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Strategy and Analysis Branch – Strategy and Performance,
Investment NSW
Level 2, 105 Prince St, Orange NSW 2800

Via email: industrypolicy@investment.nsw.gov.au

Dear Anthea

RE: Green Paper – Securing future innovation and global competitiveness in NSW

CSIRO welcomes the opportuntity to provide input to the NSW Government's consultation process on Securing future innovation and global competitiveness in NSW and is available to discuss any of the areas of mutual interest raised in our submission.

CSIRO is Australia's national science agency and is one of the largest and most diverse research agencies in the world, ranked in the top one per cent of global research agencies (see www.csiro.au). CSIRO has 14 sites in metro and regional NSW. Under the Science and Industry Research Act 1949, one of CSIRO's primary purposes is to facilitate and encourage the adoption and utilisation of scientific research for the benefit of Australia, including to create jobs and economic benefit.

CSIRO is actively engaging with NSW Government to provide advice on industry issues when requested. In March 2022, we delivered a report to Investment NSW on *NSW Emerging Technologies – Mapping the Landscape and identifying comparative advantage* which we understand will provide input to the NSW Digital Technology Strategy, as well as related strategies including Advanced Manufacturing. In August 2021 we delivered a report to the Western Parkland City Authority on *Industry Growth Opportunities* Microsoft Word - Final Report.docx (wpca.sydney).

CSIRO is also co-developing a suite of National Missions Partner with us to tackle Australia's greatest challenges - CSIRO with Federal and State Governments, University and Industry partners relevant to many of the areas outlined in the Green Paper. These Missions bring together broad coalitions around bold visions that reimagine our economies, our approach to health and wellbeing, and our environments.

We have also developed a series of Roadmaps that NSW could draw on for information on areas outlined in the Green Paper. The Roadmaps published in 2021 and 2022 are described in the attachment and relate to the areas of: Protein; CO2 Utilisation; Critical Energy Minerals; Synthetic Biology; Space; and Unlocking Innovation Potential of Australian Companies.

The attachment outlines many of CSIRO's programs and capabilities that could support NSW industry including providing SME support and education programs and includes comment the Green Paper's questions relevant to CSIRO activity.

We would welcome the opportunity to discuss how CSIRO and the NSW Government could work collaboratively together in areas aligned with NSW strategic priorities to better support innovative globally competitive industry.

Should you require additional information on any of these issues, please contact Caroline Seagrove, NSW Relationship Manager (caroline.seagrove@csiro.au).

Yours sincerely

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1. Transformative forces creating challenges and opportunities

New global megatrends are emerging that will impact of all of Australian industry and society over the coming decades. These include:

- **Climate change** and growing ecological fragility creating tightening food and other resources, species extinction, and more frequent natural disasters. Energy transition to avert the worst outcomes from climate change will also involve rapidly decarbonising the economy and finding new energy generation and storage solutions.

- **Increasing health demands** and resourcing from aging populations and a growing infectious disease risk associated with higher populations, antimicrobial resistance and more species interactions.

- **Changing regional geopolitical landscapes** the possibility of mass human movements, conflicts and trade tensions developing.

- **The next wave of industrial technologies** driven by enhanced digital connectivity, quantum computing, artificial intelligence (AI), blockchain, virtual interfaces and advanced data analytics.

These megatrends present challenges and opportunities for the Australian sciences sectors. Technical solutions will be sought for many of the emerging challenges and the Australian sciences sector will need to be prepared to respond.

This includes providing support for:

- Net-zero emissions targets and energy transition, reducing waste and pollution, and building circular economies
- engaging with our neighbours in the Asian region to provide stability and jointly exploring new opportunities, and
- exploiting the huge potential of digital technologies to modernise Australian industry, and, in doing so, create new industries and develop export markets using new digital technologies.

Digital technologies are also changing the ways in which science is undertaken and funded. AI and quantum computing alone will revolutionise the scientific sector and work done by CSIRO. Keeping Australians at the forefront of this revolution will be critical for Australia's ongoing economic competitiveness.

CSIRO's Roadmaps also consider transformative forces relating to specific areas of the Australian economy.

A range of roadmaps produced by CSIRO are summarised including in 2021 and 2022:

- Australia's Protein Roadmap - CSIRO
- CO2 Utilisation Roadmap
- Critical Energy Minerals Roadmap
- Australia's Synthetic Biology Roadmap
- Space Roadmap
- The CSIRO-BCA joint report on Unlocking the innovation potential of Australian companies

The 2020 CSIRO COVID-19-Recovery-Resilience-Report.pdf identifies a number of growth industries, including energy, food and agribusiness, health, and mineral resources, together with underpinning capabilities like advanced manufacturing and digital technologies, where Australia has an opportunity to build on our current strengths to differentiate and lead internationally.

Finally, the Australian National Outlook 2019 Australian National Outlook - CSIRO combines CSIRO's integrated modelling and research with input from National Outlook participants, a group comprised of

over 50 leaders across 22 leading Australian organisations from industry, the not-for-profit and education sectors, to provide a compelling view about Australia's future.

2. Business operating environment

Education and Outreach Programs

STEM and digital skills will play a vital role in realising the nation's innovation and productivity potential[1], with a growing demand for qualified STEM professionals[2] and workers with STEM skills[3] and STEM literacy[4]. In addition, because student enrolment[5] and performance in STEM subjects in schools is down, and there is under-representation in STEM among several groups, including young women[6]. Supporting the STEM talent pipeline will help minimise the mismatch between skill requirements of industry and the skills possessed by the workforce, and will also maximise productivity and output.[7] Furthermore, with globalisation and technology changes altering industry and the workforce, the number and variety of occupations requiring STEM skills and advanced STEM literacy will increase.[8]

CSIRO's Education and Outreach unit helps strengthen Australia's future STEM workforce through a number of programs that aim to increase the STEM and enterprise skills of participants. Specifically, these programs contribute to the "*quality and quantity of* [STEM] *workforce skills*" (Green Paper, p. 18) through inquiry-based, curriculum-aligned education opportunities that help prepare students for the "*emergence of more complex, innovative work in many industries*" (Green Paper, p.18). In addition, by focusing on relevant, immersive, real-world applications and examples, CSIRO's education programs also support the "*alignment…of education services to match industry skill needs*" (Green Paper, p.18), inspiring students[9] to learn industry-relevant skills and follow pathways to the jobs of the future. CSIRO Education and Outreach's programs are aimed at school-aged and tertiary students, for example:

School

- STEM Professionals in Schools[10] is Australia's largest national skilled volunteering program for STEM professionals and classroom educators. The program facilitates ongoing partnerships between STEM

[1] Australian Government. (2021). *The state of Australia's skills 2021: now and into the future*. Retrieved from www.nationalskillscommission.gov.au/sites/default/files/2022-03/2021%20State%20of%20Australia%27s%20Skills_0.pdf

CSIRO Corporate Plan 2021-22 (www.csiro.au/en/about/Corporate-governance/Corporate-Plan/21-22-corporate-plan)

[2] Anderson, J. (2020). The STEM education phenomenon and its impact on school curriculum. *Curriculum Perspectives, 40*, 217-223.

[3] Over the 20-year period to February 2020, before the impact of the COVID-19 pandemic on the labour market, employment in STEM occupations grew by 85.0%, or more than twice the rate of non-STEM occupations (which grew by 40.2%). Australian Government (2021). *The state of Australia's skills 2021: now and into the future*. Retrieved from www.nationalskillscommission.gov.au/sites/default/files/2022-03/2021%20State%20of%20Australia%27s%20Skills_0.pdf

[4] The National STEM School Education Strategy, 2016–2026 identifies the importance of STEM literacy in the core capabilities that Australian employers need. www.dese.gov.au/australian-curriculum/support-science-technology-engineering-and-mathematics-stem/national-stem-school-education-strategy-2016-2026

[5] Education Services Australia (2018). *Optimising STEM Industry-School Partnerships: Inspiring Australia's Next Generation Final Report*

[6] McMillan, J., Rothman, S., Buckley, S., & Edwards, D. (2021). *STEM pathways: The impact of equity, motivation, and prior achievement*. ACER.

[7] Dockery, A.M., Phillimore, J. & Bawa, S. (2021). Changing demand for STEM skills in Australia and gender implications. *Australian Journal of Labour Economics, 24*(1).

[8] Australian Government. (2020). *Australia's STEM workforce*. Retrieved from https://www.chiefscientist.gov.au/sites/default/files/2020-07/australias_stem_workforce_-_final.pdf

[9] Secondary students prefer authentic inquiry-based learning experiences, and STEM education with links to real-world issues positively affects students' interest in STEM careers. Morris, J., Slater, E., Boston, J., Fitzgerald, M. & Lummis, G. (2021). Teachers in conversation with industry scientists: Implications for STEM education. *International Journal of Innovation in Science and Mathematics Education, 29*(1), 46-57.

[10] STEM Professionals in Schools is supported by the Australian Government Department of Education, Skills and Employment and delivered by CSIRO.

professionals and teachers who work together to increase teachers' and students' STEM skills, knowledge, and confidence through a range of activities.

- Generation STEM[11] aims to attract, support, retain, and train NSW students in STEM and school, into further education and into employment. As part of the initiative, the STEM Community Partnerships Program creates partnerships between local schools and industry, with the goal of highlighting local STEM careers and opportunities, and providing avenues for students to develop their STEM skills. Deadly in Generation STEM is a STEM outreach education program characterised by connecting the curriculum to real-world problems, with a particular emphasis on linking these learnings with Indigenous knowledges and frameworks. It is targeted at both NSW Aboriginal and/or Torres Strait Islander and non-Indigenous students in years 8 to 11.
- Young Indigenous Women's STEM Academy[12] aims to increase the number of Aboriginal and Torres Strait Islander females undertaking studies and careers in STEM. The Academy does this through targeted, long-term support to help overcome the barriers that discourage Indigenous women from pursuing STEM careers.
- Bebras is an international initiative aiming to promote Computer Science among school students at all ages. The Bebras challenge is open twice a year to Australian students in years 3 to 12 and builds students' computational thinking and problem-solving skills.
- CyberTaipan is an Australian Youth Cyber Defence Competition modelled on the US Air Force Association's CyberPatriot program. The program is open to high school-aged students and aims to raise awareness of and skills in cyber security, defensive countermeasures, and securing virtual networks.

Tertiary

- The Undergraduate Research Opportunities Program [13]involves students undertaking a supervised project which is part of the research program of a research laboratory[14]. The program provides students with an insight into biomedical research careers and valuable hands-on experience and expertise in laboratory techniques. The program enhances the biomedical research industry's workforce capability by attracting high performing students and building the skills needed for a career in research.
- STEM Links, part of the Generation STEM initiative, provides high-quality internships to help tertiary students gain relevant workplace skills, and transition into STEM jobs after graduation.

Skills

Skill sets are underutilised and misaligned in areas needed for commercialisation of emerging science and technology opportunities. For example, the demand for skills in quantum technologies (researchers, engineers) exceed supply, and CSIRO's ability to attract and retain expertise is a challenge.

Data and digital skills are now required in almost all occupations. CSIRO researchers have supported the development of a "Digital capability framework" for the Department of Education, Skills and Employment which draws upon the European Union's digcomp framework. The framework is currently under review with the Industry Reference Committees and being used to support strategic review of training packages in the context of digital transformation. The framework provides a population-inclusive and sector neutral language for describing the broad digital capabilities that are needed in the Australian workforce. CSIRO researchers have developed an algorithm that identifies these digital capabilities where they are described

[11] Funded by the NSW Government through a 10-year $25 million endowment to the Science and Industry Endowment Fund

[12] Funded by the National Indigenous Australians Agency and delivered by CSIRO in partnership with CareerTrackers

[13] Sponsored by CSL Limited and delivered by CSIRO

[14] Currently, the Undergraduate Research Opportunities Program operates in Victoria only.

in Units of Competency and Qualifications within VET Training packages. They will also be comparing what digital capabilities are sought by employers in job ads to identify where there may be gaps between demand for and supply of digital capabilities within the VET system.

We note that whilst data and digital skills are important, skills that are not readily automated (e.g., interpersonal skills, high manual dexterity, novel problem-solving) are also experiencing strong growth[15]. The ability to complement technology with the less automatable human skills will be a key factor in the employability of human workers in an increasingly automated environment. Thus, reskilling and upskilling efforts should focus on complementary skills in addition to data and digital skills.

The latest advances in Artificial Intelligence are capable of performing non-routine cognitive tasks[16]. The occupations that are most exposed to this wave of artificial intelligence capability (e.g., legal professional and accountants) tend to be in more highly paid roles that require high levels of formal education[17]. It is not yet clear whether these developments will actually led to decreasing demand for some highly educated and skilled workers. It will be important to monitor these impacts to see whether workers are being displaced or whether this technology primarily serves to augment the performance of human workers. Even in situations where the technology augments the worker, increasing demand for their unique capability or allowing them to add value in new ways, educational offerings will need to adapt to ensure that the workers in the affected occupations are capability of adjusting.

Understanding where "green energy jobs" are being advertised and how the occupational, geographic and skills profile of "green jobs" compares with the profile of traditional energy jobs is the subject of a proposal for collaboration between CSIRO Data61's Knowledge Discovery and Management group and the National Skills Commission. This project should be commencing in July 2022.

[15] Borghans, L., Duckworth, A. L., Heckman, J. J., & ter Weel, B. (2008). The economics and psychology of personality traits. *Journal of Human Resources*, *43*(4), 972–1059. https://doi.org/10.3368/jhr.43.4.972; Acemoglu, D., & Autor, D. (2011). Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of Labor Economics* (Vol. 4, Issue PART B). https://doi.org/10.1016/S0169-7218(11)02410-5

[16] Brynjolfsson, E., Mitchell, T., & Rock, D. (2018). What Can Machines Learn, and What Does It Mean for Occupations and the Economy? *AEA Papers and Proceedings*, *108*, 43–47. https://doi.org/10.1257/pandp.20181019; Felten, E. W., Raj, M., & Seamans, R. (2018). A Method to Link Advances in Artificial Intelligence to Occupational Abilities. *AEA Papers and Proceedings*, *108*, 54–57. https://doi.org/10.1257/pandp.20181021; Felten, E. W., Raj, M., & Seamans, R. (2019). The effect of artificial intelligence on human labor: An ability-based approach. *AOM 2019: Understanding the Inclusive Organization - 79th Annual Meeting of the Academy of Management*, *2019-Augus*. https://doi.org/10.5465/AMBPP.2019.140

[17] Webb, M. (2019). The impact of artificial intelligence on the labor market. *Available at SSRN 3482150*. Acemoglu, D., Autor, D., Hazell, J., & Restrepo, P. (2020). *NBER WORKING PAPER SERIES AI AND JOBS: EVIDENCE FROM ONLINE VACANCIES*. http://www.nber.org/papers/w28257. Felten, E. W., Raj, M., & Seamans, R. (2019). The effect of artificial intelligence on human labor: An ability-based approach. *AOM 2019: Understanding the Inclusive Organization - 79th Annual Meeting of the Academy of Management*, *2019-Augus*. https://doi.org/10.5465/AMBPP.2019.140

3. Views on current industry programs and actions

Support for SMEs is critical across industry sectors. Since SMEs are the backbone of Australia's economy, they should be supported as much as possible to advance their innovations and commercial opportunities in these areas. (Q11)

Innovation connections, which is delivered by CSIRO on behalf of the DISER's Entrepreneur's Program, allows SMEs from $1.5M-100M in turnover undertake R&D projects with research organisations. Whilst this is a national program, the program has undertaken 694 projects in NSW since 2014. These projects have generated $63.3M of research value for NSW which is important to support the commercialisation of new products and technology. Innovation Connections alumni have also been supported by our facilitators into other programs such as the NSW TechVoucher programs. Having important links with similar programs and innovative businesses ensures we are supporting businesses to utilise opportunities that will help their business grow.(Q12)

CSIRO Kick-Start is a facilitated dollar-matched funding program that allows start-ups and small businesses access to CSIRO expertise to undertake research and development (R&D) projects. Since 2017, the program has engaged 68 NSW start-ups and small businesses, generating $22M of research value. An expansion of this program into the capabilities and research expertise of NSW universities (similar to the previous NSW TechVouchers program) would bring value to not only SMEs, but also research organisations to enable them to work more readily with industry.

Innovate to Grow is our 10-week online experiential learning program for SME leaders to understand more about R&D. The program has currently completed 9 cohorts across 5 different sectors (agrifood, mining, plastic waste, cybersecurity, space). Our recent cohort for Defence is run specifically for businesses in NSW with co-funding from Investment NSW. An expansion of this program would allow more SMEs in the sectors identified in the green paper to develop their R&D ideas into an actionable business case and/or funding proposal, as many of our alumni have gone on to undertake projects with CSIRO or university. (Q14)

Overview of Federally funded and CSIRO AI Initiatives which could be leveraged for NSW

National AI Centre

The National AI Centre led by CSIRO was launched in December 2021 to coordinate Australia's AI expertise and capabilities, and address barriers that small- to medium-sized enterprises (SMEs) face in adopting and developing AI and emerging technology. The Centre will:

- support projects that lift AI business capability to use cutting edge technology across multiple sectors, foster collaboration between industry and researchers, and attract investment
- provide a 'front door' for SMEs looking for talent, knowledge and the tools to adopt transformational AI technologies
- work across the entire AI ecosystem to ensure that activities delivered by each of the four Capability Centres are strategically aligned.

Next Generation AI and Emerging Technologies Graduates Programs

To address critical skills shortages in AI and emerging technologies, CSIRO has been allocated funding over the next six years to deliver the Next Generation Artificial Intelligence Graduates Program and the Next Generation Emerging Technologies Graduates Program. Through these programs CSIRO is working in partnership with industry and universities to grow a pipeline of home-grown, job-ready graduates to unlock the immense economic opportunity offered by artificial intelligence and emerging technologies, such as robotics, cyber security, quantum computing, blockchain and data.

CSIRO strategic Initiatives directly related to AI:

AI for Missions seeks to create novel AI research and technologies that will enable CSIRO Missions to solve Australia's greatest challenges. To deliver on this goal we will partner with universities and industry to advance the science, technology and impact of AI to support Missions.

CSIRO's Future Science Platform (FSP) Investments include:

- The Machine Learning and Artificial Intelligence FSP which focuses on cross-disciplinary projects that apply ML/AI to solve fundamental problems about conceptual and data-driven research applications. The solutions, platforms and people trained through the MLAI FSP will create a new ongoing capability within CSIRO to address core research challenges for the benefit of Australia.

- The Collaborative Intelligence (CINTEL) FSP which aims to move beyond machines replacing people or automating their jobs, and instead to create teams that maximise the benefits of both human and machine intelligence.

4. Summary of issues for specific industry sectors

Energy Sector

The generation mix in Australia's energy markets is changing as older coal-fired generators are approaching the end of their asset lives and energy systems drive towards cleaner energy sources[1]. In addition to the changing energy mix, the spatial distribution of power generation is also changing. According to the Australian Energy Market Operator (AEMO), starting around 2023, Australia could have one of the highest decentralisation ratios of non-grid generation in the world.[2] CSIRO and Energy Networks Australia estimate that by 2050, between 30 to 45 per cent of our annual electricity consumption could be supplied from consumer-owned generators.[3] Gas will play a strong underpinning transitional role as technologies for the safe and economical production and use of hydrogen evolve. Here is a high-level summary of the portfolio of these technologies:

- Gas-fired electricity generation has lower emissions than coal and there is existing infrastructure in place around Australia. Gas has a high utility for peak and shoulder periods of the day, competes cost-wise with coal and offers a 31% and 50% reduction of GHG emissions depending on the generation technology used.[4]
- Utility-scale solar and wind are cost effective and can leverage the stability of existing coal and gas generation[5]. It is possible to reach more than 75% instantaneous penetration of renewables using a highly interconnected grid to shift power around and balance the load, by leveraging fossil sources[6].
- By 2030 it is expected that four of Australia's states will be achieving at least 50% electricity generation from renewables[7]. This means energy storage will be critical to continue Australia's emissions reduction journey.
- Clean hydrogen provides an option for diversified and distributed energy production and storage. [8] Hydrogen can be introduced in gas networks, large scale underground storage, used in chemical form such as ammonia or to decarbonise some of the world's most carbon-intensive sectors – transport, steelmaking, petrochemicals, agriculture, maritime industries.
- CSIRO's bespoke life cycle analysis model of lithium ion battery chemical production provides useful insights about how important it is to decarbonise the grid for carbon-competitive manufacturing and recycling:

- Nickel sulphate – a key battery chemical –made from ore using the current WA grid contains about 32 kgCo2/Kg Ni. This drops by nearly 64% to 11.5 kg Co2/Kg Ni when the electricity inputs are 100% renewable.[9]
- Similarly the carbon intensity of Lithium Carbonate from ore drops by 55% (from 46 to about 21.1 kgCo2/Kg Li contained) when energy inputs are 100% renewable. [10]

1. AEMO 2020 Integrated System Plan (ISP), https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp
2. AEMO and Energy Networks Australia 2018, Open Energy Networks, consultation Paper. Retrieved from: https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2018/OEN-Final.pdf
3. CSIRO and Energy Networks Australia 2017, Electricity Network Transformation Roadmap: Energy Networks Australia, Retrieved from: https://www.energynetworks.com.au/resources/reports/electricity-network-transformation-roadmap-final-report/
4. Please see, https://gisera.csiro.au/research/greenhouse-gas-and-air-quality/
5. The 2020-21 GenCost report focuses on system integration costs – moving beyond LCOE to consider how the mix of energy technologies integrate and the need and cost of balancing technologies such as energy storage. See, https://www.csiro.au/en/news/news-releases/2020/renewables-still-the-cheapest-new-build-power-in-australia
6. AEMO released a renewables integration study in 2020, where they state that without any changes the current system can handle up to 50% instantaneous VRE penetration: https://aemo.com.au/-/media/files/major-publications/ris/2020/renewable-integration-study-stage-1.pdf
7. https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2020.pdf
8. National Hydrogen Roadmap models costs for different storage technologies such as battery, pumped hydro, gas turbine, H2 fuel cell. Accessible through National Hydrogen Roadmap - CSIRO
9. CSIRO, unpublished
10. CSIRO, unpublished

Health Sector

- Infectious diseases – Large scale viral outbreaks are growing in frequency and severity due to many factors including climate change, urbanisation and increased trade and travel. Australia needs to better understand these emerging risks/pathogens – how they evolve, how they transmit, and the most effective prevention and treatment options - to build resilience. CSIRO is building an Infectious Disease Resilience Mission and Anti-Microbial Resistance Mission to help, and CSIRO Futures can assist with national strategy development on this topic (and others listed below).
- Changing national health profile – Many of our health systems were built over 100 years ago based largely on acute/short-term health conditions, however we continue to need systems that are better designed for chronic conditions (aging population, increased understanding of mental health), increase in neurodegenerative disorders, changing spectrum of cancers as common cancers become more survivable. Preventative care models tie in with these drivers also as we seek to prevent rather than treat. Prevision healthcare involving tailored medical responses will also be increasingly in demand and an important science and tech-led trend over the next decade
- Digitisation - Digital solutions are being implemented to more efficiently process and share patient data, and underpin and connect smart devices for improved diagnosis and monitoring. Challenges to the digitisation trend include dated infrastructure, siloed data streams (interoperability), ever-evolving regulatory requirements, data ownership, trust and digital and health literacy.
- Financing – value-based pricing and sustainable funding are huge topics/forces in health.

- Australia has a strong medtech/biotech research sector but is poor at translating outputs into impact / commercial products. This gap could be helped by investments in translational science (to position early research for impact), technoeconomic analysis (to better assess commercial opportunities early on), and shared-access to scale-up infrastructure.
- Venture Capital in Health in Australia is small. Many of our start-ups move abroad to get additional funding (e.g. in the US) as well as to access larger markets/ecosystems and established infrastructure.
- Any important medtech that doesn't have a self-supporting private/commercial business case is an area for potential market failure. Technology/products that relate to transient health needs (e.g. during pandemics) are an example. Industry policies around local procurement can ensure there is sufficient demand to keep these pipelines and workforce operational in between peak demand periods.
- Industry growth can be supported across a myriad of technology opportunity areas, including AI in health, medical countermeasures, data standards, clinical trials, small-scale manufacturing, quantum in health etc.

<u>Manufacturing Sector</u>

The transformative forces that we see include:

- Increased demand for sovereign capability to manage global supply chain disruption
- Uptake of digital and other technologies to transform established businesses
- The ongoing rise of scale-ups and SMEs (move away from reliance on large corporates)

Australia's purchasing (both public and private) needs a clear bias towards buying local (for example generous US defence contracts support domestic business and innovation). Incentives to innovate and grow, such as follow-on investment prizes/grants AFTER major contracts or global partnerships could be established (reward successful risk)

We see the opportunities for the manufacturing industry as including:

- Maximisation of local manufacturing capabilities
- Superior componentry
- Sustainable and agile manufacturing
- Value-adding downstream processing of minerals

And some of the challenges as being:

- Domestic purchasing: Growing business and further investment requires consistency of revenue (the negative influences unrelenting global price competition could be mitigated for a period to support local innovation and regaining competitive capabilities)
- Skilled workforce shortages (ie how to retain expertise in Australia)

To address this CSIRO is engaged in activities including:

- Increased focus on R&D for small businesses (wanting to engage with expertise and innovate) – The challenge for CSIRO is how to respond in a meaningful way to support SMEs to innovate. As one measure, CSIRO aims to invest in development of IP for manufacturers which lifts their competitive advantage – product innovation should either attract a premium or match a competitors price advantage
- Engaging with WPCA/Advanced Manufacturing Research Facility to support new shared facility planning and development for Bradfield
- Active involvement with the Investment NSW Boosting Business Innovation Program to support start-ups and SMEs who want to innovate and increase R&D

In terms of the business operating environment CSIRO suggests that Infrastructure procurement tenders could be used to accept domestic supply, and consider service, support and quality attributes over price.

Energy transition from fossil to sustainable sources is inevitable and urgent. The transition to emerging future manufacturing industries in energy storage technologies, and sustainable hydrogen export will assist with workforce transition support, and will benefit from accelerated investment and early employment development.

CSIRO sees key areas where there are opportunities programs and actions to accelerate ongoing economic growth as being Future manufacturing industries including: energy storage to support renewable energy generation, the emerging sustainable hydrogen economy, recycling and circular economy. Benefits for citizens would include: Employment in high value skilled roles and long term support to maintaining our high standards of living.

There area a number of measures to encourage industry innovation and growth, including:

- Public procurement of domestic supply, and some policy to influence and monitor proportion of domestic supplier to private infrastructure investments.
- Developing incentives to change from status quo – remove risks to industry of innovating.
- Co-investment into R&D, increased grant funding for innovation (e.g. Tech Vouchers)
- The Boosting Business Program network that has been developed is a state-wide initiative that has demonstrated real impact for SMEs and Start-ups. Engaging with the existing network of delivery partners in BBIP program will provide some detailed insights and suggestions

CSIRO consider that risks from intervention could be avoided through measures including:

- Maintaining regular industry engagement to monitor unforeseen risks or evidence of policy under-performance.
- Avoiding introducing significant administrative burdens and hurdles into processes

There are several ways of demonstrating how progress is being made towards accelerating industry growth such as:

- Providing evidence that a significant proportion of State procurement has shifted to domestic suppliers.
- Success stories and case studies
- Clearly defined metrics for how success is being measured
- Ongoing tracking rather than point in time progress reporting

Quantum

CSIRO as Australia's national science agency is contributing to the nascent Quantum industry in Australia both directly and indirectly. Directly through CSIRO's research programs and initiatives and indirectly through analyses and reporting such as the CSIRO report, 'Growing Australia's Quantum Technology Industry' Growing Australia's Quantum Technology Industry - CSIRO published in 2020. That report, authored by CSIRO's Futures group, projected with appropriate investment and sector collaboration projects the Australian quantum technology industry could potentially generate over $4 billion in revenues and 16,000 jobs for Australia by 2040. The crucial factor contained in this projection is what is deemed an appropriate level of investment accompanied with sector collaboration to achieve these outcomes.

CSIRO supports the ambition of growing the Quantum industry in Australia thus enabling the endogenous growth of the knowledge and digital economy. Nations in the past have demonstrated the achievement of competitive advantage through early-stage investment in emerging knowledge intensive industries,

Quantum is just such an emergent industry. CSIRO through its Future Science Platform has placed Quantum technology and the development of an Australian Quantum industry at the forefront of its thinking.

Quantum hardware is expected to scale exponentially in the next few years, with qubit numbers exceeding 1000 in 2023 and expected to range from a few thousands to a million in the next 2-3 years [Ref. IBM, Google, IONQ roadmaps]. This trajectory of hardware scaling when coupled with advancements in error correction techniques should offer capabilities to tackle real-world problems. It is not unrealistic to imagine quantum advantage being possible in the next 3-5 years and the timeframe is very much hardware-platform dependent.

These are some specific use-case areas where quantum computing is expected to make an impact:

- Combinatorial optimisation
- Discovery and design of new materials with tailored functionalities, and improved processes in the chemical industry
- Drug discovery and design. Further than that and possibly even enabling *in silico* clinical trials Mentioned as most exciting proposition by Bijoy Sagar
- Simulating biological molecules and their behaviour
- Autonomous/robotic systems with superior performance and/or security
- Climate modelling
- Financial analysis i.e. option pricing, stock predictions, etc.
- Sensitive data security
- Quantum AI, Quantum ML, Quantum Natural language processing for meaning-aware AI.

Other technologies, skills and industries that need to be developed in parallel with quantum technologies for the benefits of quantum technologies to be realised will include:

1. Supporting infrastructure used to fabricate, control, measure quantum circuits:
    a. Materials science (new materials for sending signals into and out of mK<>Room Temperature environments)
    b. Semiconductor design, fabrication, packaging, testing and prototyping capability whether it by sovereign capability accessible on shore, or access to facilitated, rapid-turn-around offshore supply chains.
    c. Advanced/next-generation electronics and cryo-electronics, including microwave/RF technology
    d. Cryogenic cooling apparatus such as dilution refrigerators
    e. Unique and new chip design and manufacturing that supports the needs of quantum technologies (including cleanrooms, fabrication equipment, packaging and testing infrastructure)
    f. Control software and related electronics components
    g. Quantum software platforms:
    This includes both quantum compilers as well as quantum algorithms to enable practical applications on quantum hardware. I believe significant investment in Australia is needed in computer science discipline (to support both skill development as well as to create opportunities for experts) to ensure development in this domain.
2. Access (easy and fast) for research, start-up companies and SMEs to infrastructure and capability described above.
3. Broadly speaking, there needs to be a pathway that leads to the ability to use quantum advantage in each target industry.

4. Optical communications infrastructure with single photon detection for remote comms is necessary to support quantum communications development.
5. End-user training and lifting the overall "Quantum IQ" so that the opportunity to implement quantum technologies is more quickly recognised, qualified and adopted across industry sectors.

Digital

Of the several trends identified in the CSIRO-commissioned AlphaBeta Digital Innovation Report and CSIRO's Cyber Security Roadmap, three trends have been highlighted by the COVID-19 pandemic.

- Increased digital interaction :The way we interact and the volume of data being exchanged is changing rapidly. With a shift to working and learning remotely, the methods and pathways of this data exchange have shifted in a short period of time, bringing with it cyber security implications.

- Transformed supply chains Digital technologies, such as blockchain, are transforming supply chains, creating greater transparency and increasing efficiencies. This is removing the barriers between business and consumers, creating opportunities for collaboration and specialisation and encouraging localisation.

- Efficiencies sought: As companies reassess their business model in the wake of COVID-19, they are looking for digital solutions that will bring efficiencies and reduce costs. Digital 580,000 workers $122B in GVA $315B economic value

- National advantages: The digital sector continues to operate strongly in Australia despite the pandemic, and several key national advantages will continue to support its recovery and resilience development into the future. Research expertise and skilled workforce Australia is among leading countries when it comes to volume and quality of research published in the fields of artificial intelligence (AI) and computer science research. Leveraging this know-how is key to taking advantage of digital's offerings. Established and successful sectors with strong institutions, natural resources and an established trading base, Australia is home to a wide range of industries that can benefit from a digital transformation to drive productivity and prosperity. Australia's sound regulatory environment and unique geography provide a robust testing ground for digital technology development for roll out to other countries

Agriculture and Food

Key trends include:

- Supply of limited resources is fragile in a less predictable planet (especially seen during recent/ongoing COVID, natural disasters and Ukraine conflict)
- Consumers are health conscious and seeking foods aligned to their health and wellbeing
- Supply chains are more and more interdependent

Key opportunities:

- Expanding protein sources
- High-value health and wellbeing food products
- Smarter value chains
- Traceability, provenance and quality credentials
- Sustainable production chains