Initiation Research Report
4DS Memory Ltd (ASX:4DS)
New emerging memory

4DS Price: $0.075 | 4DS Valuation: $0.61 | Implied Return: 713% | 22 May, 2024

4DS – Switching ReRAM

4DS, a Silicon Valley based semiconductor company, is developing a switching ReRAM memory which aims to bridge the gap between DRAM and NAND Flash. Today's neural networks such as Deep Learning rely on SRAM but are looking for alternative memory technologies which are non-volatile (can retain data after power is switched off), with the speed of DRAM, shows high endurance and consumes less power. Two issues currently facing the AI industry are memory wall barrier and high energy usage. The former meaning processors speed outpaces the rate data is transferred. AI data centers use a very large amount of energy which puts a large strain on the electricity system. 4DS has proven its ReRAM memory at a scale of 60nm and is in the process of scaling down to 20nm which would likely grab the attention of industry participants. At 60nm 4DS has shown that its memory cells are easily integrated into any advanced CMOS process, using standard equipment and is 100% foundry compatible.

Key metrics

4DS have been fabricating its ReRAM at imec, a fully equipped semiconductor R&D facility in Belgium. The latest testing results at 60nm, initially announced August 2023 when 4DS achieved megabit success, with further improvements since then, showed:

- Write speeds of 4.7ns which is significantly faster than current DRAM write window.
- 3 billion endurance cycles; shows reliable lifetime of the cell, well beyond NAND and other emerging memory technologies.
- Read speed competitive to DRAM
- Tunable retention, from hours to months, to optimize vs endurance, enough to protect data centres from data loss due to system crash, which can cost an average of US$22,000 per minute.
- Low energy consumption compared to other emerging memories.
- Fab friendly BEOL integration compatible to any advanced CMOS logic process compatible with standard tools.
- Poised for warm data storage, meaning data which is accessed less frequently such as reporting or analytics.

Valuation

We have valued 4DS at $0.61 using a future and probability-weighted discounted cash flow model. The emerging memory market is valued at around US$8.22bn and is expected to grow at a CAGR of 16.7% to 2033. The emergence of AI has increased the need to find emerging memory which can rival NAND Flash and complement DRAM, help solve the memory wall barrier and energy usage that is causing issues for AI data centres. We believe should 4DS successfully prove that it can shrink its memory cells to 20nm the industry will take note as it shows commerciality. The question becomes how much 4DS may be able to capture of the emerging memory market. We attribute a conservative probability of success to a small portion of the overall emerging memory market. We apply a discount rate of 15% on this valuation to derive a final valuation of $0.61. This may end up being conservative but to really get comfortable with valuing 4DS we will need to see completion of the 20nm node.

Company Data

Recommendation: Speculative Buy
Shares on Issue: 1.763bn
Market capitalization: $132m
Enterprise Value: $122.8m

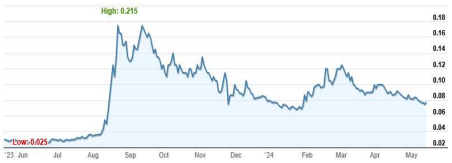
Board Structure

David McAuliffe: Executive Chairman
Howard Digby: Non-Exec Director
Dr Guido Arnout: Non-Exec Director

Major Shareholders

Citicorp Nominees: 3.18%
James Dorrian: 2.57%
Total Top 20: 21.79%

Chart



Source: Iress

4DS has developed an interface switching ReRAM to rival other emerging memory technologies in a current US$8.2bn market.

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Executive Summary

Modern systems demand increasingly better embedded memories. In computer systems memory is either volatile or non-volatile. Volatile memory (DRAM, SRAM) won't store the data when power is switched off, but the tradeoff is these memories are very fast. Non-volatile memory (Flash) can store data when the power is switched off but is generally slower. Flash drives are examples of non-volatile memory.

Embedded systems contain both RAM and Flash and are crucial components in designing efficient systems. Metrics such as performance, cost, and power consumption are extremely important. SRAM is most often used in embedded systems. In some cases, embedded SRAM consume a major portion of the chip area. Today's high-performance systems have, in some cases, 90% of the surface area covered in embedded memory. This is less the case in portable devices as SRAM has relatively higher power consumption and battery life in these devices is often limited. Hence there is a constant tradeoff between size and speed. Most deep learning systems today rely on conventional static random-access memory (SRAM) technology. But SRAM-based solutions have proven to be expensive, power-hungry, and challenging to scale for larger computational densities. To overcome these issues, the AI community is investigating alternative memory technologies.

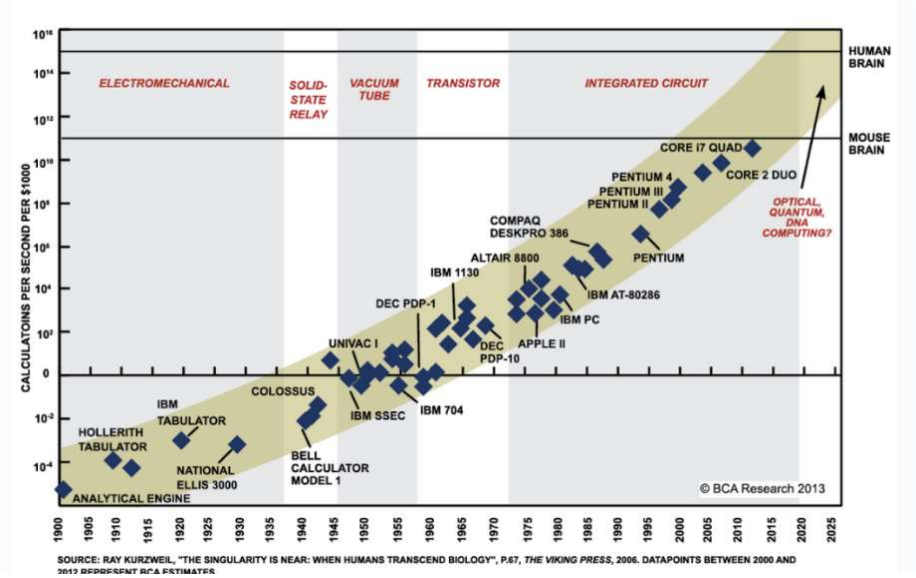
4DS have developed an interface switching ReRAM which has shown 4.7ns write speed, faster than DRAM write window, read speed competitive to DRAM, endurance of 3 billion, low power consumption, and tunable retention which allows system architects to temporarily preserve computational weights to mitigate dataflow congestion to the main AI processor. Fabrication is done at imec while testing is in-house. The upper limit of endurance is not yet known and next two platform lots, done at 60nm and 20nm, will aim to improve the current metrics. These metrics were achieved in a megabit array at 60nm scale. 4DS is currently in process of scaling to 20nm which would likely prove industry commerciality.

4DS' ReRAM technology has the potential to bridge that gap between DRAM and NAND Flash as it can offer the speed of DRAM with the non-volatility and potentially higher endurance of NAND flash, all while consuming less power. This can be beneficial for various applications from AI computing, having access to faster memory, to Internet of Things where low-power persistent memory could be ideal for battery-powered IoT devices. Flash memory has shown to have difficulty scaling with process advances and new non-volatile memory types are needed to fill the void.

Memory Cell and Semiconductor Industry

The semiconductor industry has grown by immense proportions and impacts most aspects of our lives. The birth of semiconductors can be traced back to more than 100 years with the invention of the AC/DC converter however arguments can be made the arrival of the transistor era in 1947 truly started the computer age. The invention of bipolar integrated circuits in 1959 brought on the race to minimize computers in order to make devices small in size and weight. In 1967 Texas Instruments used integrated circuits to develop the electronic desktop calculator. By 1980's integrated circuits evolved from containing hundreds of thousands to 10 million electronic components per chip. Evolutions in semiconductor space have moved by leaps and bounds. Artificial Intelligence is now dominating the headlines and soon we will be talking about quantum computers.

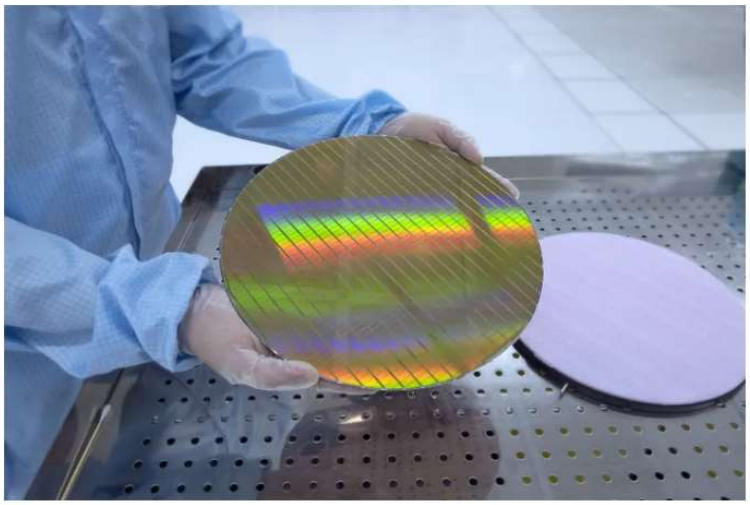
Evolution of computing has taken us from large sized transistors to Artificial Intelligence



Evolution of computing. Source: BCA Research

At the heart of the semiconductor industry is the memory chip which are integrated circuits that hold data either permanently or temporarily. Memory Chips are made from pure silica extracted from silica rich sand which are turned into raw silicon ingots which are sliced into thin cylinders called wafers. In large manufacturing plants called Fabs these wafers are turned into integrated circuits through a multi-step, complicated and very high-tech process. Fabs are cleanroom environments to prevent contamination, in fact they are cleaner than a surgeons operating theatre with next to no dust or any other contaminants being allowed inside the manufacturing area.

Wafers come in different sizes but the most typical being used today is a 300mm wafer.



A typical 300mm wafer. Source: Silicon Specialists

Due to economies of scale the 300mm wafer has become industry norm as you can produce more chips per wafer

Hundreds of memory chips are produced from each wafer and each chip is made up of billions of very small components called transistors. A transistor is a small gate that either allows energy to flow through to a capacitor or halts the energy flow. The capacitor is where the data is stored and either holds a 0 or 1. Charge that is stored in the capacitor degrades over time so the capacitor must be read and written periodically to refresh the charge. When multiple billions of transistors are combined they create complex electronic devices like memory chips that are able to perform complex computations.

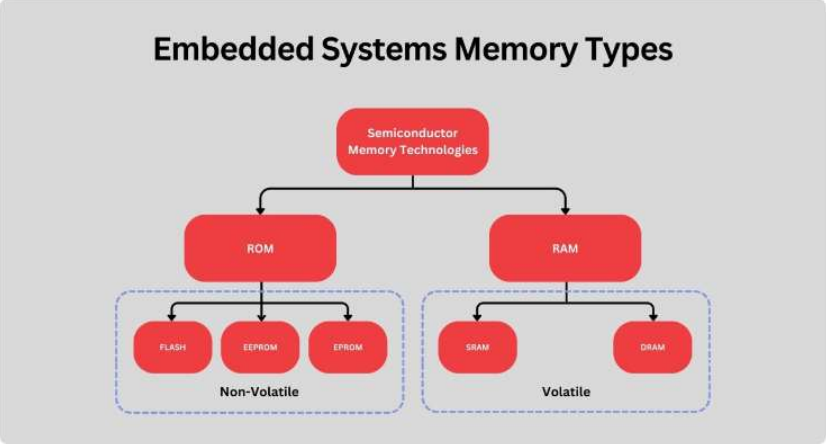
In 2022 global semiconductor sales topped $930 billion

In 2021, semiconductor unit sales reached a record 1.15 trillion-unit shipments, and in 2022 global semiconductor industry sales topped $930 billion. By delivering new functionalities, better performance and lower cost with each generation, advances in chips have spawned new products and transformed industries.

Volatile memory versus Non-Volatile Memory

Memory technologies are divided into two broad categories, volatile memory and non-volatile memory. Volatile memory (DRAM or SRAM) does not store data after power is shut off, hence the volatility, but is very fast and thus sits close to the CPU as data needs to be periodically refreshed. SRAM (Static Random Access Memory) is a volatile memory, just like its cousin DRAM, with the difference being the way it stores bits. While DRAM stores each bit in an electrical capacitor SRAM uses bistable circuits composed of four to six transistors. This makes SRAM faster, but the tradeoff is larger in size.

Another advantage is SRAM stores value for as long as power is supplied while in DRAM individual cells must be refreshed periodically to retain data.



Embedded System Memory Types. Source: RunTime

Memory Technologies are categorized as ROM and RAM with a subset of either volatile or non-volatile memories

DRAM is generally used for main memory because the same size chip can hold several times as much DRAM as SRAM. Non-Volatile memory (NVM, such as NAND Flash) does not require to be periodically refreshed and is commonly used for secondary storage or long-term consistent data. The most well-known NVM is NAND flash memory whose utilisation has exploded in an exponential way. NAND flash has found a market in devices to which large files are frequently uploaded and replaced. MP3 players, digital cameras and USB flash drives use NAND technology. NAND flash saves data as blocks and relies on electric circuits to store data. When power is detached from NAND flash memory, a metal-oxide semiconductor will provide an extra charge to the memory cell, keeping the data. NAND has a finite number of write cycles, failure is usually gradual, as individual cells fail and overall performance degrades. Since the device is cheap the user usually just buys a new one.

NAND Flash is categorized as SLC, MLC, or TLC which refers to the method in which data is stored. Single-Level cells (SLCs) can only store one bit per memory cell compared to MLCs or TLCs and have simpler retrieval, so they're generally faster and have less error correction. For this reason, SLCs are used in storage devices for automobiles or aircraft that require high reliability for an extended period.

MLCs and TLCs can store multiple bits per memory cell and have more technical complexity in implementing high speed. However, an advantage is that a product of the same capacity can be made with less space. This means that the actual number of chips with the same capacity that can be fabricated on each wafer (net die) increases, making MLCs and TLCs more cost competitive.

However, there is a trade off in write speeds and lower number of write-cycles. Typically SLC has 50,000 or more write-cycles, MLC 1,000 to 10,000 writecycles and TLC in the hundreds of write-cycles.

The memory devices we use today divide the write cycles up per cell hence the more gigagbyte of memory the more write cycles. SLCs, MLCs, and TLCs are used in a range of applications, from next-generation data centers and enterprise servers to PCs.

In 2022 global semiconductor sales topped $930 billion

NAND Flash categorized as SLC, MLC, or TLC. Source: Samsung

Moore's Law and Continual Shrinkage

Innovation within the semiconductor sector has led to increasingly smaller sizes. The smaller the transistor, the less power is required for a chip to function. Transistor sizes are measured in nanometers which is one billionth of a meter or a millionth of a mm. Engineers are now managing to produce transistors in the single digits nanometers. As a comparison a red blood cell is 7000nm and a flu virus is 100nm. Smaller chip size makes it more power efficient while being able to do more calculations without getting too hot. Heat is often the limiting factor.

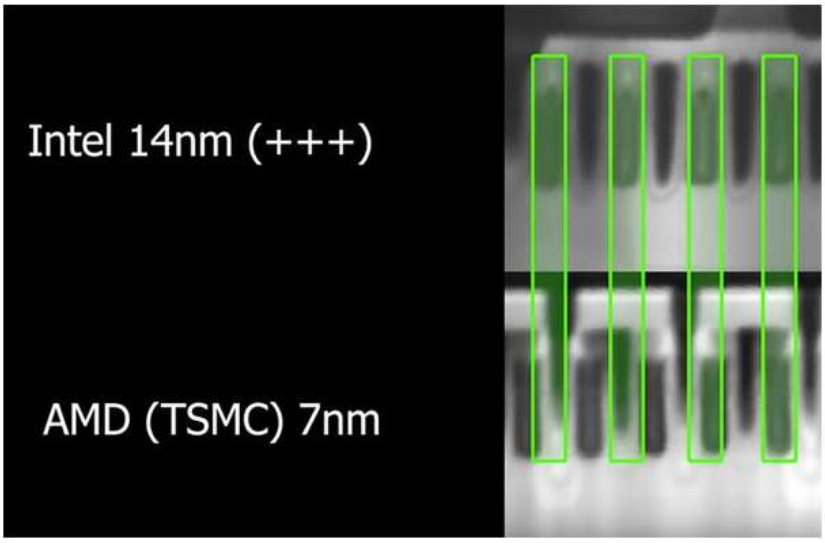
For many years transistor size have observed Moore's Law, named after Gordon Moore co-founder of Intel, which says the number of transistors on a single chip will double every two years. As an example, from 2001 to 2005 node length shrank from 130nm to 65nm. Smaller transistors can do more calculations without overheating, which makes them more power efficient.

It also allows for smaller die sizes, which reduces cost and can increase density, allowing more cores per chip. It is worth noting that transistors are not physical things attached to a chip but printed on a chip in many layers using special lighting machines, similar to how a book contains millions of letters. However, scaling has become increasingly challenging and Moore's Law does not apply any longer.

DRAM has seemingly hit its limit at 14nm as the efficiency of cost scaling has become less desirable in comparison with the introduction of new technology. Eventually 3D cell stacking will be adopted. Modern memory systems are already stacking vertically to get around scaling limitations. NAND Flash went vertical at 15nm and SRAM may stop scaling at 14nm. Instead, foundries are developing more innovative technologies and materials. For example, Intel went from 10nm node to 7nm through innovative circuit design, optimized feature construction and enhanced materials without scaling from 10nm to 7nm. The industry also recognizes that emerging persistent memories are necessary and low power high density non-volatile memory is needed for embedded and data center applications.

Comparing the number before the nanometer is not as relevant any longer as chip architecture and process is far more relevant

A good example is a recent comparison between Intel 14nm node and AMD Ryzen 3000 processor series built on TSMC 7nm node which shows they are far more similar than the naming scheme indicates. The 14nm transistor is not 14nm in width and the 7nm is not 7nm wide. Instead, the TSMC node has greater density and other factors such as transistor type and chip architecture differ. This is important to note as 4DS is currently scaling to 20nm and if achieved would be industry leading as far as emerging memories go.



Despite different naming schemes both chips are very similar in size. Source: der8auer.com

TSMC, the largest chip foundry in the world, recently published a roadmap for embedded memories.

Embedded memory roadmap. Source: TSMC

Boosting chip performance and productivity outweighs the need to constantly scale down

As the industry reaches the physical limits of shrinking the benefits of making the chips smaller are fading and the challenges of maintaining quality and reliability are rising, i.e. boosting chip performance and productivity without scaling. Barring physical scaling the semiconductor industry wants to continue scaling overall performance at reduced power consumption and cost. Traditionally this was achieved through scaling, but this is no longer the case.

Artificial Intelligence

Artificial Intelligence has been around since the 1950's when a theory was developed to eventually have machines perform a function that would previously require human intelligence. The AI systems we use today, such as ChatGPT, have evolved after decades of research and technological advancements.

In recent years AI has seen exponential growth. Generative AI, producing text, information, or images based on simple user prompts, has seen particularly strong growth. The most well-known is ChatGPT which managed to amass 100 million users only two months after release. The latest version, GPT-4, has one trillion parameters and is currently used in ChatGPT Plus and Microsoft Copilot. These are very powerful computer systems that do an extraordinary number of calculations in a very short space of time.

AI has become an integral part of our everyday lives and it is still evolving. In a relatively short space of time AI is being used in a multitude of industries.

Industry	Example use
Health	Analysise medical images and other patient data and make diagnosis using fewer resources and lead to more effective medication.
Finance	Faster and more accurate decision making
Manufacturing	Enhance productivity, efficiency and safety. Ex: Robots on the assembly line equipped with AI algorithms
Customer Service	AI power chatbots that can understand and respond to customer enquiries, resolve issues and even process transactions
Transportation	Self-driving cars. Modern cars have tons of sensors and cameras to reduce accidents and provide information.
Education	Analyse student data and provide tailored learning experience

AI systems are used in plethora of industry and AI data centres are being rolled out worldwide

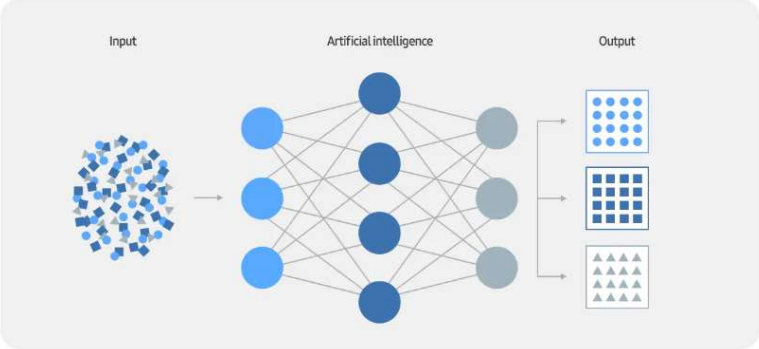
The AI systems of today process unstructured data with multi-layered neural networks and deep learning which makes it possible for systems to analyse complex information, such as visual content or spoken words.

AI systems require huge amounts of data which go through billions of weighted matrix calculations. These matrix calculations are based on neuromorphic computing which basically emulates how the human brain works. A human brain is made up of billions of neurons that talk to each other through connectors called synapses.

Each neuron has anywhere from a few to hundreds of thousands of synaptic connections which can be with itself, neighbouring neurons, or neurons in other regions of the brain. Looking at it through a 2D lens it would resemble a matrix.

Hence engineers in the AI field draw from several disciplines including computer science, biology, mathematics, electronic engineering and physics.

The growth in AI can be counted in the trillions of dollars



Pictorial of an AI system processing inputs. Source: Samsung

AI systems will continue to evolve and change how we work, how we consume media, how we travel, our privacy and more. A recent McKinsey Global Institute (2023) forecasts suggests that generative AI could offer a boost as large as $17.1 to $25.6 trillion to the global economy, on top of earlier estimates of economic growth from increased work automation. The total impact of AI and other automation technologies could produce up to a 1.5% to 3.4% rise in annual GDP growth in advanced economies over the coming decades. This kind of growth requires an enormous amount of new chips and AI infrastructure such as fab capacity, energy, data centres and more. The CEO of OpenAI, Sam Altman, reportedly sees the need for the industry to invest trillions of dollars to facilitate growth in AI.

The Challenge facing Artificial Intelligence

In AI computing the challenge is to develop ideal synapse devices that are able to be scalable while showing multi-level cell (MLC) characteristics, have low power operation and have some data retention.

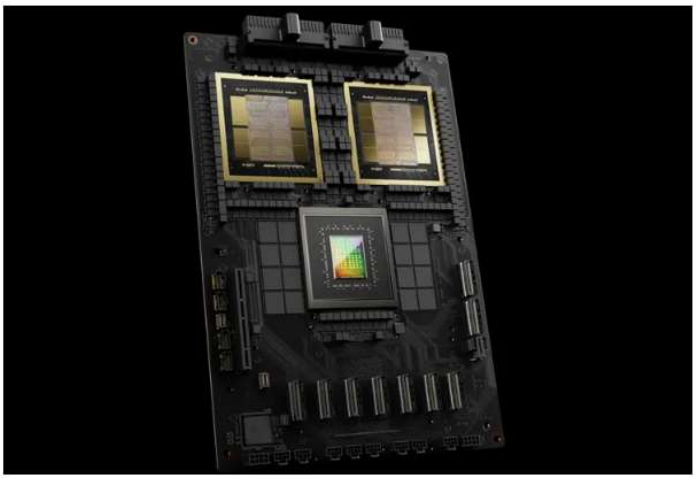
New processor architectures are constantly being researched/in development to overcome the speed, energy and memory bottleneck challenges that AI currently has.

Within the AI network inputs and weights are usually stored in conventional memories and fetched towards the processing unit to perform the multiplications. Thus, for complex problems, a gigantic amount of data needs to be moved around, compromising power efficiency and speed, and leaving a large carbon footprint.

There is currently a growing gap between model size and GPU processing power due to the limit of how much SRAM can be packed into the GPU chip.

Companies get around this by clustering GPU's together. For example, NVIDIA has recently unveiled its latest chip, the Blackwell chip, which has over 400 billion transistors with a 4nm process. Using this very powerful chip NVIDIA have created the GB200 superchip which is two Blackwell GPU's combined with NVIDIA's Grace CPU. Furthermore, the company created a full rack called the GB200 NVL72 system with liquid cooling which is 36 GB200 superchips and 72 GPU's interconnected. This system can support 27 trillion parameter model sizes. Several of these can be connected together to build an AI supercomputer which are enormously powerful.

AI systems, despite their high performance, suffer from issues such as memory wall barrier and high energy usage



GB200 superchip. Source: NVIDIA

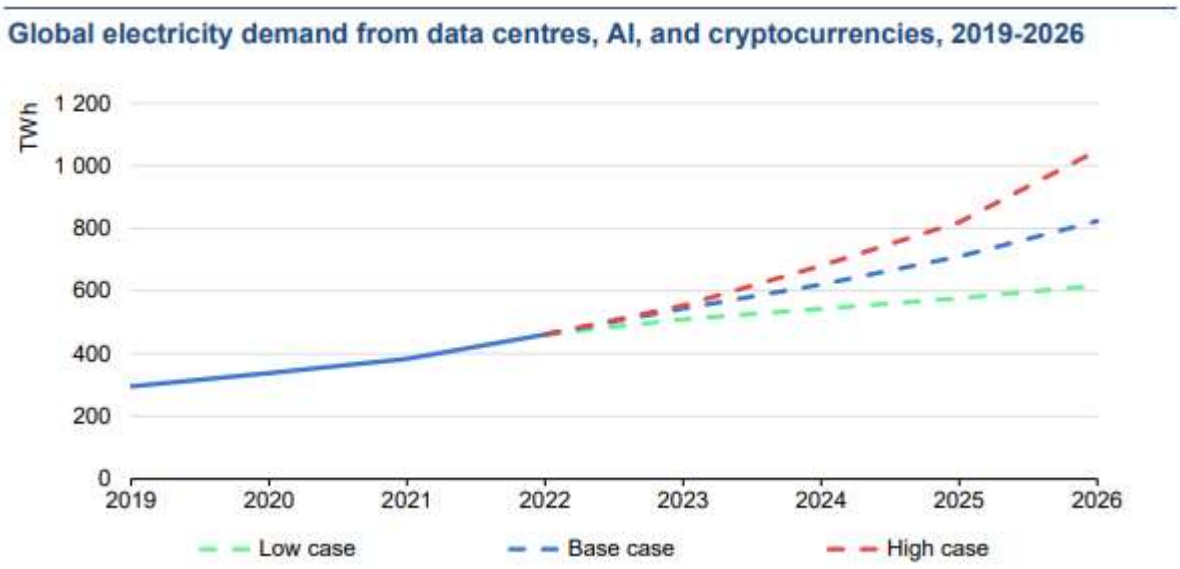
Despite the power of these AI systems they suffer from a phenomena called Memory Wall Barrier which means the capacity and speed of the data transfer has been lagging the hardware computer capabilities.

Thus, memory is the primary bottleneck in AI applications. If the GPU memory wall can be broken computing power would increase significantly yet again and it could lead to innovation breakthroughs in several industries.

The key is to find improved synapse technology that can improve current AI architectures. ReRAM, PRAM and MRAM were initially considered and tested and while showing promise have ultimately shown to have limitations for neuromorphic synapse application.

However, 4DS' Interface switching ReRAM based on PCMO with MLC characteristics shows promise. Synapses are one of the most important elements in neuromorphic computing systems.

Another issue facing AI is the huge amount of energy data centres consume. It takes 5 times as much energy to move the data in and out of the GPU than the operation itself. A study by the International Energy Agency showed current data center energy usage stands at around 460 terawatt hours in 2022 and could increase to between 620 and 1,050 TWh in 2026 — equivalent to the energy demands of Sweden or Germany, respectively. A recent IDC white paper predicts that by 2025 the global datasphere will grow to 175 zettabytes. One zettabyte equals 1 trillion gigabytes. A growth of 775% since 2010.



Source: IEA

Asset managers have taken advantage of this as investments in data centres and essential infrastructure to support them have increased significantly in recent years. The industry is looking for solutions that can replace existing memory or be used to implement neuromorphic computing for the next generation of AI hardware. NAND Flash has reached its limitations as while it preserves the data even when power is off it does not match the speed of DRAM. Ideally the industry needs synapse devices with various requirements such as being scalable, MLC characteristics, low power usage, data retention, and with speed close to DRAM speed. Essentially, to overcome the speed, energy and memory bottleneck challenges the industry needs introduction of a new non-volatile memory with high speed and high density.

4DS' Interface Switching ReRAM

4DS operates out of Silicon Valley and have been developing an Interface Switching ReRAM for the better part of a decade. 4DS' ReRAM structure uses PCMO material which is a crystal comprised of the elements Praseodymium, Calcium, Manganese and Oxygen. The PCMO layer resides between two electrodes, a bottom and top electrode (BE, TE).

4DS is working closely with imec, a prestigious Belgium R&D facility, which are highly regarded in the semiconductor industry

Initially, 4DS fabricated its ReRAM cells with R&D tools which are different from the process tools used to produce memory chips in industry fabrication labs. In 2017 4DS signed an agreement with imec, a large and prestigious R&D facility located in Belgium, which offers the same settings as fabrication facilities. As a world-leading research and innovation hub in nano-electronics and digital technologies, imec has the same state-of-the-art process tools for 300mm wafers that are used in high-density high-volume production facilities and engages in development with global makers of high-volume high-density memories.

Imec's platform is a proven Complementary Metal-Oxide Semiconductor (CMOS) megabit test vehicle fabricated on 300mm wafers on which the 4DS memory cells can be placed. CMOS is a type of technology used in the manufacturing of computer processors, memory chips, and other digital devices. CMOS logic and memory together is the majority of semiconductor device production. Essentially, by using imec 4DS is showing its memory can be duplicated by any high-density memory maker that uses the same 300mm production equipment.

Once the process flow was transferred from smaller wafers used in an R&D setting to imec's 300mm wafer equipment 4DS set out to produce non-platform and platform wafer lots for testing. Non-platform lot wafers only support standalone 4DS' memory cells while platform lot include access transistors which help produce more precise measurements of endurance and retention at higher currents, in other words contains a control logic to read and write selected bits and bytes.

The aim for 4DS was to prove a megabit chip, using the same state of the art equipment that is used by major industry players. Megabit memories are the minimum size needed to collect statistically significant and meaningful data on yield, endurance, speed and data retention that are essential for high-volume memory makers. The performance of the components is measured in many different ways however metrics such as speed, density, power consumption, and functionality carry a lot of weight.

4DS have thus far gone through four platform iterations with each showing improved results. In the early stages of development 4DS' Interface Switching ReRAM showed high density, low power consumption, good endurance and ability to retain data. Read speeds were competitive to DRAM read speed. The subsequent non-platform and platform lots showed significant improvement in metrics such as endurance, retention and read/write speeds and they also demonstrated fabrication of fully crystalline PCMO at temperatures compatible with the advanced process run in today's high-volume memory DRAM and NAND factories.

Megabit success achieved in 2023

Megabit Success

In Q3, 2023, with the fourth platform lot 4DS achieved megabit success when 4DS' ReRAM memory was successfully incorporated into the megabit array at imec. The testing showed endurance in excess of 3 billion cycles however the upper limit of endurance is unknown because of limitations in equipment and manpower to test the upper limit. As previously mentioned, fabrication is done at imec while testing is done in-house.

Analysis showed write speed of 4.7 nanoseconds, significantly faster than DRAM write window. The fast write speeds are being achieved because the 4DS cells are written with a single pulse or as the company refers to it as "one shot" programming.

This means the cell responds to a single pulse as opposed to other non-volatile memories which require an iterative, multi-pulse programming approach which takes more time and energy. Not needing to be iteratively programmed contributes to 4DS' ReRAM having higher bandwidth (write time) and lower energy requirement.

	4DS ReRam	DRAM	Filamentary ReRam
Endurance	10^9	10^15	10^4
Read Speed	Competitive to DRAM	Similar to 4DS' ReRam	>50ns
Write Speed	4.7ns	30ns	100ns
Analog/Digital	Analog/Digital	-	Digital
Energy Req.	Low	High (for persistent data)	Mid

4DS memory has shown good test results putting it on a path to superiority compared to other emerging memory technologies

The above table shows comparison of 4DS' Switching ReRAM with DRAM and Filamentary ReRAM. The main problem with filamentary emerging memory is low endurance and need for strong error correction. 4DS Switching ReRAM compared favorably with DRAM on read/write speed and shows low energy requirement per bit. The goal is not to replace DRAM but to complement it by offering the speed of DRAM with the non-volatility and higher endurance of NAND Flash while consuming less power. The data shows 4DS ReRAM may be a better solution for high bandwidth, high endurance persistent memory.

Further testing is currently being conducted with platform 5 and 6. The 5th platform is seeking to further optimize the results seen on the 4th platform using 60nm memory cell size. The 6th platform will be applied on 20nm memory cells, which will be the first time at that size and if successful will likely have very significant implications for the success of the company. Scaling down to 20nm allows for fitting more memory cells onto a chip which translates to higher memory capacity per chip, making it more attractive for applications requiring a lot of data storage. Proving the same metrics on 20nm scale is the minimum required to be industry ready and become more competitive with established memory solutions.

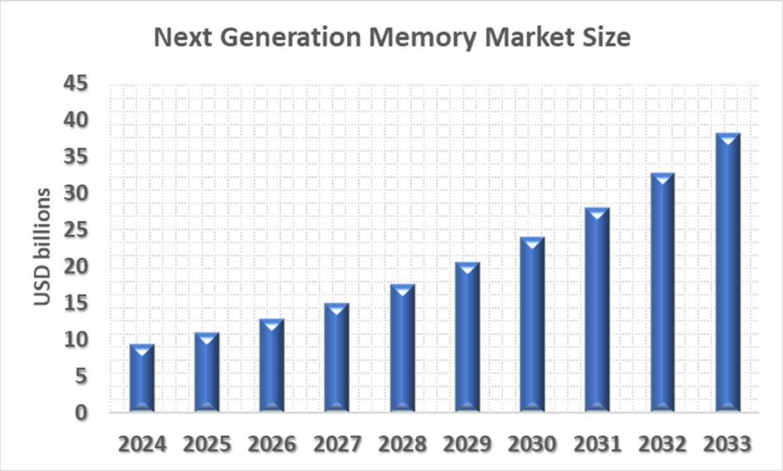
At 60nm 4DS has shown that its switching ReRAM does not need iterative programming and can be easily integrated into any advanced CMOS logic process, using standard fab equipment and is 100% foundry compatible. Being area based the 4DS ReRAM cell is persistent, high endurance and can hit the competitive benchmark of 20nm scale. It has already demonstrated comparable faster read times to DRAM and is a viable memory solution to fill the emerging need in the space between DRAM and Flash.

4DS owns 34 USA patents which have been developed in-house to create high-density storage class memory.

Valuation

We believe 4DS will have a part to play in the US$8.2bn emerging memory market

The emerging memory market surpassed US$8.22bn in CY23 and is expected to grow at a CAGR of 16.7% to 2033. An insatiable demand for increased computational power and energy efficiency is helping to drive this growth. The industry is looking toward faster and more energy efficient memory solutions in applications such as data centres, edge computing, and autonomous systems. 4DS' switching ReRAM offers high-speed data access, lower power consumption and enhanced endurance. This type of emerging memory is vital for sectors such as Internet-of-Things where low-power memory is essential for sensors and devices that require long battery life.



We anticipate 4DS's ReRAM to have a part to play in this very large emerging memory market. Should 4DS be successful in proving a 20nm memory cell it would prove to larger players the commerciality of its PCMO ReRAM and may attract a bid for its technology. We believe it is unlikely 4DS will go down the path to commercialise the technology on its own as the costs of moving into a Fab is very costly. Licensing the IP may be another option.

To place a value on 4DS we have focused on the potential of Switching ReRAM within the above market. While we have used a few assumptions we have mitigated the risks by using a probability weighted and discounted model to determine how much of the emerging memory market 4DS may be able to capture, or in the case of an acquisition how much the acquirer may value the technology given its current life cycle.

Our valuation comes in at $0.61

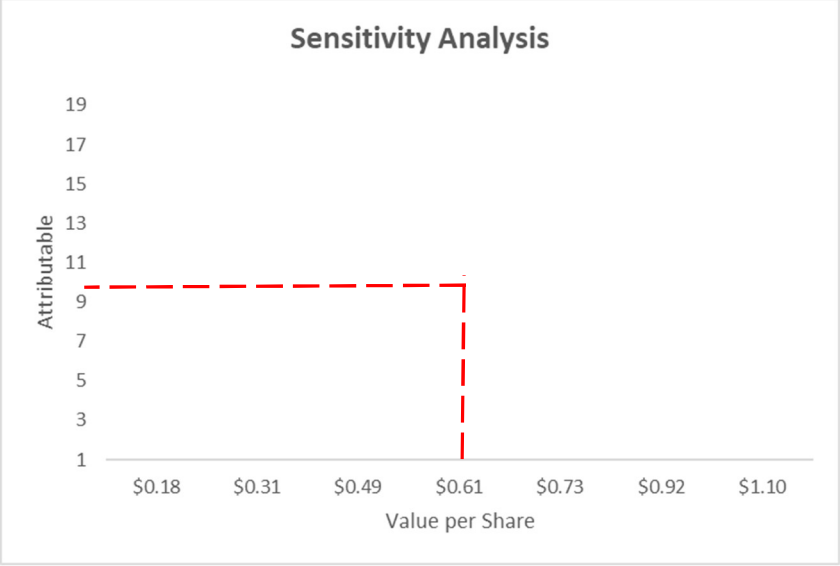
Key assumptions we use are as follows:

- We currently attribute a 10% chance that 4DS will be commercial which we believe gives us a good margin of safety.
- A buyout is likely and we have only modeled until 2028 to give us a few years to get taken out.
- Upon successful validation take-up will likely be reasonably large and a 10% market penetration is on the conservative side.
- We have kept the 10% penetration rate steady throughout the years, again to be conservative as possible.
- We do not anticipate further capital raisings. Cash on hand of $9.2m should see 4DS through current platforms (large part which has already been paid for). We believe validation of a 20nm node would attract a buyout or funding partner.
- Using a discount rate of 15% and using our above methodology we derive a valuation of $0.61

Next Generation Memory Market				
Market size (billions, USD)	**$11.19**	**$13.06**	**$15.25**	**$17.79**
Market growth (CAGR)	**16.7%**	**16.7%**	**16.7%**	**16.7%**
Market size (billions, AUD)	**$17.22**	**$20.10**	**$23.46**	**$27.37**
10% attributable to 4DS's memory	**$1.72**	**$2.01**	**$2.35**	**$2.74**
Probability of success	**10.0%**	**15.0%**	**20.0%**	**25.0%**
Risked Value (billions, AUD)	**$172.23**	**$301.48**	**$469.11**	**$684.31**

Discount factor	0.87	0.76	0.66	0.57
Discounted value	$149.76	$227.96	$308.45	$391.26

Total NPV (millions)	$1,077.43
Shares (millions)	1763.43
Value/share	**$0.61**



Year ending June	2022A	2023A	2024E	2025E
NPAT	(6.8)	(5.8)	(5.8)	(5.8)
EPS_{adj} (¢)	**0.0**	**0.0**	**0.0**	**0.0**
EPS growth		**0.0%**	**0.0%**	**0.0%**
P/E ratio	**0.0 x**	**0.0 x**	**0.0 x**	**0.0 x**
Enterprise Value (m)	132	130	135	138
EV/Sales (x)	0.00 x	0.00 x	0.00 x	0.00 x
EV / EBIT (x)	0.00 x	0.00 x	0.00 x	0.00 x
EV / EBITDA (x)	0.00 x	0.00 x	0.00 x	0.00 x
DPS ($)	0.00	0.00	0.00	0.00
Dividend Yield	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Payout Ratio	0.0%	0.0%	0.0%	0.0%
Franking	N/A	N/A	N/A	N/A
FCFPS (¢)	0.00	0.00	0.00	0.00
P/FCFPS	0.00	0.00	0.00	0.00

Profit and loss (A$m)

Year ending June	2022A	2023A	2024E	2025E
Operating revenue	0.0	0.0	0.0	0.0
EBITDA	(6.7)	(5.7)	(5.7)	(5.7)
D&A	0.0	0.0	0.0	0.0
EBIT	**(6.8)**	**(5.8)**	**(5.8)**	**(5.8)**
Net interest income	0.0	0.0	0.0	0.0
NPBT	(6.8)	(5.8)	(5.8)	(5.8)
Tax Expense (benefit)	0.0	0.0	0.0	0.0
NPAT	**(6.8)**	**(5.8)**	**(5.8)**	**(5.8)**
Significant Items	0.0	0.0	0.0	0.0
NPAT	**(6.8)**	**(5.8)**	**(5.8)**	**(5.8)**
EBITDA Margin	N/A	N/A	N/A	N/A
EBIT Margin	N/A	N/A	N/A	N/A
NPAT Margin	N/A	N/A	N/A	N/A

Cashflow (A$m)

Year ending June	2022A	2023A	2024E	2025E
Receipts	0.00	0.00	0.00	0.00
Payment to suppliers	(0.84)	(1.23)	(1.23)	(1.23)
Research payments	(4.56)	(3.50)	(1.96)	(1.96)
Interest received	0.00	0.04	0.04	0.04
Interest Paid	0.00	0.00	0.00	0.00
Income Tax	0.00	0.00	0.02	0.00
Operating cashflow	**(5.39)**	**(4.71)**	**(3.16)**	**(3.16)**
Investing cashflows				
Purchase of intangibles	0.00	0.00	0.00	0.00
Purchase of PPE	(0.25)	0.00	0.00	0.00
Financing activities				
Proceeds of shares	5.99	5.50	0.00	0.00
Options share issue	1.29	0.10	6.49	0.00
Net cashflow	**0.95**	**0.38**	**2.32**	**(5.41)**
Cash at beginning year	4.30	5.23	5.60	7.92

Balance sheet (A$m)

Year ending June	2022A	2023A	2024E	2025E
Bank Balance	5.2	5.6	7.9	2.5
Receivables	0.0	0.0	0.0	0.0
Inventories	0.0	0.0	0.0	0.0
Other	0.06	0.06	0.06	0.06
Current assets	5.29	5.66	7.92	2.52
Net PPE	0.3	0.2	0.2	0.2
Intangibles	0.00	0.00	0.00	0.00
Non-current assets	**0.41**	**0.19**	**0.19**	**0.19**
Total assets	**5.70**	**5.85**	**8.12**	**2.71**
Payables	0.08	0.08	0.08	0.08
Other liabilities	0.12	0.05	0.05	0.05
Current liabilities	**0.24**	**0.19**	**0.19**	**0.19**
Other liabilities	0.05	0.00	0.00	0.00
Payables	0.00	0.00	0.00	0.00
Total liabilities	**0.00**	**0.19**	**0.19**	**0.19**
NET ASSETS	**5.70**	**5.66**	**7.92**	**2.51**

Investment Risks

Existing technology risks Current semiconductor memory technologies of DRAM, NAND Flash, and NOR Flash face technological barriers to continue to meet long-term customer needs. These barriers include potential limitations on the ability to shrink products in order to reduce costs, meet higher density requirements, and improve power consumption and reliability. Notwithstanding these challenges, existing semiconductor memory technologies may be able to overcome these barriers and remain the dominant technology.

Development Risk. The success of 4DS relies almost entirely on the successful development of 4DS's ReRAM technology, which is in an advanced stage of development. Should the testing and verification of 4DS's technology not be completed to the satisfaction of the procedures specified by the Company, then 4DS will have to expend additional time and resources to rectify any outstanding issues which will delay the development of the next stage of development or at the very worst, if unassailable barriers are encountered, abandon the project entirely.

Commercialisation Risks. Risks will also be involved in the ability to translate the developed technology in to a solution that provides a meaningful improvement in all of the relevant metrics for memory storage in a cost effective manner to support the price needed to make an impact in the marketplace

Market adoption. 4DS's ReRAM technology is a new technology, which is designed to replace existing technologies that have a large amount of market acceptance. Following completion of the Acquisition and the Capital Raising, the Company and 4DS will continue to focus efforts on development and commercialisation of 4DS's technology. 4DS does not currently have any contracts in place to become revenue generating, there are no guarantees of success in commercialising the 4DS technology.

Competition and new technologies. The industry in which 4DS operates is competitive and includes companies with significantly greater financial, technical, human, research and development, and marketing resources than currently available to 4DS. Numerous entities around the world may resist 4DS's efforts to commercialise or market products that may compete with their own offerings. 4DS's competitors may develop new memory technologies: in advance of 4DS; that are more effective than those developed by 4DS; or have greater market acceptance. Consequently, 4DS's technology may become obsolete or uncompetitive, resulting in adverse effects on revenue, margins and profitability.

Reliance on key personnel. The responsibility of overseeing the day-to-day operations and the strategic management of 4DS and the Company depends substantially on senior management and key personnel, including 4DS's current management. There can be no assurance given that there will be no detrimental impact on the Company if one or more of these parties cease their employment. Further, there is no guarantee that 4DS will be able to attract and retain suitable qualified personnel, and a failure to do so could materially adversely affect the business, operating results and financial prospects of 4DS and the Company

Board of Directors

David McAuliffe – Executive Chairman

Mr. McAuliffe is an experienced Company Director and Entrepreneur who has had over 23 years' experience, mostly in the international biotechnology field. During that time, he was involved in numerous capital raisings and in licensing of technologies. He is a founder of several companies in Australia, France and the United Kingdom, many of which have become public companies. He is President of the Dyslexia-Speld Foundation WA (Inc).

Howard Digby – Non-Executive Director

Mr. Digby started his career at IBM and has spent over 25 years managing technology related businesses across the Asia Pacific region, of which 12 years were spent in Hong Kong. More recently, he was with The Economist Group as Regional Managing Director.
Prior to this he held senior management roles at Adobe and Gartner where his clients included major semiconductor players inclusive of Samsung, Hynix and TSMC. Upon returning to Perth, Howard served as Executive Editor of WA Business News and now spends his time as an advisor and investor, having played key roles in several M&A and reverse takeover transactions.

Dr. Guido Arnout – Non-Executive Director

Dr. Arnout has specific expertise with over 30 years in commercialising electronics technology from concept to product. He was the founding President & CEO of PowerEscape, which introduced the first tools for the development of low-power software executing on multicore devices. He was also founding President & CEO of CoWare, which pioneered system-level design tools for hardware-software co-design and the time-based licensing business model. Dr. Arnout co-founded the Open SystemC Initiative (OSCI), an industry consortium to standardise a language for system level design, and as its President submitted the SystemC language to IEEE. He served as VP of Engineering and later senior VP of marketing of CrossCheck Technology. He co-founded and later became VP of Engineering of Silvar-Lisco, the first commercial EDA (electronic design automation) company.

Glossary

DRAM – Dynamic Random Access Memory is a type of semiconductor memory which stores data in a capacitor. Capacitors leak data so the information needs to be refreshed periodically. Thus, DRAM is a dynamic memory.

SRAM – Static Random Access Memory uses bistable latching circuitry to store each bit. While no refresh is necessary it is still volatile in the sense that data is lost when the memory is not powered.

ROM – Read Only Memory, can be read from but cannot be written to.

ReRAM – Resistive RAM. Works by changing the resistance of materials. An electric current is applied to a material, changing the resistance of that material. The resistance state can then be measured. This principle is called 'memrister' and relies on the principle of hysteresis.

MRAM – Magnetoresistive Random Access Memory uses magnetic properties to store data, this type of memory is already in use but is very expensive.

Flash Memory – Modern form of erasable memory. These type of memories can be written and erased multiple types and are guaranteed to withstand between 100,000 and 1,000,000 program/erase cycles. With NOR flash, the memory cells are connected in parallel enabling the device to have better random access. NAND flash is optimized for density and access is performed in a serial manner. This reduces the amount of access circuitry required. For this reason NOR has traditionally been used for code access and NAND for data access.

Non-Volatile Memory (NVM) – Memory which stores data even when the power source is turned off. NVM's capacity is harder to scale at smaller geometries.

Volatile Memory - Volatile memory needs to have power in order to function. This is because memory is implemented in terms of stored capacitance (DRAM), or requires an active bistable latch (SRAM). As soon as the power is removed, their ability to retain storage is lost. For example, a DRAM has a retention time of about 100ms.

Embedded Memory - Storage devices that store binary information, including instructions (Programs), and data, and provide that information to the MPU/MCU as and when it is required.

Rating

BUY – anticipated stock return is greater than 10%
SELL – anticipated stock return is less than -10%
HOLD - anticipated stock return is between -10% and +10%
SPECULATIVE BUY – high risk stock with price likely to fluctuate by 50% or more and anticipated return is greater than 10%

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Disclosure of Interests

Lodge directors, consultants and advisers currently hold less than 1% of total shares in the Company and may buy or sell the shares from time to time. Lodge has earned and will continue to earn broking commissions by acting for individual clients that are buying or selling their shares in company. The Company currently is, or in the past 12 months was, a client of Lodge Partner's affiliated company and authorised representative Lodge Corporate Pty Ltd. During this period, Lodge Corporate provided investment banking services to the company. In the past 12 months, Lodge Corporate have received compensation for Investment Banking services from the company. Lodge Corporate intends to seek or expect to receive compensation for Investment Banking services from the Company in the next twelve months.

Analyst Verification

I verify that I, Sven Restel, have prepared this research report accurately and that any financial forecasts and recommendations that are expressed are solely my own personal opinions.

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