Progressing its technology on several fronts

Share Price: $0.55

Archer Materials (ASX:AXE) is a technology company developing two semiconductor devices, ^{12}CQ and Biochip. ^{12}CQ is a quantum technology that could enable quantum chips in mobile devices at room temperatures, while the Biochip is a lab-on-a-chip technology being developed to enable more efficient and practical detection of diseases. Since our initiation report from early February, the company has accomplished two feats with its technologies that will be the focus of this update note.

ASX: AXE

Sector: Technology

3 April 2024

Market Cap. (A$ m)	140.2
# shares outstanding (m)	254.9
# shares fully diluted (m)	254.9
Market Cap Ful. Dil. (A$ m)	140.2
Free Float	100%
52-week high/low (A$)	0.72 / 0.30
Avg. 12M daily volume ('1000)	342.3
Website	https://archerx.com.au

Source: Company, Pitt Street Research

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

Source: Refinitiv Eikon, Pitt Street Research

Biochip miniaturised

Archer Materials designed a miniaturised version of its Biochip for a fabrication at a commercial foundry – from 10mm^2 to 1.5mm^2. This new design has been sent to a foundry partner for a whole-wafer fabrication of the reduced size devices. This is a big deal not just because it illustrates Archer Materials' expertise with this graphene transistor technology, but also broadens the Biochip's potential reach and ultimate commercial lifespan.

^{12}CQ moving forward in parallel

Archer Materials' other major achievement was building a single chip integrated pulsed electron spin resonance (p-ESR) microsystem with its Swiss partner EPFL. Archer and EPFL intend to use this p-ESR microsystem to perform complex measurements involving the potential electron spin manipulation of Archer's ^{12}CQ quantum materials. The p-ESR chip's features open potential opportunities for Archer to develop quantum sensors, miniaturised spectrometers, and analytical devices for precision sensing.

More upside to come

We reiterate our optimism that there is significant potential for Archer Materials to create shareholder value as it advances its Biochip and ^{12}CQ technologies. We continue to observe that relevant ASX peers trade at valuations that are clearly higher than Archer Materials' valuation. We see upside for the stock to a range of $0.60-$1.00 per share. Please see p.9 for the key risks associated with an investment in Archer Materials.

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Re-introduction to Archer Materials, ^{12}CQ and Biochip

Archer Materials is the only company on the ASX, and only one of a handful in the world, developing the particular technologies it is working on.

Archer Materials (ASX:AXE) is developing the ^{12}CQ and Biochip technologies. It is the only company on the ASX, and one of only a handful in the world, developing the particular technologies it is working on. If and when one or both of its technologies is successfully developed and commercialised, there is an enormous market to penetrate. Even though there remains some way to tread along the road to development, there are clear catalysts ahead of the company to create shareholder value before it.

Quantum technology with ^{12}CQ

^{12}CQ (pronounced one-two-see-queue) is a carbon-based semiconductor technology being developed for potential quantum bit (qubit) application. This technology could pave the way for mobile quantum devices, resolving the impediments that have prevented quantum devices, namely computing devices, from reaching the mainstream – which currently include the practicalities of operation and scale.

^{12}CQ comprises of:

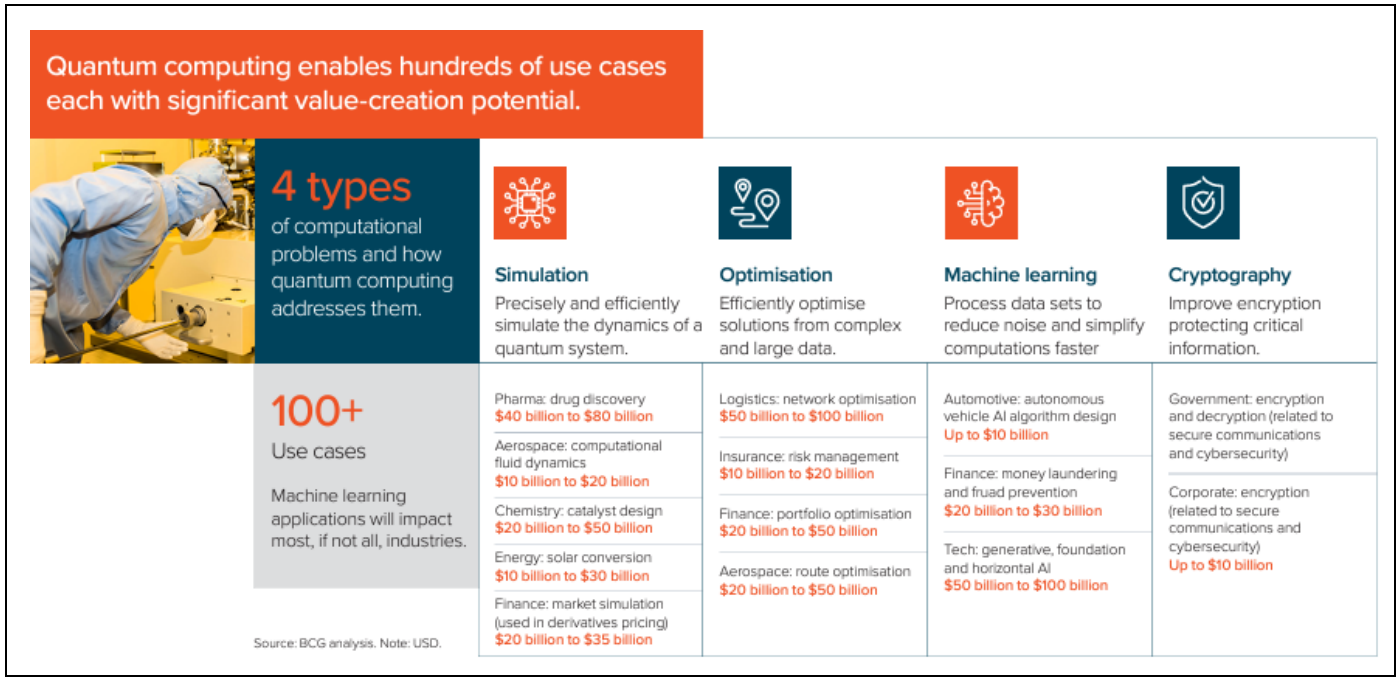
- A carbon nanosphere adapted to store a qubit (a basic unit of information in quantum computing) represented by an electronic spin,
- Readout and control devices to set the qubit and read the value stored on the carbon nanosphere.

Once fully developed, ^{12}CQ may potentially enable quantum technologies, including computing, to be accessible to a broader target market.

Once fully developed, ^{12}CQ may potentially enable quantum technologies, including computing, to be accessible to a broader market than what today's quantum solutions, by having them operative at practical conditions.

Quantum processing devices could accomplish substantially more than classical computers (Figure 1), because given their unique processing capacity, they could potentially make calculations much faster than regular computers. See Appendix I for details on how ^{12}CQ would work.

Figure 1: The possibilities of quantum computing



Source: Company

Biochip is a step-change in medical diagnostics

Biochip is a Lab-on-a-Chip technology being developed to enable rapid, parallelised detection of diseases.

Archer Materials' Biochip is a Lab-on-a-Chip technology being developed to enable rapid, parallelised detection of diseases. It would allow droplets of biological specimens to be analysed and processed using graphene sensors. It does so by using graphene field effect transistors (gFETs), allowing an ultrasensitive approach to detection compared to conventional sensors used in current Lab-on-a-Chip devices and other electronic devices.

Droplets of biological specimens (from saliva, blood, breath or tears etc) would be collected and delivered onto the Biochip. From there, the sample is divided in regions of the chip and the liquid shuttled to smaller built-in sensing areas that analyse for evidence of electrically active biochemical targets, for instance, chemicals created from reactions with the viruses or bacteria. A biochip can be tuned to detect multiple diseases (multiplexing) at once.

Biochip could generate faster and more reliable results than competing technology and (crucially) on device.

Archer's Biochip would aim to generate faster, reliable results, than competing technology and (crucially) on device. It would not need additional equipment, cold supply chains, highly trained medical personnel or sample purification requirements or assay procedures in the same way that other medical diagnostic methods involving nucleic acids and biosensors (such as PCR tests) do.

In 2023, the Biochip became a strong focus of Archer Materials and the company made significant progress, taking it from concept to design and through successful early-stage testing at semiconductor foundries.

Archer Materials' recent achievements

Biochip miniaturised

Archer Materials designed a miniaturised version of the Biochip for fabrication at a commercial foundry – from 10mm^2 to 1.5mm^2.

Archer Materials designed a miniaturised version of Biochip for a fabrication at a commercial foundry – from 10mm^2 to 1.5mm^2. This design was achieved by Archer personnel redesigning the layout of the circuits creating the gFET transistors.

This new design has been sent to a foundry partner – Netherlands-based fab Applied Nanolayers (ANL) - for a whole-wafer fabrication of reduced-size gFET chips. It will be tested on a four-inch wafer, which is expected to produce 1375 chips on it, compared to the 45 chips produced using earlier designs in previous four-inch wafer fabrication runs. The wafer will be diced and assembled at Archer's newly established outsourced semiconductor assembly and testing partner, AOI Electronics in Japan. Delivery of the packaged chips is anticipated in mid-2024.

Why is this important?

The design of a miniaturised version of Biochip is important for two reasons. Firstly, it illustrates Archer Materials' expertise with this technology. This point cannot be underestimated because scaling down chips while not just maintaining, but enhancing performance is not an easy thing to do, especially in a way that is not cost-prohibitive.

Secondly, it broadens the Biochip's potential reach and ultimate commercial lifespan. If the Biochip is successfully commercialised, it could enable the ability to parallelise the detection of biologically relevant targets on a chip – in other words, to detect multiple targets at once rather than one at a time.

Archer Materials and EPFL developed a pulsed electron spin resonance (p-ESR) spectrometer on chip.

A new p-ESR chip developed

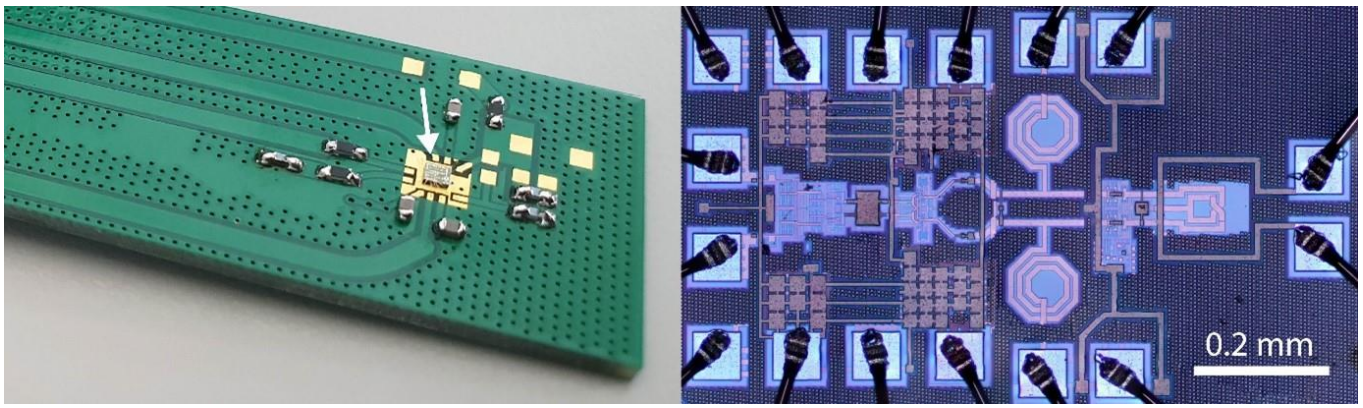
Archer Materials developed a pulsed electron spin resonance (p-ESR) spectrometer [1] on chip (Figure 2) with its research partner EPFL (École Polytechnique Fédérale de Lausanne) based in Switzerland. Archer intends to use the p-ESR microsystem to perform complex measurements involving the potential electron spin manipulation of Archer's ^{12}CQ quantum materials.

What is p-ESR microsystem?

The p-ESR microsystem is a tiny, integrated device designed to detect and analyse the behaviour of unpaired electrons, that potentially carry spin quantum information, in materials at a small scale.

It measures 0.7 mm^2 in size and consists of an excitation microcoil, a detection microcoil, a low noise microwave preamplifier, a mixer, and an intermediate frequency amplifier. All these components work together to detect and amplify signals related to the behaviour of unpaired electrons. The chip analyses samples with a volume of about 0.1 nano Litres (nL) and has a power consumption is less than 100 mW.

Figure 2: The p-ESR chip (left - indicated by the arrow) and the magnification of the chip area (right)



Source: Company

What can the microsystem do?

It can precisely and accurately measure ESR parameters such as spin-spin relaxation time and spin-lattice relaxation time. These are important parameters for determining the time-window for processing electron spin information in solid-state quantum electronic devices.

Furthermore, it can achieve this with low power consumption (20-100mW of power), with very small numbers of electron spins in samples a fraction of a billionth of a litre, all using wide radio frequency. It can be used in various experiments to study different materials and phenomena. For instance, it has been used to perform advanced experiments like single pulse, Rabi nutation, Hahn echo, and others on standardised samples with sizes as small as 0.02 nL at room temperature in air. The small area occupied on the chip by the complete receiver makes it also suitable for arrays of detectors for parallel (simultaneous) sample analysis.

[1] Essentially a sensor.

This gives the company room to explore possible nearer term applications and products with more mature markets

Why this is big deal?

For Archer Materials it gives the company room to explore possible nearer term applications and products with more mature markets (e.g. industrials). For markets it is already targeting with its Biochip, the p-ESR chip could potentially help it rapidly develop applications that may not need biological regulatory approvals for biosensor diagnostics. The p-ESR chip has the potential to be a standalone product with further engineering, for instance, to fully-integrate the microwave source and detector on the chip and other modifications to the magnets. Whether or not it is a standalone product, it is playing, and will continue to play, an important role in driving the ^{12}CQ quantum chip development.

Where and how an ESR microsystem could be useful

In quantum computing, ESR systems help to characterise and manipulate electron spins.

Electron spin states are an attractive realisation of a quantum bit (qubit) as they can undergo a transition between the 'spin-up' and 'spin-down' quantum states. The most commonly used technique for manipulating electron spin is electron spin resonance (ESR). In quantum computing an ESR system could help to characterise and control electron spins in quantum materials. Other applications could include portable healthcare diagnostics, portable analytical devices, or educational tools in quantum physics. Traditional ESR instrumentation are bulky and occupy labs, similar to magnetic resonance imaging (MRI) machines.

What the future holds for the p-ESR project

To demonstrate the operation and function of the p-ESR chip, several experiments were performed by EPFL at room-temperature in air and in a laboratory without radio and microwave frequency shielding, in other words: normal conditions. This included single pulse, Rabi nutation, Hahn echo, two echoes, Carr-Purcell, and inversion recovery echo conducted at 9.1 GHz using nanolitre sample of 1% α,γ-bisdiphenylene-β-phenylallyl ("BDPA") in polystyrene. The results obtained on 1% BDPA in polystyrene mean that the microsystem can be potentially applied to incorporate broad types of materials for spin detection and manipulation.

The measurements will continue throughout the rest of CY24 and will enable Archer Materials to explore future opportunities this chip could present. These could include radiofrequency circuits for potential applications in quantum technology. There may not be an immediate financial impact on Archer, although in the longer-term, it could make ^{12}CQ an even more lucrative prospect than it already is.

Our valuation of Archer Materials

We believe Archer Materials' shares have the potential to rerate to a range of $0.60 to $1.00 in the medium term.

We reiterate our view from our initiation report on Archer Materials. We believe its shares have the potential to rerate to a range of $0.60 to $1.00 in the medium term. We note that the gap has closed somewhat since our initiation report in February, although there is still a gap between Archer Materials and its peers, particularly those at a similar development stage (Figure 3).

Figure 3: Valuations of ASX-listed peers

Company	Ticker	#shares	Share Price	Market Cap (A$ m)
Weebit Nano	WBT	188.0	3.23	607.4
BrainChip	BRN	1839.3	0.34	625.3
AudioPixels	AKP	29.2	6.20	181.0
4DS Memory	4DS	1749.1	0.09	157.4
BluGlass	BLG	1528.0	0.034	52.0
Revasum	RVS	118.6	0.115	13.6
BlueChiip	BCT	787.1	0.007	5.5
Average				***234.6***
Archer Materials	**AXE**	**254.85**	**0.55**	**140.2**

Source: Market Research Future, Pitt Street Research

There's high potential for Archer Materials to rerate to peer valuations

Although Archer Materials is earlier in development than Weebit Nano and BrainChip, we think these peers are an example of a stage of business maturity that Archer could become down the track.

Although Archer Materials is earlier in development than Weebit Nano and BrainChip, we think they are an example of a stage of business maturity that Archer Materials could become down the track assuming, overall, things go to plan. These examples do also show that it is a long and difficult road that may involve some trial and error. We would argue Archer Materials is at a similar stage to 4DS Memory and Audio Pixels and does not deserve to be trading lower than those two companies. We believe there is scope for a higher valuation of Archer Materials' shares.

In our initiation report, we also observed semiconductor M&A activity, noting the average valuation in the 5 years to the end of January 2024 is an Enterprise Value (EV)/Revenue of 3.7x. We ultimately decided not to try and value Archer using M&A given most semiconductor M&A transactions were completed prior to the current rate hiking cycle and involved companies that were generating commercial revenues.

Key share price catalysts

Any re-rating would be subject to the right share price catalysts becoming reality, as outlined below.

- The continued achievement of technology development milestones of both ^{12}CQ and the Biochip will be the key value drivers.
- Additionally, potential development partnerships with leading technology and life sciences companies will likely provide validation of Archer Materials' technologies, which in turn would be a major share price catalyst, in our view.
- The expansion of the company's IP portfolio. Additional technologies could help grow the company's valuation, although it would likely depend on how the portfolio was expanded as well as how far advanced any such technology was.
- The eventual commercialisation of Biochip and ^{12}CQ. It is difficult to exactly estimate when it would occur, although the Biochip could likely be first and the company's p-ESR microsystem will aid in bringing technologies to market.

Key risks facing Archer

The key risks we see Archer Materials as a company and listed stock include:

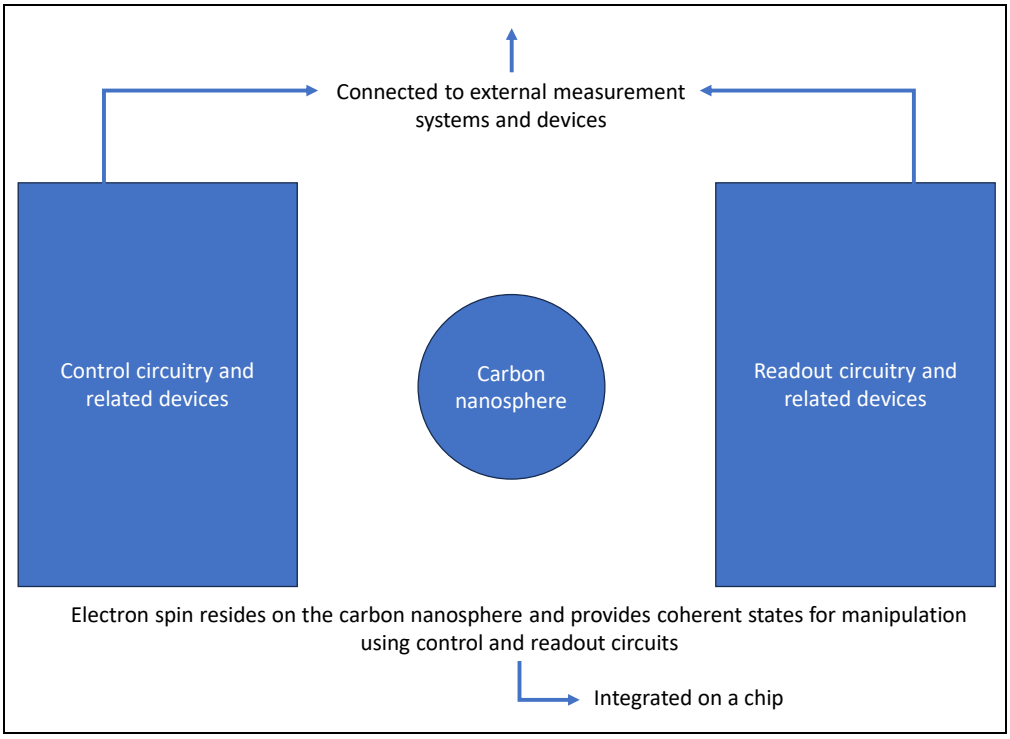
- **Development risk**: The road to a viable commercial product is still long for Archer Materials' ^{12}CQ technology and, to a lesser extent, for its Biochip technology. A lot of development and engineering work still must be done, which brings with it risk of technical failures, or at the very minimum extended development periods. This is true for most, if not all, emerging semiconductor technologies.
- **Technology transfer risk**: Once Archer Materials reaches the point where one of its technologies has become commercially viable, the technology will need to be transferred to manufacturing partners. Typically, these transfers take longer than expected given that manufacturing partners operate commercial fabs that leave little room for trial runs of new types of chips. In other words, technology transfers usually don't have the highest priority in commercial fabs.
- **Key man risk**: We believe that Dr. Mohammad Choucair, with his extensive scientific background and networks, is the main driving force behind the development of Archer Materials' technologies. If, for whatever reason, Dr. Choucair was no longer able to lead the company's product development and commercialisation efforts, we believe completion of both projects would be in very serious jeopardy.
- **Small cap risk**: As the investment climate in 2022 and 2023 has shown, investing in small caps is not for the faint-hearted. Pre-revenue and cash flow-negative small caps in particular have been hit hard as interest rates were jacked up by Central Banks around the world. Although current market consensus seems to be that interest rates will be cut starting sometime in 2024, that is not a given, which means that small cap valuations may stay depressed for longer than currently anticipated.
- **Funding risk**: Archer Materials is pre-revenue and will likely remain pre-revenue until the Biochip is successfully commercialised, which means the company will have to rely on outside funding through debt and/or equity until that time. Although the company had over $21m in cash per 31 December 2023 and no debt, market conditions may remain adverse for pre-revenue small caps for some time to come, which may limit Archer Materials' ability to raise sufficient capital on acceptable terms.

Appendix I - How ^{12}CQ would work

In simple terms, ^{12}CQ would work as follows:

1) A carbon nanosphere is positioned in a magnetic field (Figure 4), which "sets" the basic value of the qubit. Specifically, depending on how the magnetic energy in the electron in the carbon nanosphere affects the spin of this electron, the state of the electron can be an "up" spin or a "down" spin.
2) To change the state of the qubit, electromagnetic radiation, like microwaves, are directed at the nanosphere, for example using pulsed ESR concepts, which changes the spin of the electron, e.g. from Down to Up.
3) In quantum computing, however, the state of the qubit (the spin) can be Up and Down at the same time, and even a complex combination of both. This is known as Superposition, which makes quantum computing so powerful. You can manipulate electron spin using pulsed ESR.
4) To read out a value of the qubit, a second microwave pulse is sent out. The energy of this second pulse is only absorbed if the spin of the electron is Down. If the spin is Up, the new pulse won't be absorbed. Hence, whether or not the energy from the second microwave pulse is absorbed tells you what state the qubit was in, Up or Down, or 1 or 0.
5) Along with Superposition, Entanglement would then be required, presumably by engineering two of the carbon nanospheres close together to 'connect' them and performing the scientific experiments and measurements to test for proof of entanglement.

Figure 4: Basic ^{12}CQ configuration



Source: WIPO, Company, Pitt Street Research

Appendix II – Glossary

Bit – or binary digit is the minimum unit of binary information stored in a computer system.

Carbon nanosphere – The nanostructured carbon material of approximately 50 nanometres in size used in the ^{12}CQ chip.

Electron spin – The intrinsic angular momentum possessed by an electron. A quantum property that contributes to the magnetic properties of atoms and is crucial in quantum mechanics.

Graphene Field Effect Transistor (GFET) – A transistor composed of graphene.

Nucleic acids – Large biomolecules that play essential roles in all cells and viruses.

Nucleic Acid Sequence – The order of nucleotides in DNA.

Pulsed electron spin resonance (p-ESR) – ESR generally, is a method for studying molecules or atoms that have unpaired electrons.

Quantum - The principles of quantum mechanics that are leveraged to perform computations, in the context of the phenomena of superposition and entanglement of quantum states.

Qubit (or quantum bit) – The basic unit of quantum information in quantum computing.

Spectrometer – Essentially, an instrument that measures a physical characteristic over a given range, and can sometimes be used, broadly, in sensing**.**

Appendix III – Analyst Qualifications

Marc Kennis, lead analyst on this report, 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 Pitt Street Research, an issuer-sponsored equity research firm.

Nick Sundich is an equities research analyst at Pitt Street Research.

- Nick obtained a Bachelor of Commerce/Bachelor of Arts from the University of Sydney in 2018. He has also completed the CFA Investment Foundations program.
- He joined Pitt Street Research in January 2022. Previously he worked as a financial journalist at Stockhead for over three years.
- While at university, he worked for a handful of corporate advisory firms.

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