Moving ahead in conjunction with the broader industry

Share Price: $0.37

Shareholders in Archer Materials (ASX:AXE), the technology company developing quantum technology ^{12}CQ and lab-on-a-chip technology Biochip, own a stock that is progressing, in an industry that is making steady progress.

ASX: AXE

Sector: Technology

3 July 2024

Market Cap. (A$ m)	94.3
# shares outstanding (m)	254.9
# shares fully diluted (m)	254.9
Market Cap Ful. Dil. (A$ m)	94.3
Free Float	100%
52-week high/low (A$)	0.79 / 0.30
Avg. 12M daily volume ('1000)	349.1
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

Archer is continuing to move forward

Archer Materials is continuing to advance both its 12CQ and Biochip through the R&D stage, and so are most of its peers. Archer Materials has managed its cash well with no capital raisings in 2 years and A$20m in the bank as of 31 March 2024. A highlight of CY24 has been the successful fabrication of the Biochip graphene field effect transistor (gFET) designs through a 6-inch whole wafer run by Graphenea, the company's foundry partner in Spain. Graphenea produced 145 chips. This will help Archer Materials advance fabrication to produce gFET chips at scale. In mid-May 2024, we saw some of this first hand, taking a site tour of the Sydney Nanoscience Hub Research and Prototype Foundry (RPF), which Archer Materials shares with other companies to develop its technologies. This will be a key focus of this report.

Australian Government quantum bet should lead to more investments

Some investors were disappointed when they heard media headlines that the government was investing in PsiQuantum, inevitably preferring that Archer received an investment itself. This was a broader investment in quantum computing capabilities by the Australian and Queensland governments in partnership with PsiQuantum – it was not entirely an equity issue deal. We believe this deal will lead to more facilities like the RPF and likely more investments from established Technology players and that the broader Australian Quantum Computing ecosystem will benefit from this investment, and by extension, Archer.

Upside to come, even prior to commercialisation

Without putting a formal valuation on Archer Materials – with the company being early-stage – we continue to express that there is potential for shareholder value to be created as Archer Materials progresses its Biochip and ^{12}CQ technologies. We continue to observe that relevant ASX peers trade at valuations that are clearly higher than Archer Materials'. We see upside for the stock to a range of $0.60-$1.00 per share. Please see p.8 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' (ASX:AXE) two technologies are the ^{12}CQ quantum chip and Biochip.

Archer Materials' (ASX:AXE) two technologies are the ^{12}CQ quantum chip and Biochip. We will briefly recap both, although it is the former (^{12}CQ) that will be the focus of this update and that has attracted the most investor intrigue because Archer Materials is one of a few companies in the world, and the only ASX-listed company, working on such a technology. In many ways, the attention towards Archer Materials after the PsiQuantum investment is a testament to the position it is in, viewed as a candidate that could have received that investment. Ultimately, as we will outline in this report, Archer Materials will benefit from that investment.

^{12}CQ offers potential for accessible quantum computing

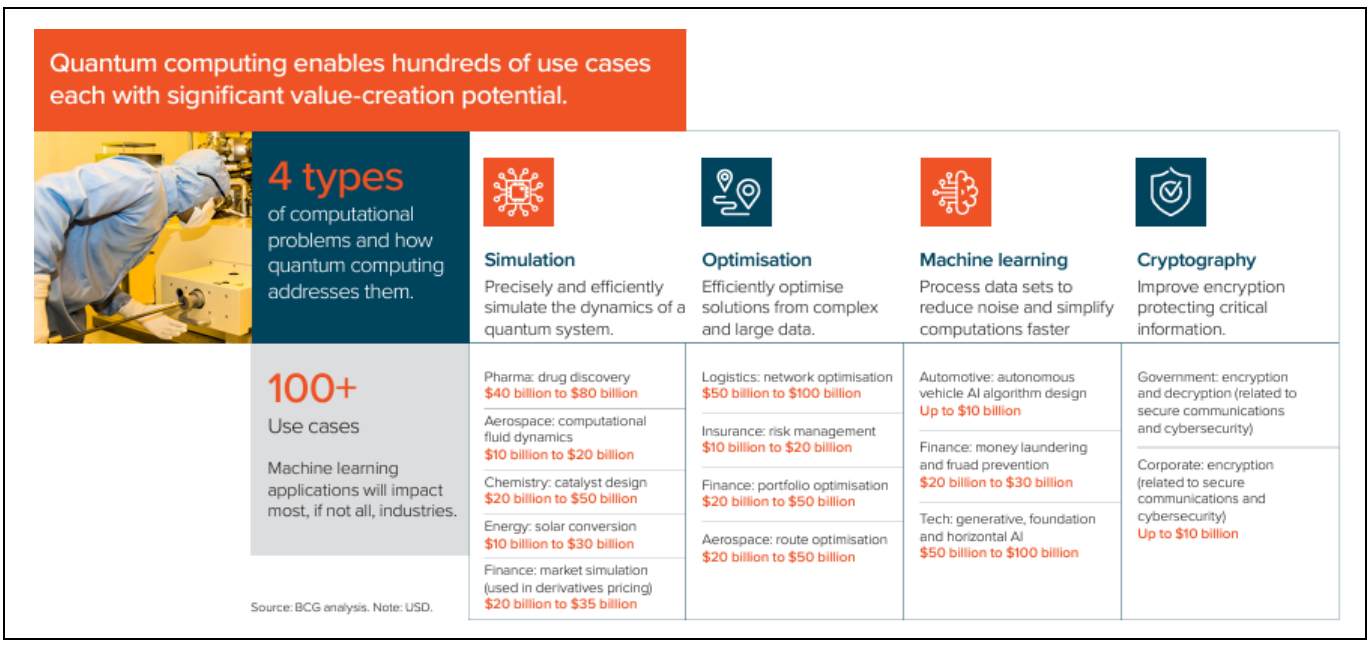
^{12}CQ (pronounced one-two-see-queue) is a carbon-based semiconductor technology being developed for potential quantum bit (qubit) application. This technology could pave the way for mobile quantum devices, resolving the impediments that have prevented quantum devices, namely computing devices, from reaching the mainstream – which currently include the practicalities of operation and scale. ^{12}CQ technology 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. In previous reports, we have implemented an appendix with further details on how ^{12}CQ would work and we have done so again in this report.

Figure 1: The possibilities of quantum computing



Source: Company

Biochip: Medical diagnostics, but not as you know them

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. The Biochip would allow 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, processed, 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.

Archer Materials' 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 Biochip from concept to design and through successful early-stage design fabrication testing at semiconductor foundries.

Archer Materials' recent progress

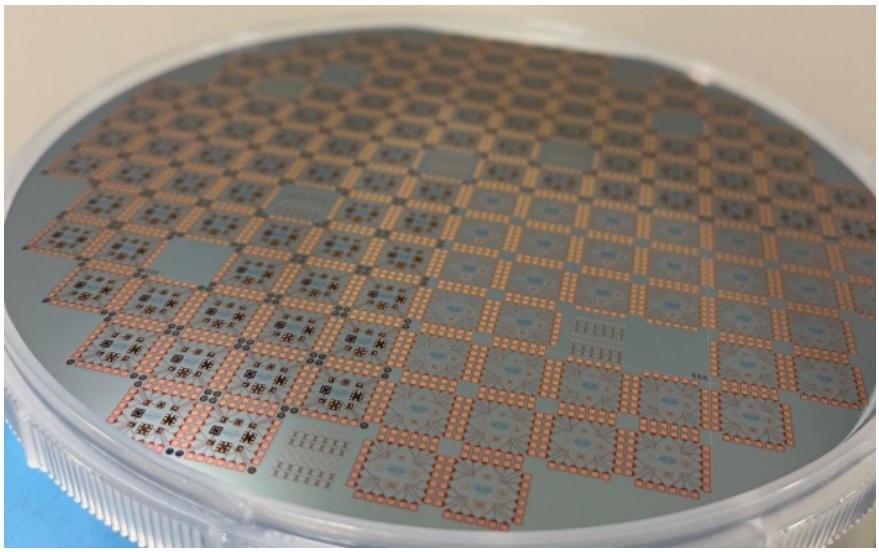
The Biochip has been the key focus of Archer Materials for the last 18 months or so, testing its Biochip gFET designs with external foundry partners. The company closed out CY23 having validated its first-generation Biochip gFET designs with trial wafer runs at foundries in Germany and the Netherlands, the latter of which was a four-inch run. Having passed these with flying colours, the design was sent to Graphenea, a foundry based in Spain, for a six-inch whole wafer run.

In mid-June, Archer Materials revealed the results of the fabrication, and it was a complete success. The fabrication produced 145 chips with 8 gFET devices on each chip. Archer Materials confirmed the gFETs performed as expected, with the required stability observed in the Dirac point[1] within the desired testing measurements voltage range. Figure 2 depicts Archer's gFET chips fabricated on a six-inch wafer by Graphenea.

Wafer runs will help Archer Materials optimise its gFET designs, performance and readiness for more comprehensive fabrication processes that will be able to produce gFET chips at scale. The fact that it was able to work on a six-inch wafer was positive because Archer has used four-inch wafers in the process of development. Taking small but gradual steps like this will maintain device stability and ensure the design will be suitable for necessary steps in chip making, such as liquid multiplexing.

[1] The dirac point is a point where conduction and valence bands in materials meet up and form a cone-like structure. As part of testing, stability of the gFET at the Dirac point is observed. The changes in Dirac point can be used to point to sensing events, and the data is collected electronically.

Figure 2: Archer's gFET chips



Source: Company

PsiQuantum: What the investment means for Archer Materials

Investors in Archer Materials raised plenty of eyebrows over the A$940m PsiQuantum investment. They may think that the investment means either Archer Materials is currently behind PsiQuantum or that at least the Australian and Queensland governments think it is. But either way, the (wrong) consensus is that Archer Materials will lag PsiQuantum because it received this money.

Despite the Federal and State Governments choosing to invest $940m into PsiQuantum, it is not the case that Archer Materials is necessarily behind PsiQuantum, because all players are in the R&D phase.

While no one can control private perceptions of government officials, it is not the case that Archer Materials is necessarily behind PsiQuantum. All quantum players are at an R&D phase and are at least a few years away from commercialisation[2][3]. This rings true even with major technology companies, like Microsoft and IBM, with established businesses that can help fund their own quantum aspirations. No doubt A$940m would make a difference to any quantum computing aspirant, and it will to PsiQuantum. But we believe the investment is about more than just one company, it is about the whole ecosystem, which will derive benefit, including for Archer.

The goal is not necessarily to support one company, even if the optics of such an investment may indicate a bet on the Government's part that PsiQuantum will be *the* quantum company.

The investment was more than just one company. This is an investment in the broader

The Federal Minister for Industry and Science, Ed Husic, told the Australian Financial Review that one of the two questions in the EOI (Expression of Interest) process was what opportunities there would be for spillover benefits for Australian communities and industries[4], however it was revealed by The Australian earlier this month that PsiQuantum was the only quantum computing company the Government put through a formal due-diligence process.

[2] https://www.weforum.org/publications/quantum-economy-blueprint/
[3] https://www.weforum.org/publications/state-of-quantum-computing-building-a-quantum-economy/
[4] https://www.afr.com/technology/answers-emerge-slowly-to-government-s-1bn-quantum-questions-20240502-p5foj2

Why and how Archer will benefit

Some consequences from the deal require that PsiQuantum will:

- establish partnerships with the local quantum industry to create advanced manufacturing clusters and develop an innovation precinct next to the quantum computing site,
- create a dedicated climate research centre,
- open new digital and advanced tech supply chain opportunities, and
- invest in university and research collaborations, including PhD positions, mentoring and internship opportunities[5].

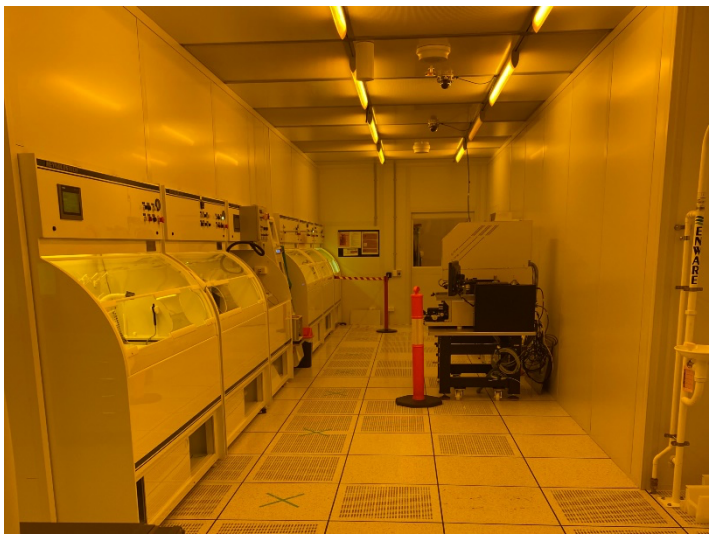
We expect to see the Government investment in PsiQuantum benefit the broader Australian quantum computing ecosystem.

Even if only some of these come to fruition, Archer Materials will ultimately be a beneficiary, in our view. Investors may not realise that Archer Materials doesn't own the facilities it uses. The company is reliant on facilities and equipment, such as the Nanoscience Hub at the University of Sydney, sharing it with other smaller technology companies and even larger companies, such as Microsoft.

We were treated to a site visit at the Nanoscience Hub Research and Prototyping Foundry (RPF), hosted by Archer. Figures 3 and 4 show just a couple of examples of the facilities and equipment housed in the infrastructure required. The specific costs of individual components would likely depend on the individual part because these can be highly specified, although we were told, for example that typical helium fridge setups and housing would cost about A$6m each. Helium fridges are used to cool semiconductor devices down to -269°C, and are also used in the operation of quantum computers.

Many parts are also subject to 'supply chain issues' or have lingering questions over their heads – the bulk of the world's helium is set to run out in 20 years and the majority of it comes from Russia, China, Japan, and the US[6]. We also observe that the whole Nanoscience Hub cost A$150m back in 2016, including some of the equipment. The speciality equipment needs to be perfect to avoid contamination to the wafers.

Figure 3: Wafer chemical processing equipment in the semiconductor cleanroom facility at the RPF



Source: Nicholas Sundich, Pitt Street Research

Figure 4: Cryogenic measurement systems at the RPF

Source: Nicholas Sundich, Pitt Street Research

[5] https://international.austrade.gov.au/en/news-and-analysis/news/psiquantum-to-build-worlds-first-fault-tolerant-quantum-computer-in-australia
[6] https://www3.weforum.org/docs/WEF_Quantum_Economy_Blueprint_2024.pdf

This 'share house' model is one of the key reasons Archer Materials has not raised capital in roughly two years and remains well funded with A$20m in the bank to fund development activities.

The point we are trying to illustrate here is that Archer Materials is not as far behind as some investors might imagine it is, even though another company is to receive $940m in government money. Yes, Archer Materials' intellectual property is at least a few years away from commercialisation and the company is currently advancing through the R&D stage, but so are most other companies, including PsiQuantum (at more mature/later stages). Yet, Archer Materials is well positioned because of its technology, partnerships, expert staff, and because it shares major facilities with other companies.

As we've just shown, infrastructure necessary for quantum computing does not come cheap and is extremely difficult to 'reverse engineer' and build. So, it makes sense for companies like Archer Materials to use third-party facilities, because the capex is virtually zero. This 'share house' model is one of the key reasons why Archer Materials has not raised capital in roughly two years and remains well funded with A$20m in the bank.

Development will be a measured grind and not necessarily about major capital raise headlines. Commercialisation and adoption of quantum computing technology - whether from Archer Materials, PSIQuantum or someone else – has been realistically set to 2030 by the quantum communities themselves. The Government's investment is in-line with the actions taken by the major economies investing in quantum, including the US, UK and China. It is an acknowledgment that quantum technologies, including quantum computing, is of critical long-term importance to Australia's economic prosperity.

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 continue to believe Archer Materials' shares have the potential to rerate to a range of $0.60 to $1.00 in the medium term. Since our initiation report, its shares did re-rate and hit $0.60 briefly, but have since retreated possibly due to exogenous factors in a largely retail trading environment.

We observe again that there is still a gap between Archer Materials and its peers, particularly those at a similar development stage (Figure 5).

Figure 5: Valuations of Archer's ASX-listed peers

Company	Ticker	#shares	Share Price	Market Cap (A$ m)
Weebit Nano	WBT	188.044	2.44	458.8
BrainChip	BRN	1839.25	0.22	404.6
4DS Memory	4DS	1749.1	0.08	139.9
BluGlass	BLG	1528	0.032	48.9
Revasum	RVS	118.6	0.145	17.2
BlueChiip	BCT	787.1	0.005	3.9
Average				***178.9***
Archer Materials	**AXE**	**254.85**	**0.37**	**94.3**

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 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 Materials 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 chip and the Biochip will be the key value drivers.
- Additionally, potential development partnerships with leading semiconductor, 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 commercialisation would occur, although the Biochip could likely be first and the company's 12CQ chip will aid in bringing technologies to market.

Key risks

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 a 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.

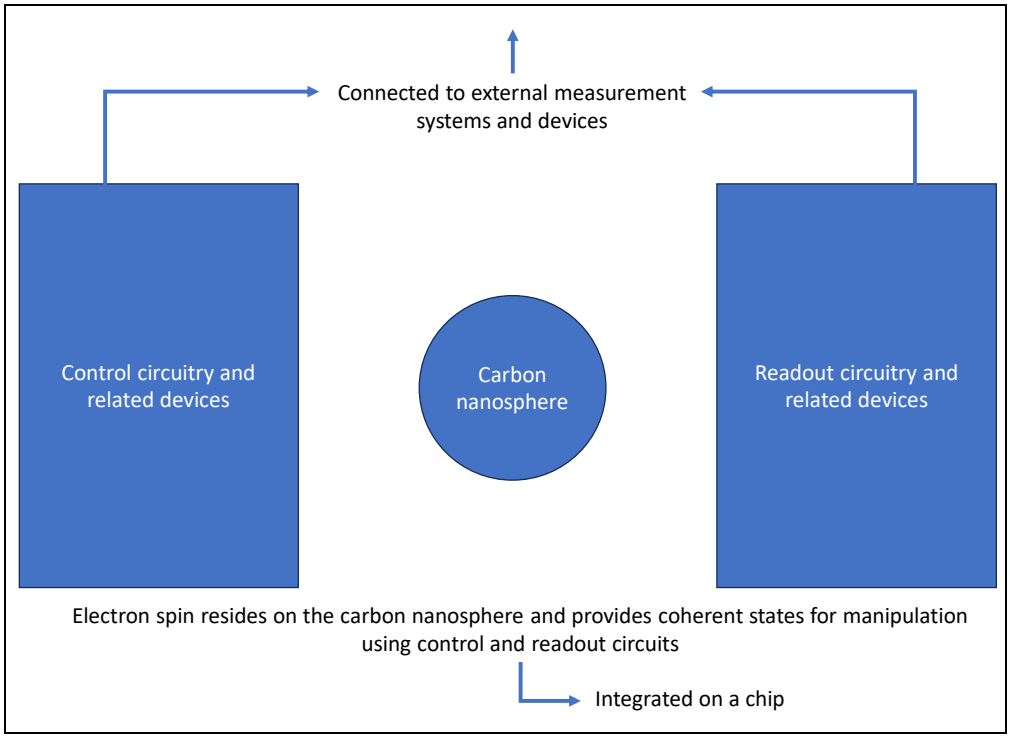
- **Key man risk**: We believe that Dr. Mohammad Choucair, with his extensive scientific background and networks, is the main driving force behind the development of Archer Materials' technologies. If, for whatever reason, Dr. Choucair was no longer able to lead the company's product development and 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 A$20m in cash per 31 March 2024 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 6), 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 manipulate 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, to achieve control.
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 6: 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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