have separate processors and memory units, conventional chip architecture poses substantial challenges when it comes to hardware implementation and deployment of neuromorphic computing. To try and deal with that, several deployment techniques have been proposed, which entail cutting down on memory requirements to fit the hardware, which is actually undesirable. This has brought ReRAM into the picture.

ReRAM could offer the following advantages:

1) smaller footprint and non-volatility (compared to SRAM),

2) lower voltages and scaling below 28nm (compared to Flash),

3) lower cost, lower area, multi-level cell (compared to MRAM).

Neuromorphic computing could be another use-case for Weebit's ReRAM in the long term

Taking this a step further, WBT's ReRAM can implement synapses similar to human synapses, as demonstrated at the Flash Memory Summit in 2019 using Spiking Neural Network (SNN) algorithms developed by CEA-Leti. The demonstration provided a proof-of-concept, highlighting the potential of WBT's ReRAM, which can be further explored in the long term to address a potential US$35bn opportunity by 2035.

Limited competition in mainstream applications

The NVM market is a competitive space and is expected to remain that way as new firms emerge in a bid to develop next-gen technology. Leading foundries, such as Global Foundries and UMC, have all partnered with IP licensors who are aiming to develop and sell market-disrupting alternatives for Flash memory.

MRAM and PCM are niche technologies compared to ReRAM

While new players are experimenting with technologies such as Flash, MRAM and PCM, we believe Weebit Nano would primarily face competition from other ReRAM developers as ReRAM is the most versatile option out of all alternatives. Additionally, MRAM, PCM would likely only be viable for certain, specific applications.

In recent years, Crossbar and Adesto have emerged as two competing ReRAM developers. However, Crossbar has decided to focus on only a niche segment, the hardware security field, and is primarily working in China following funding by several Hong Kong and China-based funds. In contrast, Adesto

(now a part of Renesas Electronics) has not provided any updates on its ReRAM technology for a long time. Renesas is not a memory company and isn't investing in ReRAM.

Realistically, this only leaves one other firm that currently leads WBT with its own ReRAM technology – TSMC – the largest chip foundry in the world.

A big market opportunity for non-TSMC ReRAM

IDM's and other foundries could leverage Weebit Nano's technology to compete with TSMC

TSMC is working with a technology partner and has already brought ReRAM at 40nm to the market. It has also developed ReRAM at 22nm. Both are now production-ready. It has an established brand name and a huge resource base. However, since it is a foundry, the only companies that can use its ReRAM technology are TSMC's customers. Therein lies the opportunity for Weebit Nano, in our view.

All other foundries competing with TSMC who are looking to integrate ReRAM into their offering, will require ReRAM technology of their own as they won't be able to access that of TSMC. Since WBT's embedded ReRAM technology is currently the only other option on the market, the company should be able to benefit from this dynamic and partner with foundries around the world. WBT already announced it is currently talking to multiple tier-1 fabs. Additionally, we would expect Integrated Device Manufacturers (IDMs) and fabless chip designers, such as Intel, NXP, STM, NVIDIA and ARM to be interested in integrating non-TSMC ReRAM into their products as well.

Realistically, we expect WBT to be able to sign one or more commercial deals, in addition to the existing one with SkyWater, in the near to medium term.

Agility and flexibility are WBT's greatest trump cards

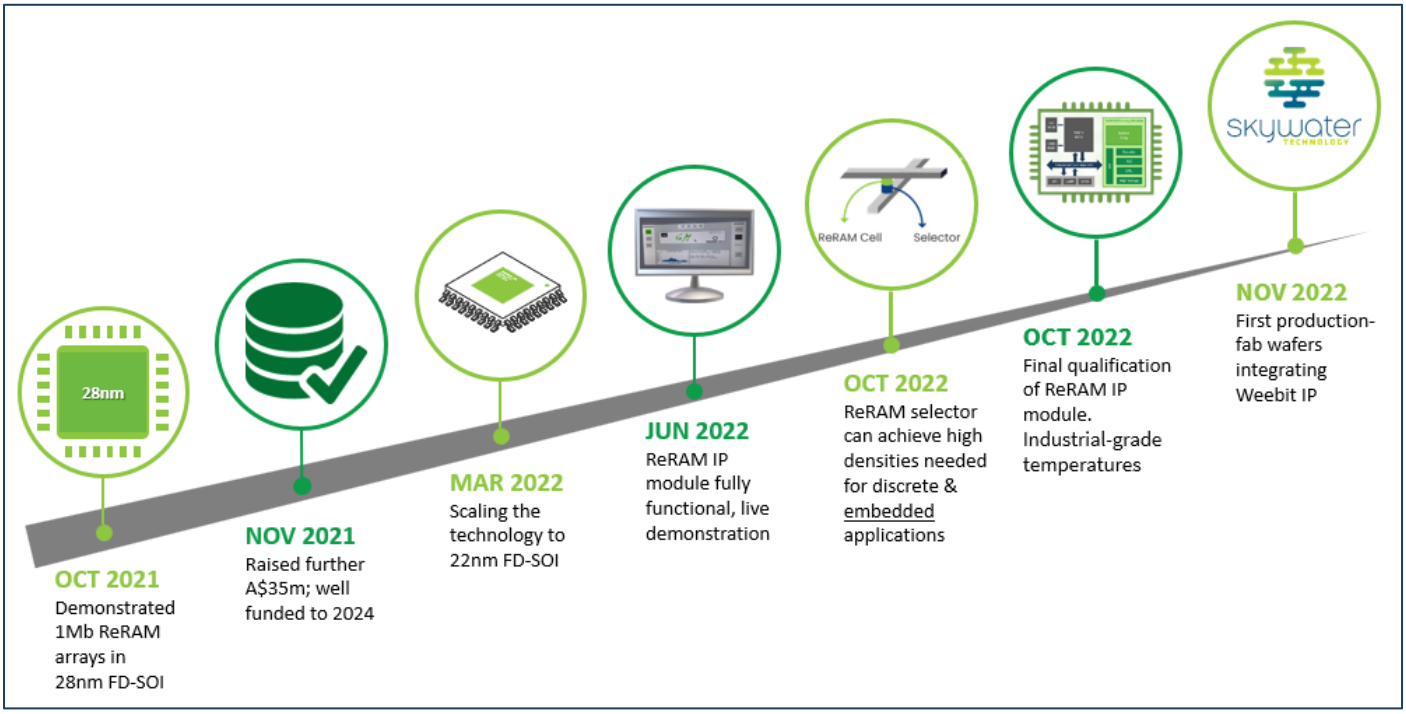
Apart from being the only other ReRAM game in town besides TSMC, WBT has a few other things going for it. As opposed to TSMC, which essentially sells ReRAM as a standard IP stack that customers have to design into their own products themselves, WBT is very open and willing to work with customers to provide them with tailor-made solutions.

This flexibility is expected to win over foundries, IDMs and fabless chip companies looking for specific solutions to their design challenges. Where TSMC gives them an off-the-shelve product, WBT will be able to provide bespoke solutions.

Weebit's road to commercialisation by 2023

Weebit Nano has taken notable strides forward to successfully develop and commercialise its proprietary ReRAM technology for the NVM market. Since July 2021, it has raised A$50.8m through a private placement and exercise of options, which has enabled it to achieve the following milestones (Figure 7).

Figure 7: Key milestones achieved in the last 13 months



Sources: Investor Presentation – August 2022, Investors, Company website

Secured first commercial agreement

The agreement with SkyWater provides market validation and should provide Weebit Nano with its first revenues

In September 2021, Weebit Nano signed its first commercial agreement with NASDAQ-listed SkyWater Technology (NASDAQ: SKYT), a US-based foundry which will license Weebit ReRAM technology, integrate it into customer designs and commercialise it.

SkyWater Technology is a pure-play semiconductor foundry that partners with IDMs and OEMs in the Consumer, Healthcare, Industrial, Aerospace & Defence and Automotive markets. It has a DMEA-accredited fab facility in Minnesota with the capacity to support mid-sized, domestic manufacturers, an advanced packaging facility in Florida and is building a US$1.8bn R&D and production facility in Indiana.

Under the terms of the 6-year agreement, WBT will receive milestone-based licence fees and volume-based royalty payments for granting SkyWater a non-exclusive right to use the company's ReRAM technology. After the technology transfer and the completion of the qualification processes, SkyWater will initially offer WBT's ReRAM to customers as an embedded NVM on SkyWater's 130 nm CMOS process, a 'sweet spot' for analogue, power management, automotive, IoT and rad-hard designs. While the initial agreement covers only the 130nm process technology, SkyWater could seek to integrate it within its other platforms over time as WBT scales down its technology to smaller process geometries.

A significant milestone for WBT, the agreement will facilitate volume production of the company's ReRAM technology, generating its first revenue. It will also provide market validation, which can indirectly provide a quicker pathway to additional deals with current and future prospects.

Scaled down to 28nm and 22nm, where Flash can no longer scale

Almost a month after announcing the agreement with SkyWater, WBT demonstrated production-level parameters of its ReRAM technology in a 28nm process in October 2021. In doing so, the company has achieved a key milestone as 28nm is considered the 'sweet spot' for embedded NVMs. Embedded Flash is unviable below 40nm.

The demonstration was carried out jointly by WBT and CEA-Leti and proved the data retention and endurance capabilities of the 1Mb ReRAM arrays at 28nm, which consume low power, operate at a low voltage and offer 5x more memory density.

Three milestones achieved in the last 13 months to accelerate the path to commercialisation

Following on from this, in March 2022, the company announced that it is working on scaling down its technology further by designing a memory module that incorporates an 8Mb ReRAM block at 22nm.

The company also publicly demonstrated its 128Kb ReRAM array in a 130nm ReRAM module, a crucial component in embedding NVM into SoCs, which allows customers to easily reconfigure their designs. The functioning of the ReRAM module showed the real-world potential and application of ReRAM in an SoC.

As WBT moves towards commercialisation in the embedded NVM market, these three milestones will serve the essential purpose of engaging in discussions with potential customers who typically look for a proof-of-concept.

WBT is one step away from commercialisation

Taped out demonstration chips to SkyWater's facility

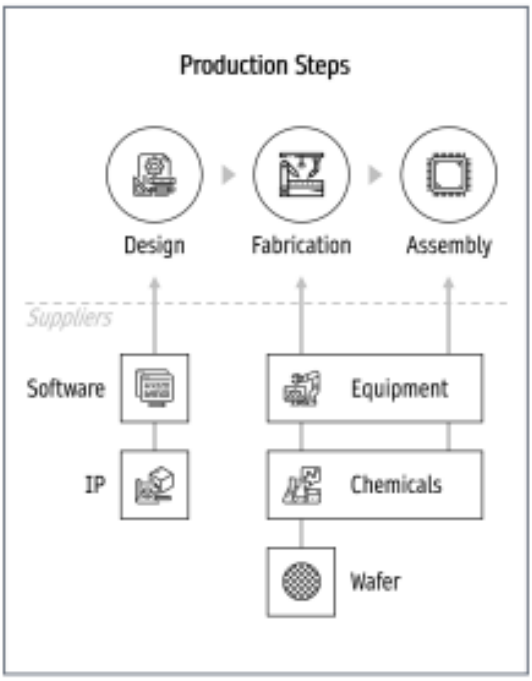
In June 2022, the company taped out demonstration SoCs containing WBT's embedded ReRAM module to SkyWater, thus concluding the transfer of technology to SkyWater's fab facility. With this, the company is now only one step away from achieving volume production of its technology.

Having already received positive results from qualification tests on modules manufactured by CEA-Leti, WBT will move into a detailed technology qualification process (expected to be completed in the first half of 2023) with SkyWater now that it received back the demonstration wafers. Once this qualification is complete, it will pave the way for the commercialisation of Weebit's ReRAM technology.

Weebit Nano is a licensing play

In the semiconductor industry's value chain, Weebit Nano will be positioned as a licensor of IP technology in the 'design' stage of production (Figure 8).

Figure 8: Semiconductor industry value chain



Sources: 'The global Semiconductor value chain', Stiftung Neue Verantwortung

Weebit Nano is an IP licensor to foundries, fabless companies and IDMs

WBT's proprietary technology will be licensed to semiconductor companies and foundries on a non-exclusive basis:

- Foundries (such as SkyWater Technology) can leverage Weebit Nano's IP, offering it to their customers who will integrate and customise the ReRAM into their design.
- Fabless companies (such as Nvidia and Qualcomm) can incorporate WBT's IP through design-in into their SoC designs and manufacture these SOCs through partnerships with third-party foundries.
- IDMs design, manufacture and sell their brand of chips. They can leverage WBT's technology and incorporate it into their own designs to cut down development costs and add to their products' capabilities.

In return, a typical IP licensor in the semiconductor industry, such as Weebit Nano, will generate revenue in the form of:

- Licence fees paid upfront, and potential follow-up licence fee payments made upon the attainment of specific milestones. Licence fees depend on several factors, such as the complexity and cost involved in developing IP, target markets and expected production volumes.
- Non-recurring Engineering (NRE) costs incurred during R&D and testing (could be paid in full by the licensor or could be shared between the two companies).
- A per-unit royalty fee typically between 1% and 5% of the selling price of the chip based on production volumes, if the product company licenses the technology directly, or several percent of the uplifted wafer cost if the product company receive the IP through the foundry.

Valuation for WBT of A$4.75 per share

In our research update on WBT from January 2021, available here, we valued the company at A$4.75 per share, representing an enterprise value of $750m. We derived this value using semiconductor industry M&A transactions and parallels to ASX-listed peer BrainChip (ASX:BRN). We reiterate this A$4.75 per share valuation.

Conclusion

With its ReRAM technology developed to where it is today, we believe WBT will be able to address three separate end markets in due course, creating substantial commercialisation opportunities.

The fact that the company is only one step away from commercialisation of embedded ReRAM through SkyWater is highly encouraging. It will further derisk the investment proposition and should pave the way for additional commercial deals with foundries, IDMs and fabless chip companies in the near to medium term.

If and when such commercial deals materialise, we believe they will serve as a catalyst for further share price appreciation.

Key investment risks

- Alternative emerging memory technologies are being developed by WBT's competitors. These technologies could potentially be superior in nature and/or could be commercialised sooner than WBT's technology, which would inhibit the company's future growth. However, apart from Crossbar and Adesto, we don't see the other ReRAM players as potential competitors. As discussed previously, Crossbar seems to have shifted focus to a niche end-user segment, while Adesto was acquired by Dialog Semiconductor for an EV of US$500m (A$758m at the time), specifically for its IP in the IoT space. Dialog was sub sequentially acquired by Renesas (2021).
- Although WBT now seems adequately funded for the medium term, the company may need to raise further capital. That may be required, for instance, if its current development programs and technology transfer/qualification take longer than currently anticipated or multiple growth opportunities arise, resulting in dilution for existing shareholders (albeit at offer prices reflecting the company's progress).
- Although substantially less of a threat that is now mainly a China issue, COVID-19 still poses a potential risk to WBT as a potential resurgence of COVID-19 may lead to an inability to travel, which would pose challenges to WBT's technical and commercial people in its conversation with partners and prospects. This may slow down further commercialisation.

Appendix I – Analyst certification

Marc Kennis has been an equities analyst since 1996.

- Marc obtained an MSc in Economics from Tilburg University, Netherlands, in 1996 and a postgraduate degree in investment analysis in 2001.
- Since 1996, he has worked for various brokers and banks in the Netherlands, including ING and Rabobank, where his focus has been on the technology sector, including the semiconductor sector.
- After moving to Sydney in 2014, he worked for several Sydney-based brokers before setting up TMT Analytics Pty Ltd, an issuer-sponsored equity research firm.
- In July 2016, with Stuart Roberts, Marc co-founded Pitt Street Research Pty Ltd, which provides issuer-sponsored research on ASX-listed companies across the entire market, including technology companies.
-

Appendix II – ReRAM technology…how does it work

ReRAM technology: The right balance between Flash memory and DRAM

ReRAM is a fast, cost-effective and energy-efficient non-volatile memory (NVM) technology. It can be considered a hybrid memory technology, as it is non-volatile like Flash memory and nearly as fast as DRAM, which is volatile, i.e., a DRAM cell will lose the value (1 or 0) that is stored if the power is switched off. WBT is developing a ReRAM technology, which, in terms of performance metrics, sits right between Flash and DRAM.

How does it work?

Generally, in the case of NAND Flash memory, the values of 1 and 0 are attributed based on the trapped electrical charge present in the memory cell's floating gate. However, in the case of a ReRAM cell, the values (1 and 0) are attributed based on the resistance level of the cell material sandwiched between the two electrodes (Figure 9). A value of 1 is attributed to a state of low resistivity, while a value of 0 is attributed to a state of high resistivity.

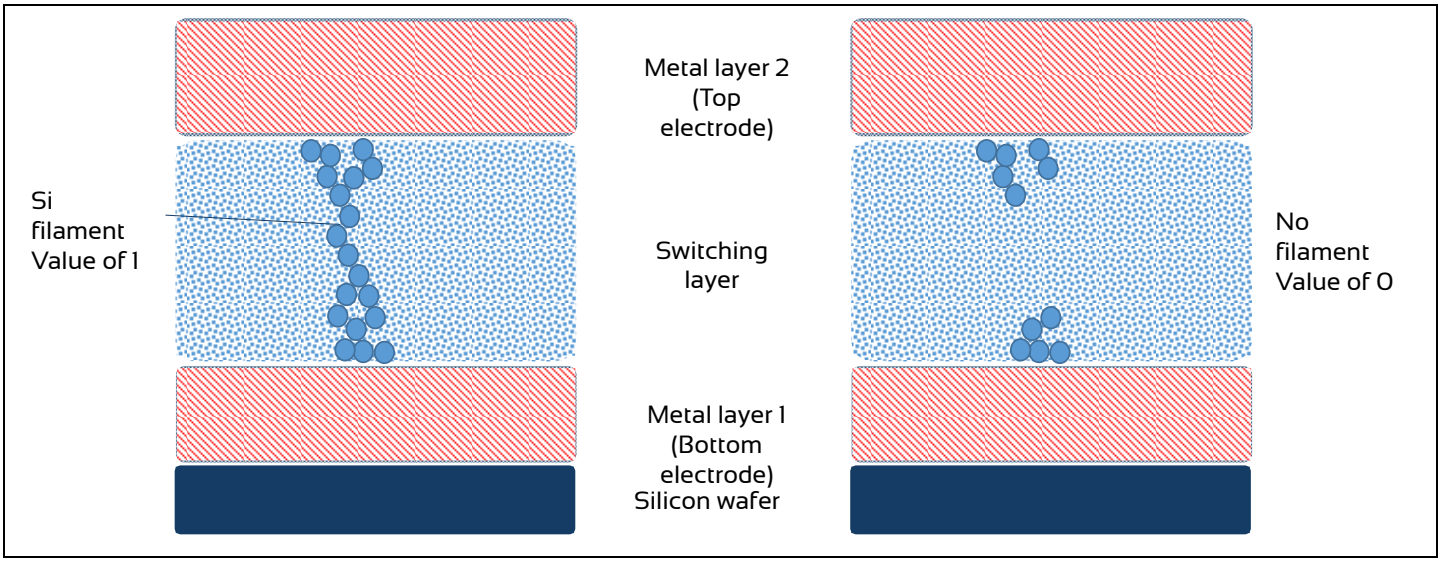
There are two ways of changing the resistance level of a ReRAM cell.

- Through interface switching, which changes the resistivity of the entire layer between the electrodes or
- By creating a filament that connects the two electrodes.

WBT uses the latter.

The technology WBT is developing is based on forming a conductive channel between the two metal electrodes of a ReRAM cell. These electrodes are typically made of metals, such as titanium, tungsten, aluminium or copper. The conductive channel is formed inside a non-conductive layer.

Figure 9: Cell switching by forming and breaking a filament in the switching layer



Source: Pitt Street Research

By applying a certain voltage to one of the electrodes, a switchable filament made of oxygen vacancies can be formed within the switching layer (Figure 9). In this high-conductivity, low resistance state, the cell value is 1. By subsequently applying a reverse voltage to the electrode, the filament can be broken down again, effectively switching the memory cell back to the original state of 0.

The actual filament is formed as the applied electrical voltage strips away some of the oxygen atoms in the switching layer, leaving the dialectic atoms to cluster and create a conductive pathway to the other electrode. The filament is ~5nm to 7nm in diameter.

Appendix III – Glossary

Access time: It refers to how long it takes to read data or write data to a memory cell.

BEOL: It refers to Back-End-Of-Line. It is the second portion of IC fabrication in which interconnecting layers are formed which connect transistors on the wafer.

CMOS: It refers to 'Complementary Metal-Oxide Semiconductor', a popular semiconductor technology used to manufacture most chips in the semiconductor industry.

Data retention: It refers to the amount of time the data stored in memory will retain its value without any power supply.

Discrete/Stand-alone NVM: It refers to a chip which contains only memory.

DMEA: It refers to Defence Microelectronics Activity, a provider of microelectronics to all branches of the U.S. government.

DRAM: It refers to Dynamic Random Access Memory, a type of volatile memory which is used in computer processors as the main memory

Embedded NVM: It refers to memory that is embedded on an SoC.

Endurance: It refers to the number of times a block of memory can be programmed and erased before the memory wears out and becomes unreliable.

Fabless: It refers to companies which design chips for customers.

FEOL: It refers to Front-End-Of-Line. It is the first portion of IC fabrication in which individual components are constructed and patterned inside the wafer substrate.

Fabs/Foundries: It refers to companies which manufacture chips for customers.

IC: It refers to Integrated Circuit, a set of semiconductor components connected on a single semiconductor wafer.

IDM: It refers to a company which designs and manufactures its own brand of chips.

OEM: It refers to Original Equipment Manufacturer, a company which produces equipment and parts which are sold by another company to their customers under their own brand name.

Scaling geometry: It refers to achieving a reduction in the size of a chip (measured in nanometres/nm) in the fab manufacturing process.

Neurons: It refers to fundamental units of the brain which carry information throughout the body.

nm: It refers to nanometre. It equals one billionth of a metre, or a millionth of a millimetre.

NVM: It refers to non-volatile memory, a type of memory which retains data even when the power supply is disconnected.

NRE: It refers to non-recurring engineering costs, a one-time cost which is incurred in the R&D and design phase of a product.

Rad-hard: It refers to radiation hardened, a term used to describe devices which can tolerate substantial amounts of radiation.

SNN: It refers to Spiking Neural Networks. They are artificial neural networks which mimics the brain's neural networks.

SoC: It refers to System-on-a-Chip, a chip which integrates a computer system on it.

SRAM: It refers to Static Random Access Memory, a type of volatile memory which is used to store local data and machine code.

Synapses: These refer to structures in the human body which facilitate communication between two neurons.

Wafer: It refers to a thin slice of semiconductor material.

zb: It refers to Zettabyte, a unit for measuring computing memory. It equals 10^{21} bytes. For reference, an mb equals 10^{6} bytes.

General Advice Warning, Disclaimer & Disclosures

Terms & Conditions

The information contained herein ("Content") has been prepared and issued by Pitt Street Research Pty Ltd ACN 626365615 ("Pitt Street Research"), an Authorised Representative (no: 1265112) of BR Securities Australia Pty Ltd. ABN 92 168 734 530, AFSL 456663. All intellectual property relating to the Content vests with Pitt Street Research unless otherwise noted.

Disclaimer

Pitt Street Research provides this financial advice as an honest and reasonable opinion held at a point in time about an investment's risk profile and merit and the information is provided by the Pitt Street Research in good faith. The views of the adviser(s) do not necessarily reflect the views of the AFS Licensee. Pitt Street Research has no obligation to update the opinion unless Pitt Street Research is currently contracted to provide such an updated opinion. Pitt Street Research does not warrant the accuracy of any information it sources from others. All statements as to future matters are not guaranteed to be accurate and any statements as to past performance do not represent future performance.

Assessment of risk can be subjective. Portfolios of equity investments need to be well diversified and the risk appropriate for the investor. Equity investments in a listed or unlisted company yet to achieve a profit or with an equity value less than A$50 million should collectively be a small component of an individual investor's equity portfolio, with smaller individual investment sizes than otherwise. Investors are responsible for their own investment decisions, unless a contract stipulates otherwise.

Pitt Street Research does not stand behind the capital value or performance of any investment. Subject to any terms implied by law and which cannot be excluded, Pitt Street Research shall not be liable for any errors, omissions, defects or misrepresentations in the information (including by reasons of negligence, negligent misstatement or otherwise) or for any loss or damage (whether direct or indirect) suffered by persons who use or rely on the information. If any law prohibits the exclusion of such liability, Pitt Street Research limits its liability to the re-supply of the Information, provided that such limitation is permitted by law and is fair and reasonable.

General Advice Warning

The Content has been prepared for general information purposes only and is not (and cannot be construed or relied upon as) personal advice nor as an offer to buy/sell/subscribe to any of the financial products mentioned herein. No investment objectives, financial circumstances or needs of any individual have been taken into consideration in the preparation of the Content.

Financial products are complex, entail risk of loss, may rise and fall, and are impacted by a range of market and economic factors, and you should always obtain professional advice to ensure trading or investing in such products is suitable for your circumstances; ensure you obtain, read and understand any applicable offer document.

Disclosures

Pitt Street Research has been commissioned to prepare the Content. From time to time, Pitt Street Research representatives or associates may hold interests, transact or hold directorships in, or perform paid services for, companies mentioned herein. Pitt Street Research and its associates, officers, directors and employees, may, from time to time hold securities in the companies referred to herein and may trade in those securities as principal, and in a manner which may be contrary to recommendations mentioned in this document.

The analyst has received assistance from the company in preparing this document. The company has provided the analyst with communication with senior management and information on the company and industry. As part of due diligence, the analyst has independently and critically reviewed the assistance and information provided by the company to form the opinions expressed in the report. Diligent care has been taken by the analyst to maintain an honest and fair objectivity in writing this report and making the recommendation.