THE *Futurist* EDITION

Good things

There's more to
Australian Mining

Produced by the
Minerals Council of Australia

THE *Futurist* EDITION

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30 things

Contents

Acronyms

AI	Artificial Intelligence
ANSTO	Australian Nuclear Science and Technology Organisation
AROSE	Australian Remote Operations in Space and on Earth consortium
AR	Augmented Reality
CCS	Carbon Capture and Storage
CERN	European Organization for Nuclear Research
eVTOL	Electric Vehicle Take-Off and Landing Aircraft
EV	Electric Vehicles
GIS	Geographic Information Systems
GPS	Global Positioning System
IEA	International Energy Agency
IMF	International Monetary Fund
IoMT	Internet of Military Things
IoT	Internet of Things
ILC	International Linear Collider
IVF	In Vitro Fertilisation
LHC	Large Hadron Collider
ML	Machine Learning
NASA	National Aeronautics and Space Administration
NFT	Non-Fungible Tokens
OG	Original Gangster
SMR	Small Modular Reactor
UAV	Unmanned Aerial Vehicle
UN	United Nations
VR	Virtual Reality

Whatever shape the future takes, Australia's minerals industry will be at the forefront of making the imaginable possible

Australia's minerals industry has underpinned decades of high living standards as the nation's largest exporter, company taxpayer and a significant employer. Parallel to the industry's unrivalled economic contribution is the role mining plays supplying the minerals and metals critical for today's technologies, and tomorrow's.

From cloud robotics to space exploration, quantum computing to advanced bionics, the pace and progress of human advancement will be determined by the technologies made possible by minerals and metals. Minerals like the silicon in next generation augmented reality (AR) electronics, or the neodymium in the permanent magnets that power electric vehicles (EVs), or the copper and nickel in zero emissions energy systems.

Following on from *30 Things*, a guide to the minerals and metals essential for modern life, *30 Things: The Futurist Edition* takes a peek into the future and the raw materials critical to the technologies at our fingertips – and on the cusps of our imaginations.

Many of the emerging technologies explored on these pages will intrigue and fascinate, and some may even give reason for pause. This is equally as important. The onward march of technology requires broad public conversations about what we are prepared to accept, individually and as a society.

But for as many hard conversations, new technologies will increasingly provide solutions to some of the world's most complex social and environmental challenges. Solutions like micro-hybrid robots that clean plastic from our oceans, or early warning sensors that protect against natural disasters. Not to mention we are only one subatomic collision away from unlocking the secrets of the universe, thanks to the minerals-heavy technology powering particle accelerators.

But whatever the future holds, one thing is certain. The world will need more minerals and metals in the future – not less. Global decarbonisation alone will drive demand for lithium, manganese, cobalt, graphite and rare earth elements for a long time to come.

Australian mining is changing, too. The same technologies – AI, AR and VR – are making our industry safer, smarter and more sustainable. And while we have long been recognised as world leaders in innovation, workforce and environmental stewardship, we embark on this next leg of the journey committed to being a responsible and trusted partner as we provide the minerals and metals the world needs into the future.

Tania Constable
Chief Executive Officer
Minerals Council of Australia

Virtual real estate sales topped US$500 million in 2021, and could be valued in the trillions in a few short years_

Morgan Stanley

Computer processors

14	29	79	31	73
Si	Cu	Au	Ga	Ta
Silicon	Copper	Gold	Gallium	Tantalum

Immersive headsets

58	47	25	3	27
Ce	Ag	Mn	Li	Co
Cerium	Silver	Manganese	Lithium	Cobalt

Microphone & speakers

60	59	62	29	6
Nd	Pr	Sm	Cu	C
Neodymium	Praseodymium	Samarium	Copper	Carbon

Server farms

29	13	66	6	30
Cu	Al	Dy	C	Zn
Copper	Aluminium	Dysprosium	Carbon	Zinc

Mobile displays

50	49	63	64	39
Sn	In	Eu	Gd	Y
Tin	Indium	Europium	Gadolinium	Yttrium

Virtual future for live music

More than 12.3 million people attended the VR Travis Scott concert in *Fortnite* in 2020. The collaboration reportedly grossed the rapper $20 million, which included the in-concert sale of physical merchandise as well as virtual skins and emotes (dance moves participants can buy for their avatars).

The metaverse (which means *beyond our universe*) is a parallel virtual world with a fully functioning digital economy_

01

The metaverse

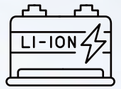
Welcome to the metaverse – a network of 3D immersive worlds where real people can live, work and play virtually. From 'holidaying' with distant loved ones to buying 'land' and building on a virtual block to collaborating with colleagues at the virtual office, the metaverse promises to democratise social and economic participation in a massive reimagining of the internet. Tech companies such as Meta, Microsoft and Epic Games are investing billions of dollars in the virtual space, as are high-end brands racing to market to consumers in the digital world. Bloomberg predicts the metaverse will generate revenues of $800 billion as soon as 2024, largely through video games and live entertainment.

EV batteries

3	28	27	25	6
Li	Ni	Co	Mn	C
Lithium	Nickel	Cobalt	Manganese	Carbon

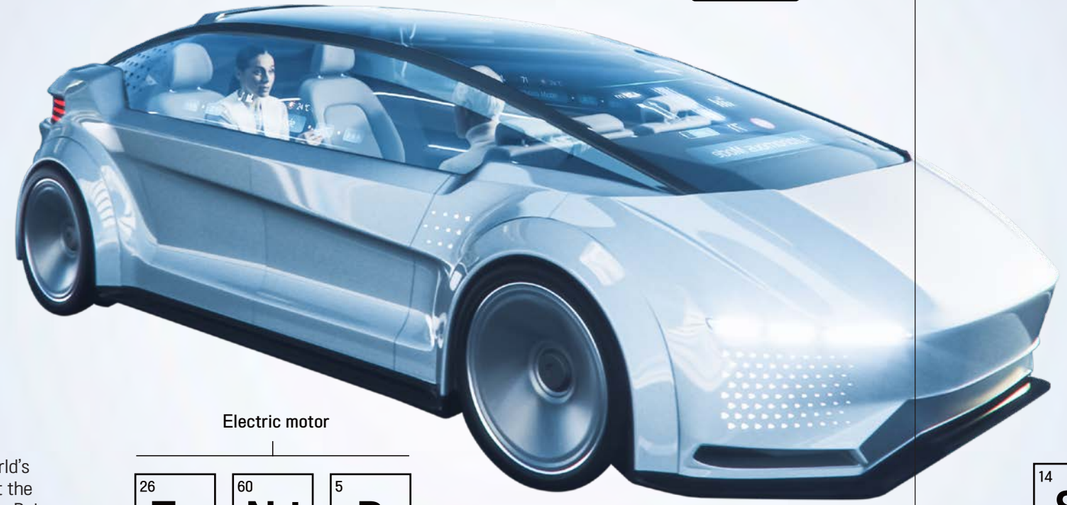
A new lithium-ion battery design could reduce charging time to 10 minutes _

Pennsylvania State University



Ultra-resolution cameras

58	14	29
Ce	Si	Cu
Cerium	Silicon	Copper



The first autonomous car

General Motors sponsored the world's first known autonomous vehicle at the 1939 New York World Fair. Norman Bel Gedde's Futurama exhibit featured an electric vehicle guided by radio-controlled electromagnetic fields generated by magnetic spikes embedded in the road.

Electric motor

26	60	5
Fe	Nd	B
Iron	Neodymium	Boron

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Navigation

79	22	64	50
Au	Ti	Gd	Sn
Gold	Titanium	Gadolinium	Tin

Car body

13	26	12	21	58
Al	Fe	Mg	Sc	Ce
Aluminium	Iron	Magnesium	Scandium	Cerium

Light-emitting radar (lidar)

22	60	13	29
Ti	Nd	Al	Cu
Titanium	Neodymium	Aluminium	Copper

Ultrasonic sensors

82	29	14	22	40
Pb	Cu	Si	Ti	Zr
Lead	Copper	Silicon	Titanium	Zirconium

Ultra-fast computer chips

14	31	73	79
Si	Ga	Ta	Au
Silicon	Gallium	Tantalum	Gold

02

Driverless vehicles

While modern cars include self-driving features such as lane detection, parking assist and emergency braking, a truly driverless vehicle – a car requiring no human intervention – is a way off. That doesn't mean companies like General Motors, Tesla and Alphabet aren't committed to the task. In states across America, self-driving vehicles are navigating public roads, giving way to pedestrians and avoiding hazards, generating massive amounts of data for the developers racing to crack the market. With 90 per cent of accidents caused by human error, autonomous cars promise to improve road safety, reduce emissions and ease congestion – but perhaps don't go trading in the family sedan just yet.

An AI system solved the mechanics of a flatworm's regeneration in 42 hours, a mystery that eluded scientists for 100 years_

Tufts University, Massachusetts

Power source

25	28	27	6	29
Mn	Ni	Co	C	Cu
Manganese	Nickel	Cobalt	Carbon	Copper

Robot frame & shell

14	22	12	6	26
Si	Ti	Mg	C	Fe
Silicon	Titanium	Magnesium	Carbon	Iron

Cloud servers

29	41	66	68	51
Cu	Nb	Dy	Er	Sb
Copper	Niobium	Dysprosium	Erbium	Antimony

CPU (Central Processing Unit)

79	31	14	47	46
Au	Ga	Si	Ag	Pd
Gold	Gallium	Silicon	Silver	Palladium

Sensors (Displays & speakers)

65	63	58	39	60
Tb	Eu	Ce	Y	Nd
Terbium	Europium	Cerium	Yttrium	Neodymium

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At your service...

Hotel guests are hosted by multilingual humanoid staff at Japan's robot-run Henn na Hotel in Nagasaki. Robots are not a new or strange phenomenon in Japan, with robot coffee vendors, tour guides and even casino croupiers working alongside their flesh and blood colleagues.

Humanoid robot Sophia was named the United Nation's Innovation Champion in 2017 - the first non-human to be given a UN title _

United Nations Development Programme

5G Network

55	47	68
Cs	Ag	Er
Cesium	Silver	Erbium

03

Cloud robotics

Robots have traditionally been limited to pre-programmed algorithms, but not for much longer. Cloud robotics combines cloud computing, deep learning, big data and connectivity to create robots that interact and learn from each other in real-time. And if that doesn't evoke dystopian scenes, scientists at Binghamton University in the US have developed a shape-shifting metal that could be the pre-cursor to a liquid metal robot like the T-1000 character from *Terminator 2*. Scientists moulded a liquid metal lattice into the shape of a human hand from bismuth, indium and tin (a compound known as Field's alloy). Encased in a silicon skin, the liquid metal hand can be crushed but returns to its original shape on heating.

Advanced imaging

66	64	22	29	30
Dy	Gd	Ti	Cu	Zn
Dysprosium	Gadolinium	Titanium	Copper	Zinc

Artificial pancreas

29	14	73
Cu	Si	Ta
Copper	Silicon	Tantalum

6	3
C	Li
Carbon	Lithium

Nuclear medicine diagnoses and treats illnesses such as cancer_

Smart bandages

Scientists at the Technion Israel Institute of Technology have developed a self-healing polymer dressing that closes and supports the healing of wounds. Integrated carbon nanotubes and electrical biosensors monitor for infection, dispense antibiotics and relay the data to a smart phone or other device.

Cancer treatments

79	92	42	53
Au	U	Mo	I
Gold	Uranium	Molybdenum	Iodine

Bluetooth pacemakers

22	14	79	28	24
Ti	Si	Au	Ni	Cr
Titanium	Silicon	Gold	Nickel	Chromium

Surgical tools

47	41	26	78	74
Ag	Nb	Fe	Pt	W
Silver	Niobium	Iron	Platinum	Tungsten

If every person on Earth was a nanometre in size, the planet's population would fit in a Hot Wheels matchbox car_

Australian Academy of Science

Anti-bacterials

29	47	79	51
Cu	Ag	Au	Sb
Copper	Silver	Gold	Antimony

04

Advanced healthcare

Nanoscience, genomics and advanced robotics will revolutionise medical science. Gold nanoparticles are already being engineered to find and treat cancers at the cellular level. Genomic editing will eliminate some diseases, while gene therapy holds the key to curing others, like Alzheimers and Parkinsons. Stem cell advancements promise life-changing treatments for multiple sclerosis and diabetes, while a patient's genetic profile will drive personalised therapies. Telemedicine will also expand healthcare access to millions, and with advancements in robotics, AI, AR and VR, robotic surgery suites controlled remotely by a human surgeon wearing a VR suit might not be too far away.

05

Smart housing

The future of housing is smart, green and interconnected. Voice assistants such as Siri and Alexa are commonplace in homes today, and everything from toothbrushes to refrigerators to light bulbs are connected to the internet. Home entertainment will be more immersive and robots will help with chores. Smart homes will be powered by renewable energy (Tesla has developed solar roof tiles in addition to its batteries); vertical axis wind turbines and heat exchange technology. While aluminium and copper are mainstays, new building materials will also make housing more efficient. Researchers at Washington University in the US have developed a 'smart brick' that utilises red pigment (iron oxide) to store energy like a battery.

Paint, cladding, plumbing

30	22	13	24
Zn	Ti	Al	Cr
Zinc	Titanium	Aluminium	Chromium

Steel & concrete

26	6	28	25	23
Fe	C	Ni	Mn	V
Iron	Carbon	Nickel	Manganese	Vanadium

Air conditioning

29	13	30	78	79
Cu	Al	Zn	Pt	Au
Copper	Aluminium	Zinc	Platinum	Gold

Smart refrigerators with built-in AI could soon be able to monitor product usage, expiry and and even reorder items_

Amazon

Smart whitegoods

13	29	60
Al	Cu	Nd
Aluminium	Copper	Neodymium

26	28
Fe	Ni
Iron	Nickel

Hydroponics

15	19
P	K
Phosphorus	Potassium

By 2025, IoT-connected devices globally will more than double to 30.9 billion units_

Statista

IOT (Internet of Things)

14	29	73	50	49
Si	Cu	Ta	Sn	In
Silicon	Copper	Tantalum	Tin	Indium

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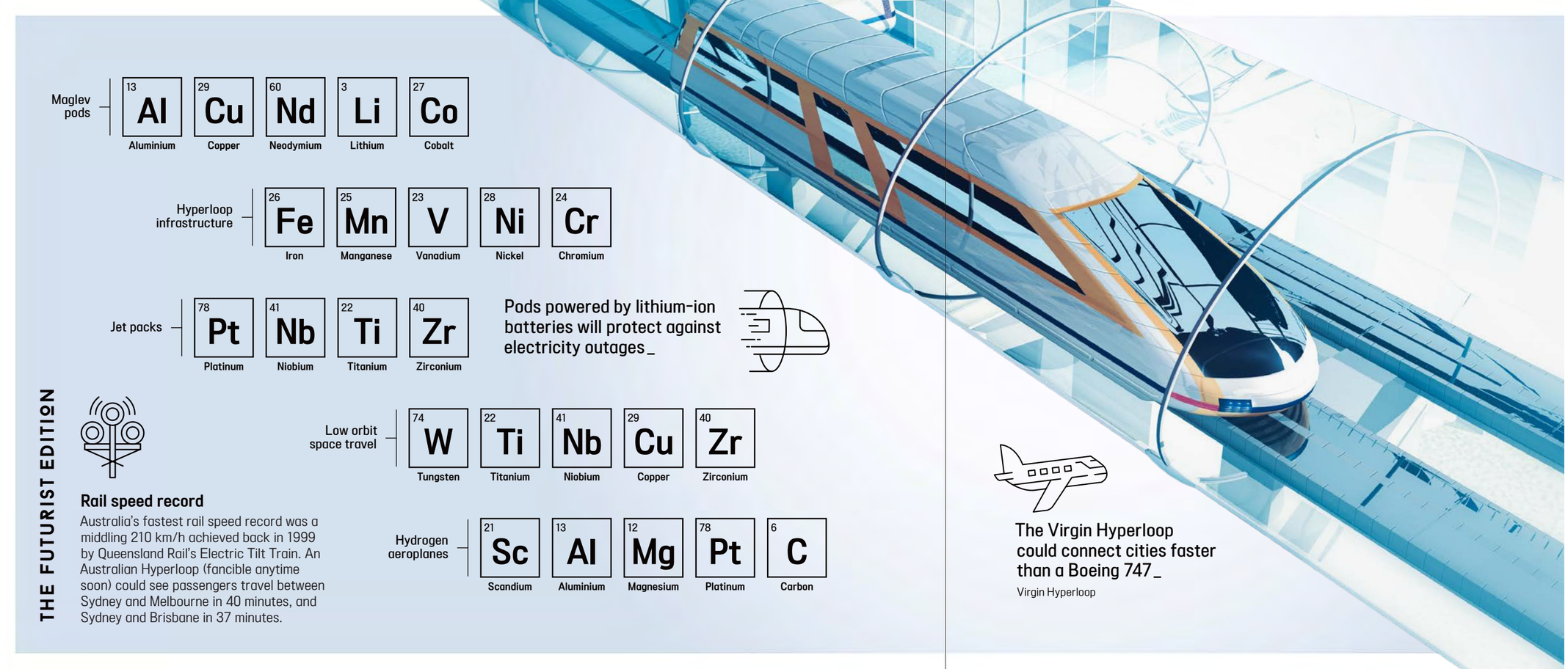
Floating cities

Boston arthitect E. Kevin Schopfer conceived a floating city housing 30,000 residents off the coast of Haiti after the 2010 earthquake. Anchored to the ocean floor, 'Harvest City' – a 3.2 km diameter floating complex – was designed to be less susceptible to typhoons and earthquakes.

06

Hyper-fast transport

Faster than a speeding bullet train, hyper-fast transport is on the horizon. Tesla founder Elon Musk open sourced his proposal for magnetic levitation (or maglev) pod travel in 2013. Since then, startups from India to the Netherlands have joined the race to develop the technology. The frontrunner is Richard Branson's Virgin Hyperloop, which successfully conducted a passenger trial in November 2020. In simple terms, the Hyperloop is a near-vacuum sealed tube through which magnetic pods are propelled at up to 1200 km/h, just shy of the speed of sound. Fast and immune to weather, a proposed route between New York and Washington DC could reduce travel time from 2 hours and 56 minutes to 29 minutes.



Maglev pods

13	29	60	3	27
Al	Cu	Nd	Li	Co
Aluminium	Copper	Neodymium	Lithium	Cobalt

Hyperloop infrastructure

26	25	23	28	24
Fe	Mn	V	Ni	Cr
Iron	Manganese	Vanadium	Nickel	Chromium

Jet packs

78	41	22	40
Pt	Nb	Ti	Zr
Platinum	Niobium	Titanium	Zirconium

Pods powered by lithium-ion batteries will protect against electricity outages_

Low orbit space travel

74	22	41	29	40
W	Ti	Nb	Cu	Zr
Tungsten	Titanium	Niobium	Copper	Zirconium

Rail speed record

Australia's fastest rail speed record was a middling 210 km/h achieved back in 1999 by Queensland Rail's Electric Tilt Train. An Australian Hyperloop (fancible anytime soon) could see passengers travel between Sydney and Melbourne in 40 minutes, and Sydney and Brisbane in 37 minutes.

Hydrogen aeroplanes

21	13	12	78	6
Sc	Al	Mg	Pt	C
Scandium	Aluminium	Magnesium	Platinum	Carbon

The Virgin Hyperloop could connect cities faster than a Boeing 747_

Virgin Hyperloop

Vertical farm structures

13	14	26	6	30
Al	Si	Fe	C	Zn
Aluminium	Silicon	Iron	Carbon	Zinc

Vertical farm robotics

28	22	79	78	73
Ni	Ti	Au	Pt	Ta
Nickel	Titanium	Gold	Platinum	Tantalum

Vertical farming produces crops using 70–95 per cent less water than normal cultivation_

Lab-made dairy

Japanese scientists unveiled a lab-made Wagyu marbelled steak in 2021. Now biotech companies have zeroed in on dairy – milk, cheese, icecream and yoghurt. Instead of meat grown from stem cells, researchers aim to replicate the milk proteins, whey and casein, through a process of fermentation.

Automated harvesters

14	30	26	29	28
Si	Zn	Fe	Cu	Ni
Silicon	Zinc	Iron	Copper	Nickel

Agricultural drones

25	28	29	3
Mn	Ni	Cu	Li
Manganese	Nickel	Copper	Lithium

Australian supermarkets offer more than 250 plant-based alternative meat products_

Food Frontier

LED lighting

58	47	31	57
Ce	Ag	Ga	La
Cerium	Silver	Gallium	Lanthanum

Food laboratories

29	47	28	22
Cu	Ag	Ni	Ti
Copper	Silver	Nickel	Titanium

07

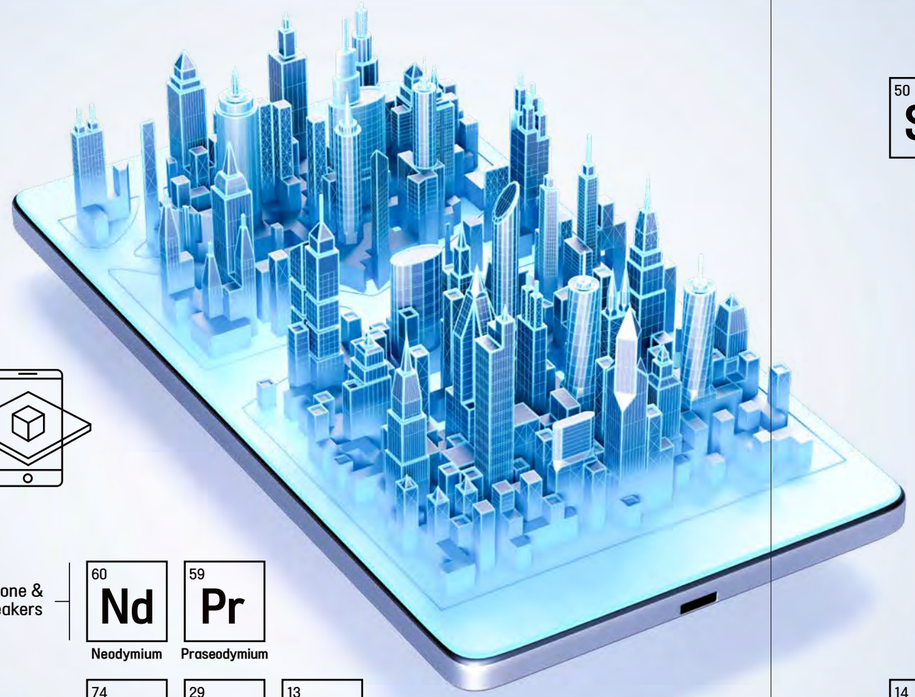
Food production

Climate change and population growth will mean food producers need to do more with less. By 2050, 70 per cent more food will be required to feed the planet's two billion extra people, according to the UN. Machine learning will underpin the technological change required to boost yields, reduce waste and get products to market faster and more efficiently. Plant-based proteins and lab-made meat and dairy will be part of our diets, and with 80 per cent of us living in cities, vertical gardens, rooftop farming and at-home hydroponics will boom. Scientists are forging ahead with 3D-printed food (food-grade syringes replace materials cartridges); and floating farms moored to seabeds and inland lakes could become a reality.

08

AR smart phones

Smartphone makers are scrambling to bring an AR-optimised smartphone to market. While the ultimate destination might be smart glasses and contact lenses that integrate our physical world with a virtual overlay, reimagining the smartphone in our back pocket is the first step. AR has come a long way since Pokemon GO launched in 2016, with real-world application across all industries from retail to real estate. Big things are also predicted for AR in the workplace. Virtual team meetings, screen-free computing and interactive holograms of blueprints and product models could be in our future. The AR market is expected to generate global revenue of $152 billion by the end of 2030, according to GlobalData.



Mobile internet: 47 Ag Silver; 68 Er Erbium; 29 Cu Copper; 55 Cs Cesium; 21 Sc Scandium

Mobile AR user devices globally will number 1.7 billion by 2024 _
Statista

Microphone & speakers: 60 Nd Neodymium; 59 Pr Praseodymium; 74 W Tungsten; 29 Cu Copper; 13 Al Aluminium

Next level stadium experience

Football fans got a glimpse of the future at the US NFL Super Bowl. Stadium-goers were treated to augmented reality player stats, on-field graphics and comps in 2022. Sponsors are also shifting budgets from flashy commercials towards sharable digital experiences, utilising AR filters and lenses.

Touchscreen: 50 Sn Tin; 49 In Indium; 29 Cu Copper; 14 Si Silicon

CPU: 51 Sb Antimony; 14 Si Silicon; 31 Ga Gallium; 79 Au Gold; 73 Ta Tantalum

Pokemon GO made $1.21 billion revenue in 2021, higher than its peak usage in 2016 _
Sensor Tower

Battery: 3 Li Lithium; 28 Ni Nickel; 27 Co Cobalt; 25 Mn Manganese; 6 C Carbon

Smart glasses: 14 Si Silicon; 60 Nd Neodymium; 13 Al Aluminium; 29 Cu Copper

09

Renewable energy

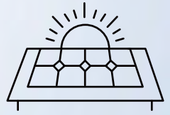
Solar and wind energy generation has come a long way in the last decade. Researchers believe the key to overcoming intermittency and storage challenges is integrating solar, in particular, into our everyday lives. Solar-powered outdoor signage is one successful application; solar roof tiles are another, replacing the need for bulky rooftop panels. Car makers, such as Hyundai and Lexus, have begun installing solar cells on the roofs of EVs and in the near future, glass windows embedded with solar cells could be used to power office buildings, and eventually even our smartphones. Another frontier is solar fabrics – textiles that have micro solar cells integrated into the fibres. Solar thermal fuels are also on the horizon.

High-voltage sea cables could enable underwater solar and wind energy exports between nations _

Sun Cable

Almost one-third of Australian households have solar panels – the highest take up in the world _

Clean Energy Regulator



Solar textiles

Forget the nightstand – charging your mobile phone or smartwatch might soon be as simple as slipping into a solar sweater. Nottingham Trent University successfully embedded miniaturised solar cells into yarn that can be knitted into textiles and washed and worn like any other item of clothing.

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Solar panels	47 Ag Silver	14 Si Silicon	29 Cu Copper	13 Al Aluminium	15 P Phosphorus
Hydrogen	78 Pt Platinum	29 Cu Copper	26 Fe Iron	39 Y Yttrium	
Carbon Capture & Storage	26 Fe Iron	74 W Tungsten	28 Ni Nickel	6 C Carbon	42 Mo Molybdenum
Wind turbines	60 Nd Neodymium	29 Cu Copper	26 Fe Iron	13 Al Aluminium	5 B Boron
Smart energy grid	26 Fe Iron	29 Cu Copper	66 Dy Dysprosium	79 Au Gold	50 Sn Tin
Energy storage	30 Zn Zinc	23 V Vanadium	3 Li Lithium	28 Ni Nickel	

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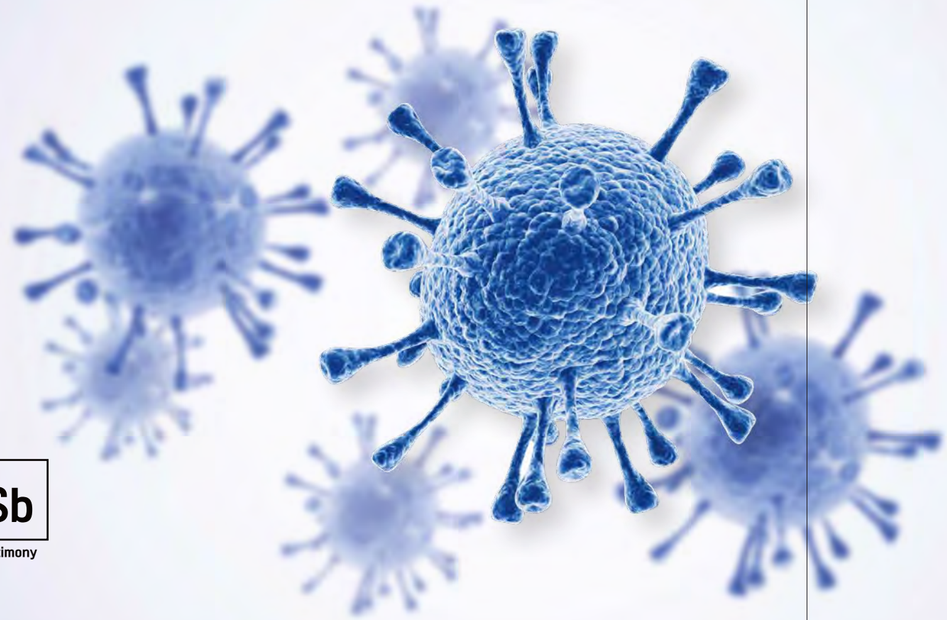
Disease immunity could one day be delivered by nanorobots injected into the bloodstream and tasked with preventing viruses _



Antimicrobial materials

47	79	29	51
Ag	Au	Cu	Sb
Silver	Gold	Copper	Antimony

Digital revolution

The COVID-19 pandemic supercharged the digital revolution in Australia. Australian Communications and Media Authority research revealed unprecedented demand for internet services in 2020-21 as work from home became the norm, and education, shopping and health consults moved online.

Laboratory safety systems

13	14	5	26	24
Al	Si	B	Fe	Cr
Aluminium	Silicon	Boron	Iron	Chromium

PCR testing

12	29	82	51
Mg	Cu	Pb	Sb
Magnesium	Copper	Lead	Antimony

Electron microscope

79	57	74	58	30
Au	La	W	Ce	Zn
Gold	Lanthanum	Tungsten	Cerium	Zinc

Antiviral production

29	26	30	73
Cu	Fe	Zn	Ta
Copper	Iron	Zinc	Tantalum

MRNA production Bioreactor vessel

26	28	24	6	29
Fe	Ni	Cr	C	Cu
Iron	Nickel	Chromium	Carbon	Copper

Portable, wearable air purifiers that remove viruses and pathogens from the air you breath could be the next big thing in pandemic PPE _

Air Ring

10

Synthetic virology

COVID-19 turned the world upside down, and scientists warn it won't be the last pandemic we see. The greatest protection against a cataclysmic viral threat in the future is early warning. Advances in genomics and information science, including the advent of gene editing tool CRISPR and AI-enhanced global detection systems, will be critical. It will also require a global commitment to the development and integration of diagnostic tools and data sharing. Shortening vaccine development timelines against future threats is another priority, as is surveillance and reporting of animal supply chains. Science, coupled with advances in technology, is the best weapon humanity has against future pandemics.

Quantum computers require extremely cold temperatures for stability. D-Wave quantum computer cores operate at -273°C _

D-Wave Systems

Quantum processor

14	31	32	29	6
Si	Ga	Ge	Cu	C
Silicon	Gallium	Germanium	Copper	Carbon

41	13	79	47	70
Nb	Al	Au	Ag	Yb
Niobium	Aluminium	Gold	Silver	Ytterbium

Cooling system

26	24	29	28	22
Fe	Cr	Cu	Ni	Ti
Iron	Chromium	Copper	Nickel	Titanium

Data storage

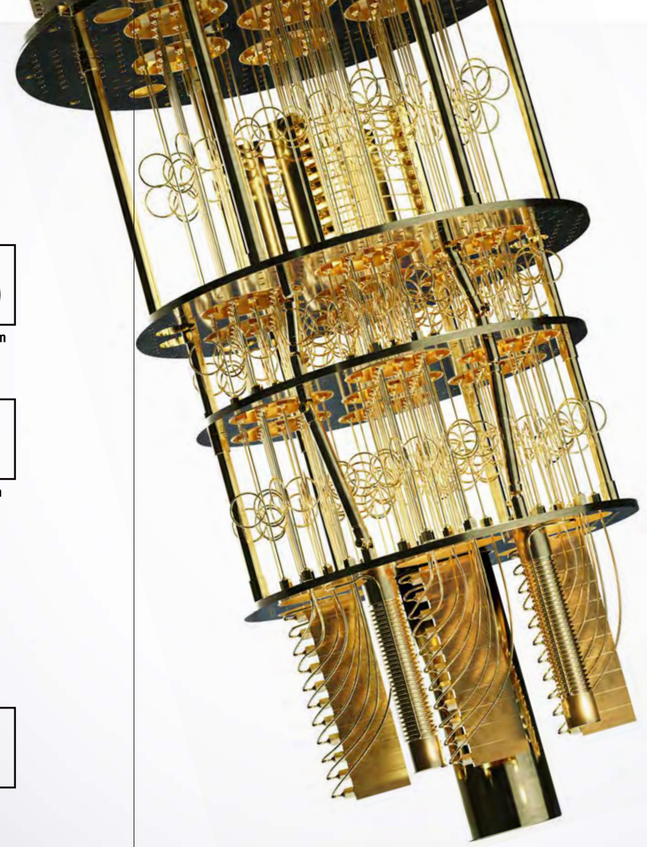
66	14	13	60	78
Dy	Si	Al	Nd	Pt
Dysprosium	Silicon	Aluminium	Neodymium	Platinum

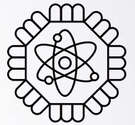
Visual display

50	49	63	64	39
Sn	In	Eu	Gd	Y
Tin	Indium	Europium	Gadolinium	Yttrium

Master moves

World chess champion Garry Kasparov was defeated by IBM's Deep Blue supercomputer in 1997, which demonstrated its ability to examine 200 million possible moves every second. By comparison, a quantum machine would have calculated 1 trillion moves per second, and 4 trillion moves in two seconds.





Quantum computing will reshape the material world, from medicine to manufacturing, finance to logistics _

Network connectivity

66	68
Dy	Er
Dysprosium	Erbium

21	55
Sc	Cs
Scandium	Cesium

11

Quantum computing

Supercomputers are so last century. Unlike computers today which use binary bits (one and zero) to perform tasks, a quantum computer uses quantum bits, or 'qubits'. Every qubit adds an exponential amount of processing power that makes light work of complex simulations and sub-atomic modelling, promising unimaginable advances in biology, chemistry and material sciences. Big tech companies are leapfrogging each other with advances in the technology. Along with blistering speed, quantum computers use 100 to 1000 times less power than a regular computer. While quantum computers won't help your child plough through their homework, they will redefine the world they grow up in.

Cochlear implant

78	22	77	29
Pt	Ti	Ir	Cu
Platinum	Titanium	Iridium	Copper

Australian scientist Professor Graeme Clark AC invented the cochlear impant - the first bionic ear - in the 1970s _

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Bionic eye

An Australian-made bionic eye is being fast-tracked for worldwide commercialisation. Developed by Bionic Vision Technologies, the system sends electrical signals from tiny cameras embedded in a pair of glasses to a wearable processor that transmits visual information to an implant behind the retina.

Bionic eye

14	42	49	47	29
Si	Mo	In	Ag	Cu
Silicon	Molybdenum	Indium	Silver	Copper

Bionic arm

22	13	29	3	21
Ti	Al	Cu	Li	Sc
Titanium	Aluminium	Copper	Lithium	Scandium

Neural implants

79	78	74	6	73
Au	Pt	W	C	Ta
Gold	Platinum	Tungsten	Carbon	Tantalum

Exoskeleton

6	22	13	12	25
C	Ti	Al	Mg	Mn
Carbon	Titanium	Aluminium	Magnesium	Manganese

Pacemaker

47	22	51	27	79
Ag	Ti	Sb	Co	Au
Silver	Titanium	Antimony	Cobalt	Gold

Night vision for humans could become a reality after scientists gave the superpower to mice by simply injecting a nanoantenna _

University of Massachusetts

12

Advanced bionics

The rise of robotics and AI has supercharged the world of bionics. Prosthetics fitted with electrodes and sensors can now respond to muscle movement and even stimulate specific nerves to relay pressure and other senses. Advances in neurotechnology are also giving hope to paralysed patients. Doctors in Switzerland implanted nerve boosters in the spines of three paralysed men, enabling them to walk short distances. In 2019, a French man was able to move all four of his paralysed limbs by wearing a mind-controlled exoskeleton suit. Meanwhile, researchers have discovered a self-regeneration gene in some species that could one day see humans - in the far far away future - regrow body parts, just like the salamander or jellyfish!

A sweat-powered smartwatch has been developed that uses as little as 20 microlitres of fluid in place of battery electrolytes _

University of Glasgow

Smart watch

60	50	49	79	74
Nd	Sn	In	Au	W
Neodymium	Tin	Indium	Gold	Tungsten

Biometric sportswear

29	47	14	60	3
Cu	Ag	Si	Nd	Li
Copper	Silver	Silicon	Neodymium	Lithium

Interactive display

3	27	25	29	6
Li	Co	Mn	Cu	C
Lithium	Cobalt	Manganese	Copper	Carbon

Smart shoes

14	29	31	73	28
Si	Cu	Ga	Ta	Ni
Silicon	Copper	Gallium	Tantalum	Nickel

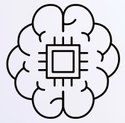
THE FUTURIST EDITION

Instant wardrobe

Changing your outfit could soon be as simple as pressing a button. Researchers at the University of Central Florida have developed a color-changing fabric which can be controlled via an app. Threads containing micro-wires and colour-changing pigments are woven into garments.

A neural implant is being developed that could one day allow human recipients to access the internet simply by using their mind _

Neuralink



Heated jacket

6	29
C	Cu
Carbon	Copper

3	28
Li	Ni
Lithium	Nickel

13

Wearable technology

Exercise trackers have been counting our steps and monitoring our heart rates for over a decade. The next wave of wearable tech is advanced textiles – garments with interwoven sensors that relay user data to a smartphone. From footwear (Nike Adapt Shoes) to sleepwear (Under Armour), fashion labels have long dabbled in this space. Ohio State University researchers are also developing 'e-threads' – textiles embedded with antennas and power sources that can transmit data, boost mobile phone reception and perhaps one day even control video games. Wearable health devices, such as glucose monitors and barely there second skin adhesives loaded with sensors, will also become the norm in medicine.

The James Webb Space Telescope has reached its cosmic base 1.5 million kilometers from Earth. That's four times further away than the Moon _

NASA

James Webb Space Telescope

4	79	22	13	48
Be	Au	Ti	Al	Cd
Beryllium	Gold	Titanium	Aluminium	Cadmium

NASA Deep Space Network

60	50	49	26	29
Nd	Sn	In	Fe	Cu
Neodymium	Tin	Indium	Iron	Copper

Square Kilometre Array (Radiotelescope network)

13	29	32	66	74
Al	Cu	Ge	Dy	W
Aluminium	Copper	Germanium	Dysprosium	Tungsten

Observatory

14	26	30	13	47
Si	Fe	Zn	Al	Ag
Silicon	Iron	Zinc	Aluminium	Silver

Roman Space Telescope (Launch date: 2027)

47	22	57	52	41
Ag	Ti	La	Te	Nb
Silver	Titanium	Lanthanum	Tellurium	Niobium

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Modern astronomy

Italian scientist Galileo Galilei (1564–1642) pioneered the use of the telescope in astronomy. Among his discoveries was the moons of Jupiter and the stars of the Milky Way. Unfortunately for Galileo, his work challenged the doctrine of the day and he spent his final years under house arrest.

The Webb telescope is so sensitive to infrared light it could detect the heat signature of a bumblebee at the distance of the moon _

NASA

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Deep space astronomy

Infrared astronomy is another giant leap towards unravelling the mysteries of the universe. NASA's James Webb Space Telescope, launched in December 2021, is a hundred times more powerful than its Hubble predecessor. Powerful mirrors made from beryllium and arranged in 18 gold-plated hexagon segments will enable the infrared telescope to observe the earliest formation of stars and galaxies some 13.5 billion years ago. This peek back in time is made possible because of the time it takes light to travel the vast distances of space. To avoid self-generating radiation, the telescope will be cooled to -223°C by a tennis court-sized sunshield coated with aluminum and doped-silicon to deflect heat.

Japanese scientists are building a space elevator – a 96,000 km tether from the seabed to space made of ultrastrong carbon nanotubes _

Obayashi Corporation

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Rapid transit

Intercontinental flights could eventually be superceded by suborbital flights, with passenger spacecraft launching and landing anywhere in the world in less time than it takes to watch an inflight movie. SpaceX, Virgin Galactic and Blue Origin are among the players hoping to reshape air travel.

Shuttle	13 Al Aluminium	22 Ti Titanium	29 Cu Copper	21 Sc Scandium	12 Mg Magnesium
Thermal protection	26 Fe Iron	14 Si Silicon	13 Al Aluminium	6 C Carbon	28 Ni Nickel
Rocket engines	41 Nb Niobium	74 W Tungsten	26 Fe Iron	28 Ni Nickel	24 Cr Chromium
Control system	14 Si Silicon	79 Au Gold	73 Ta Tantalum	31 Ga Gallium	66 Dy Dysprosium
Life support	3 Li Lithium	6 C Carbon	29 Cu Copper	47 Ag Silver	95 Am Americium

Space tourism could be worth US$4 billion by the year 2030 _

UBS, 2021

Launch pad

26 Fe Iron	28 Ni Nickel
30 Zn Zinc	

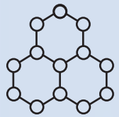
15

Space tourism

What might once have seemed like science fiction is quickly becoming science fact. Virgin Galactic, SpaceX and Amazon's Blue Origin are on the cusp of offering commercial space travel, albeit at a steep price. Nevertheless, the commercialisation of low earth orbit has bolstered plans for critical infrastructure as space travel becomes more accessible. Reusable rockets, commercial spaceports, even space hotels could be a reality by 2050. Meanwhile, NASA is planning a return trip to the moon in 2025 – more than 50 years after its first lunar landing. Many more multi-nation moon missions are expected to follow (and maybe even to Mars) not only to visit, but to build bases that will allow humans to stay.

Researchers have developed a 3D-printed porous graphene that is lighter than air but as much as 10 times stronger than steel _

Massachusetts Institute of Technology

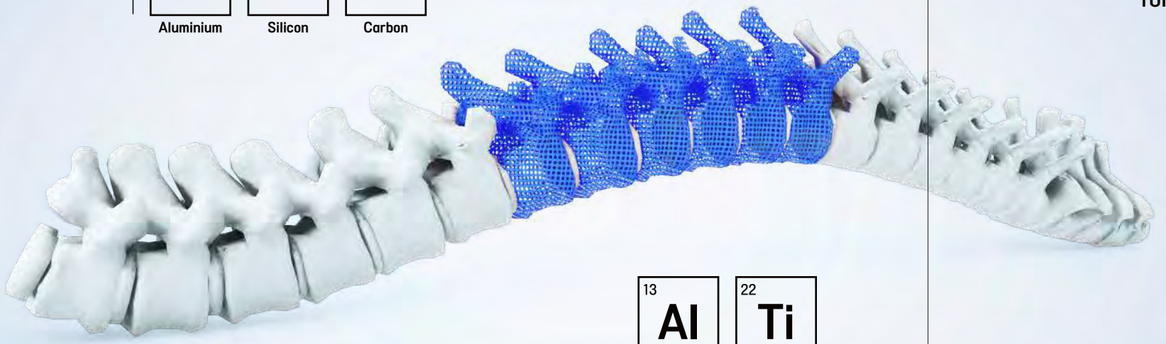


3D nozzle

30	29	26	6	42
Zn	Cu	Fe	C	Mo
Zinc	Copper	Iron	Carbon	Molybdenum

Print bed

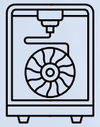
13	14	6
Al	Si	C
Aluminium	Silicon	Carbon



13	22
Al	Ti
Aluminium	Titanium

Print filaments

50	82	26	30
Sn	Pb	Fe	Zn
Tin	Lead	Iron	Zinc



Aerospace

Aerojet Rocketdyne credits its ability to deliver hypersonic flight in large part to 3D printing. The US-based company uses additive manufacturing for rocket engine and defense system applications, and cites costs savings, design flexibility and shorter lead times as some of the benefits.

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26	13	6	14	29
Fe	Al	C	Si	Cu
Iron	Aluminium	Carbon	Silicon	Copper

Motion system

Australian researchers have used 3D printers to create nutritious, safer to swallow meals for people with swallowing disorders _

University of Technology Sydney, Deakin University

73	29	14	26
Ta	Cu	Si	Fe
Tantalum	Copper	Silicon	Iron

Powerboard

50	49	63	57
Sn	In	Eu	La
Tin	Indium	Europium	Lanthanum

Touch interface

29	74	78	51	79
Cu	W	Pt	Sb	Au
Copper	Tungsten	Platinum	Antimony	Gold

CPU

16

3D printing

3D printing will change the way that manufacturers develop, produce and distribute products. Customiseable and on-demand, personal fabricators could eventually become as ubiquitous in the home as a microwave. An extension of 3D printing is bioprinting – the artifical creation of human skin, tissue, blood vessels and bones. While the science is some way off, creating a fully transplantable human organ (bioprinting) is already underway in research facilities around the world. In Australia, University of New South Wales researchers have developed a ceramic ink that could eventually be used to print replacement bone inside the human body, as reported in the journal *Advanced Functional Materials*.

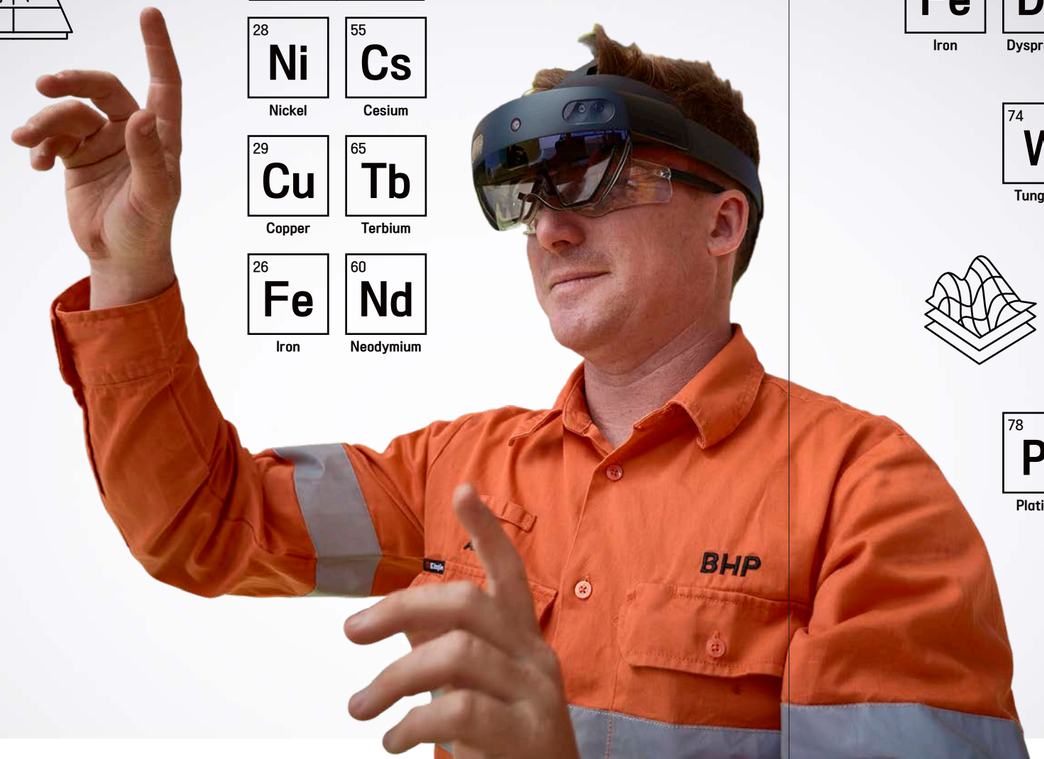
Mining is critical to decarbonisation. Solar plants, wind farms and EVs are more minerals intensive than hydrocarbon equivalents _

Microgrids (energy)

29	13	14
Cu	Al	Si
Copper	Aluminium	Silicon
3	27	25
Li	Co	Mn
Lithium	Cobalt	Manganese

Exploration geophysics

28	55
Ni	Cs
Nickel	Cesium
29	65
Cu	Tb
Copper	Terbium
26	60
Fe	Nd
Iron	Neodymium



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Aussie-made 'Rover'

Nobody knows a lunar-like landscape like Australia's remote miners. Rio Tinto has joined the Australian Remote Operations for Space and Earth consortium – AROSE – to help investigate the feasibility of a locally made lunar rover for possible deployment during NASA's return mission to the Moon.

Autonomous trucks

26	66	47	39	73
Fe	Dy	Ag	Y	Ta
Iron	Dysprosium	Silver	Yttrium	Tantalum

Remote drilling

74	23	26	28	63
W	V	Fe	Ni	Eu
Tungsten	Vanadium	Iron	Nickel	Europium

Geoscience Australia's *Exploring for the Future* program is discovering the minerals critical to emerging technologies _

Hydrogen fuel cell

78	29	58	13	28
Pt	Cu	Ce	Al	Ni
Platinum	Copper	Cerium	Aluminium	Nickel

Drone aircraft

14	3	31	79
Si	Li	Ga	Au
Silicon	Lithium	Gallium	Gold

17

Mines of the future

Diverse, digital and decarbonised, Australian mining will become even safer and more sustainable as it contributes the raw metals needed for the global transition to net zero emissions. From robotics to AI, VR to electrification, mine sites of the future (and indeed today) are deploying increasingly advanced technology at an unprecedented rate. Technology is removing people from potentially hazardous situations, predicting and modelling operational improvements and enhancing environmental outcomes. From exploration through to development, operations through to rehabilitation, the technological transformation will secure the future of mining and enable the industry's critical role in global decarbonisation.

On Earth, fusion requires temperatures exceeding 100 million degrees Celsius. That's around six times hotter than the Sun's core _

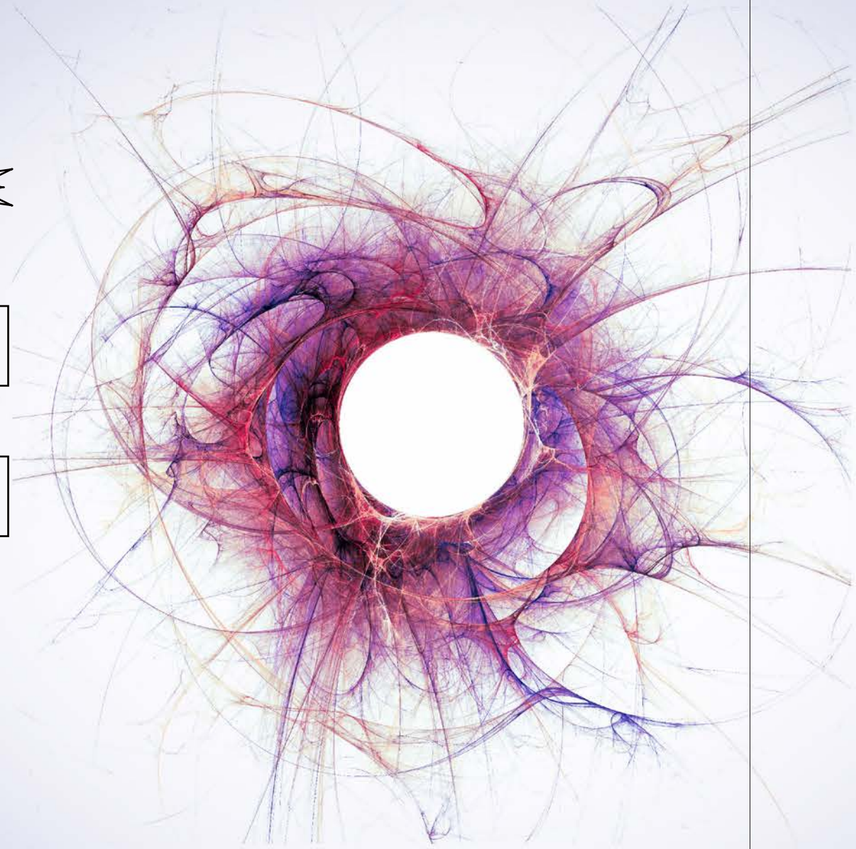
International Atomic Energy Agency

Cryogenic system

26	28	24
Fe	Ni	Cr
Iron	Nickel	Chromium

Reactor fuel

1	3
H	Li
Hydrogen	Lithium



Magnetic force

The world's largest nuclear fusion reactor being built in France is part of a 35-nation collaboration to harness fusion energy. The reactor contains the world's most powerful magnet – 280,000 times stronger than the Earth's magnetic field, and capable of lifting an aircraft carrier out of the water.

Fusion reactors

74	42	4	26
W	Mo	Be	Fe
Tungsten	Molybdenum	Beryllium	Iron

Plasma heating

28	26	74	29	13
Ni	Fe	W	Cu	Al
Nickel	Iron	Tungsten	Copper	Aluminium

Fusion energy could one day generate a near inexhaustible supply of clean energy for the planet _

High temperature superconducting magnets

41	50	29	22	26
Nb	Sn	Cu	Ti	Fe
Niobium	Tin	Copper	Titanium	Iron

Control room

60	32	52	38
Nd	Ge	Te	Sr
Neodymium	Germanium	Tellurium	Strontium

18

Fusion energy

Fusion energy is the game changing technology humankind has been waiting for – climate friendly, low waste energy to power a carbon-free planet. Fusion occurs when two atoms of hydrogen combine at extreme temperates to form an atom of helium, generating an enormous amount of energy in the process. It is the same process which powers the sun and the stars. The challenge for engineers is creating star power on earth – but they're getting closer. UK researchers created 59 megajoules of fusion over five seconds in early 2022 – enough energy to boil about 60 kettles. That might not sound super impressive, but it was twice as much the previous record breaking output in 1997.

Urban greening has a role in climate mitigation. In Colombia, 30 shaded 'green corridors' have reduced urban temperatures in tropical Medellin by 2°C _

World Economic Forum

Carbon Capture and Storage

26	28	23
Fe	Ni	V
Iron	Nickel	Vanadium

74	24	6
W	Cr	C
Tungsten	Chromium	Carbon

Low methane cows

Agriculture is a large contributor of the greenhouse gas methane, and the docile culprit is burping cattle. UK company Zelp has developed a methane-zapping halter for belching bovines that oxidises methane as it is exhaled. The tech tracks methane data for farmers, as well as other herd health metrics.

13	29	22	5	50	
Al	Cu	Ti	B	Sn	Direct air capture
Aluminium	Copper	Titanium	Boron	Tin	

14	73	79	3	66	
Si	Ta	Au	Li	Dy	Soil carbon sensors
Silicon	Tantalum	Gold	Lithium	Dysprosium	

22	21	41	47	
Ti	Sc	Nb	Ag	Satellite observation
Titanium	Scandium	Niobium	Silver	

Food production and distribution contributes 34 per cent of carbon emissions globally – around 17 times more than commercial aviation _

European Commission Joint Research Centre

26	77	14	29	42	
Fe	Ir	Si	Cu	Mo	Green steel (Molten oxide electrolysis)
Iron	Iridium	Silicon	Copper	Molybdenum	

19

Carbon reduction

Atmospheric CO_2 levels have almost doubled since the industrial revolution. While human activity has brought us to this point, human ingenuity might just be our salvation. From digitisation and electrification to green steel and alternative fuels, technological innovation is driving global decarbonisation efforts. Industry is doing much of the heavy lifting with technologies such as carbon capture and storage and direct air capture (ambient air carbon capture for sequestration or the production of carbon neutral fuels). Future technologies will also be critical, such as FuelGems' revolutionary fuel additive that reduces vehicle emissions, or Solidia's lower carbon concrete that cuts production emissions by 70 per cent.

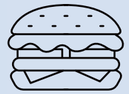
20

Water management

Water scarcity will affect the entire planet by 2040, according to the UN. Hedge funds are already trading 'water futures' like other precious commodities, and competition between nations for water will escalate. While Australia survived its 'Millennium Drought' (1997–2009) by halving business and residential water use and investing in desalination plants, it will take more than that in the future. Global solutions to water scarcity will require the deployment of advanced technologies, from nanotechnology filtration to membrane chemistry to smart monitoring. Improving the energy efficiency of desalination will be critical, as will water treatment innovation and enhanced water re-use and recycling.

Agriculture is the world's most water intensive industry. A hamburger with cheese and bacon takes around 3140 litres to produce _

United Nations Environment Assembly



Distribution: 26 Fe Iron; 30 Zn Zinc; 29 Cu Copper; 28 Ni Nickel; 24 Cr Chromium

Filtration: 6 C Carbon; 26 Fe Iron; 28 Ni Nickel; 13 Al Aluminium; 30 Zn Zinc

Desalination plants: 13 Al Aluminium; 29 Cu Copper; 14 Si Silicon; 22 Ti Titanium; 26 Fe Iron

74 W Tungsten; 50 Sn Tin

GIS (Geographic Information Systems): 47 Ag Silver; 60 Nd Neodymium; 49 In Indium; 50 Sn Tin; 73 Ta Tantalum

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Cleaner oceans

Tiny hybrid robots made from frog embryonic cells and AI could one day clean the world's oceans of microplastics. Neither traditional robot nor new animal species, Xenobots are a living programmable organism co-developed by Tufts University and the University of Vermont in the US.

Weather radar: 29 Cu Copper; 28 Ni Nickel; 13 Al Aluminium

One in four people will be affected by recurring water shortages by 2050 _

United Nations

Dams: 26 Fe Iron; 30 Zn Zinc; 28 Ni Nickel; 25 Mn Manganese

Alaskan wood frogs are the living dead of the amphibian world – freezing solid in winter before coming back to life in spring _

National Wildlife Federation

Cryogenic tank (for the dead)

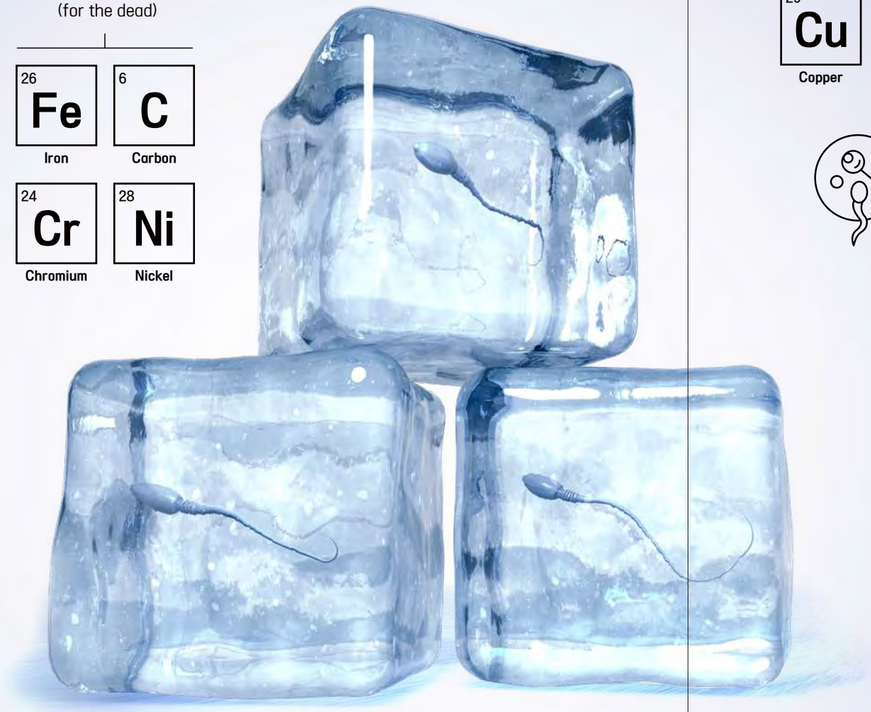
26 Fe Iron	6 C Carbon
24 Cr Chromium	28 Ni Nickel

Suspension facility

26 Fe Iron	12 Mg Magnesium
29 Cu Copper	42 Mo Molybdenum

Aussies on ice

Cryopreservation is coming down under with a first-of-its-kind cryonics facility opening near Holbrook in rural NSW. Southern Cryonics will offer whole-body suspensions for around $150,000 per person, as well as long-term storage, for around 40 deceased people hoping for a second chance at life.



29 Cu Copper	3 Li Lithium	28 Ni Nickel	14 Si Silicon	27 Co Cobalt	Biomedical monitoring

Almost one in 20 Australian and New Zealand babies were conceived through IVF in 2019 _

UNSW Australia and New Zealand Assisted Reproduction Database

28 Ni Nickel	14 Si Silicon	29 Cu Copper	30 Zn Zinc	51 Sb Antimony	Liquid nitrogen production
26 Fe Iron	13 Al Aluminium	24 Cr Chromium	28 Ni Nickel	25 Mn Manganese	IVF storage
13 Al Aluminium	26 Fe Iron	79 Au Gold	50 Sn Tin		Cryosauna (for the living)

21

Cryonics

While the science might be shaky (and the science community sceptical) that doesn't mean cryonic resurrection won't be possible one day. More than 500 deep-frozen humans in cryonic facilities worldwide have bet their speculative futures on it. Cryo technology – the ultra-low temperature preservation of goods and biomaterials – also has current-day applications that doesn't involve raising the dead. It is widely used in transport, food processing, animal husbandry and pharmaceutical industries, and underpins the success story that is IVF. The challenges facing cryonics might seem insurmountable today, but only time will tell if science can make the necessary strides to realise future reawakenings.

Autonomous air taxis could be transporting spectators between venues during the 2032 Olympic and Paralympic Games in Brisbane _

Wisk Air

Electric propulson

29	60	5	26	59
Cu	Nd	B	Fe	Pr
Copper	Neodymium	Boron	Iron	Praseodymium

Super efficient batteries

3	28	27	25	29
Li	Ni	Co	Mn	Cu
Lithium	Nickel	Cobalt	Manganese	Copper

Aircraft body

13	21	12	6	22
Al	Sc	Mg	C	Ti
Aluminium	Scandium	Magnesium	Carbon	Titanium

Vision-based sensors

58	14	73	13
Ce	Si	Ta	Al
Cerium	Silicon	Tantalum	Aluminium

Navigation

50	49	47	29	74
Sn	In	Ag	Cu	W
Tin	Indium	Silver	Copper	Tungsten

The scenic route

Australian tourism operators have inked deals for 50 eVTOL aircraft from US firm Eve, with progressive deliveries expected from 2026. Queensland's Nautilus Aviation and Sydney Seaplanes will kick off electric air taxi operations domestically with scenic tours, including over the Great Barrier Reef.

Charging station

13	26	29	6
Al	Fe	Cu	C
Aluminium	Iron	Copper	Carbon

A New York startup is building a 40-seater eVTOL air bus (a real life Thunderbird 2!) powered by high density lithium batteries _

Kelekona

22

Flying taxis

Fast, efficient and carbon neutral, electric air taxis will revolutionise urban travel. Start ups and established players are feverishly working to develop and certify electric vertical take-off and landing (eVTOL) aircraft, with experts predicting commercial flights as early as 2026. Smaller than a helicopter and built for cross-city transit (automated flights will come later), eVTOLs can travel within a 240 km radius. Flights will take off from vertiports dotted across the city and could be just the answer to beating peak-hour traffic or swapping the city for the coast. Investment in the sector is coming thick and fast. Morgan Stanley predicts the urban air mobility market could be worth more than $1 trillion by 2040.

23

Supply chain security

Supply chain security will only become more complex in the future. Robotics, automation and advanced analytics will continue to drive digital transformation of the sector, hastened by online shopping, shortened product life cycles and shifting consumer expectations. Mammoth distribution centres and neighbourhood drone deliveries will become more commonplace, and blockchain technology will support new standards in transparency as the ethical sourcing of product materials becomes more important. Demand for sustainably sourced critical minerals for manufacturing, such as lithium, cobalt, copper and nickel, will skyrocket and companies will need an added level of digital dexterity to respond to cybersecurity threats.

Online giant Amazon's market capitalisation is more than the GDP of Australia ($1.69 trillion to $1.63 trillion) _

Amazon (US$, 2021)

Road network

30	26
Zn	Fe
Zinc	Iron

Magway (pod propulsion delivery)

60	29	26	42
Nd	Cu	Fe	Mo
Neodymium	Copper	Iron	Molybdenum

Communications

47	68
Ag	Er
Silver	Erbium

32	21
Ge	Sc
Germanium	Scandium

58	26	47	28	73
Ce	Fe	Ag	Ni	Ta
Cerium	Iron	Silver	Nickel	Tantalum

Automated warehouses

Australia is well positioned to supply the critical minerals required to safeguard future supply chains _

14	29	79	3
Si	Cu	Au	Li
Silicon	Copper	Gold	Lithium

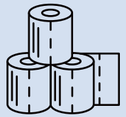
GPS tracking

13	26	66	12
Al	Fe	Dy	Mg
Aluminium	Iron	Dysprosium	Magnesium

Automated vehicles

3	28	27	25	62
Li	Ni	Co	Mn	Sm
Lithium	Nickel	Cobalt	Manganese	Samarium

Delivery drones

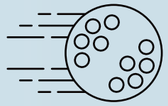


Supply shocks

COVID-19 shone a light on vulnerabilities in global supply chains. Everybody remembers the toilet paper wars of 2020. A far more serious supply issue was the shortage of silicon microchips used in everything from smartphones to electric vehicles. Securing supply chains is a top priority going forward.

A golf ball-sized amount of uranium in a fast reactor provides a lifetime's amount of energy for one person _

Nuclear Energy Institute



Floating nuclear energy plant

30	25	92	29	28
Zn	Mn	U	Cu	Ni
Zinc	Manganese	Uranium	Copper	Nickel

Small Modular Reactors

92	29	72	40	74
U	Cu	Hf	Zr	W
Uranium	Copper	Hafnium	Zirconium	Tungsten

26	63	49	22
Fe	Eu	In	Ti
Iron	Europium	Indium	Titanium

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Nuclear battery

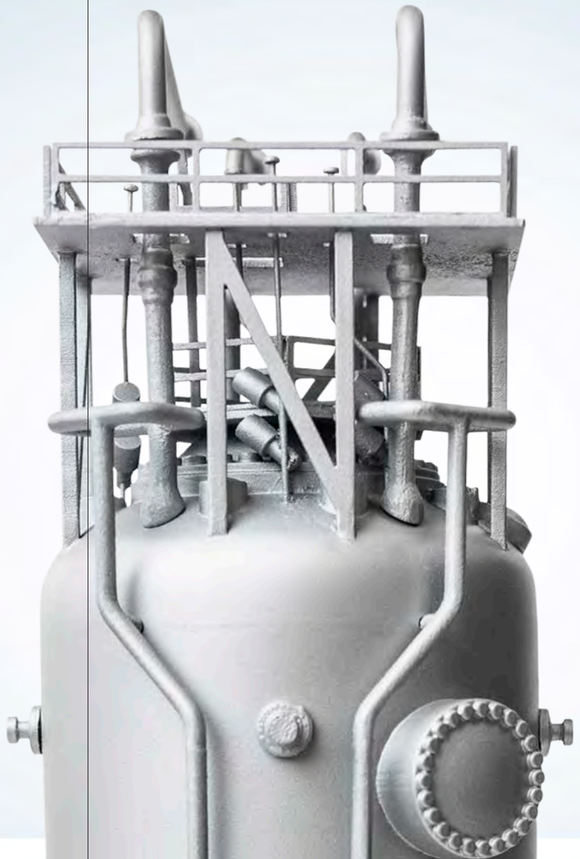
A nuclear waste powered battery that lasts up to 28,000 years might one day power everything from smartphones to electric vehicles to spacecraft. The Nano Diamond Battery, developed by US startup NDB, uses layers of synthetic diamonds to protect the battery's radioactive core.

Global electricity produced by Australia's uranium exports is equivalent to 96 per cent of Australia's total electricity needs _

Australian Safeguards and Non-Proliferation Office

Micro nuclear reactor

40	92	22	5
Zr	U	Ti	B
Zirconium	Uranium	Titanium	Boron



Zero carbon shipping

92	26	6
U	Fe	C
Uranium	Iron	Carbon

40	72
Zr	Hf
Zirconium	Hafnium

Nuclear medicine

42	62
Mo	Sm
Molybdenum	Samarium

39	27	92
Y	Co	U
Yttrium	Cobalt	Uranium

24

Advanced nuclear

Safe, cheap, zero emissions energy is within reach thanks to advanced nuclear technologies. Nuclear energy provides around 10 per cent of the world's electricity, saving the planet more than 2 billion tonnes of CO_2 emissions annually. Beyond electricity generation, emerging reactor designs will process heat, produce hydrogen and desalinate water. Small modular reactors, available later this decade, will provide low cost, reliable energy for millions. Medical research reactors will also be critical, like Australia's OPAL reactor in Lucas Heights. One in two Australians will benefit from life-saving nuclear medicine during their lifetime, according to ANSTO, which produces more than 10,000 nuclear medicine doses weekly.

Bitcoin mining consumes more energy than Norway, and 10 times more energy than Google, Meta and Microsoft combined _

Cambridge Centre for Alternative Finance

Share trading platforms

14	63	29	57	59
Si	Eu	Cu	La	Pr
Silicon	Europium	Copper	Lanthanum	Praseodymium

Precious metals

79	47	78
Au	Ag	Pt
Gold	Silver	Platinum

46	76
Pd	Os
Palladium	Osmium

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Digital gold

Gold-backed digital tokens have emerged as a new wealth asset. Perth Mint issued the world's first gold digital token on a public blockchain – the Perth Mint Gold Token – in 2020. Backed by government guaranteed gold stored at The Perth Mint, digital tokens are traded through the Mint's GoldPass app.

Banking apps

50	49	3	28	27
Sn	In	Li	Ni	Co
Tin	Indium	Lithium	Nickel	Cobalt

Digital wallet

28	31	66	74	6
Ni	Ga	Dy	W	C
Nickel	Gallium	Dysprosium	Tungsten	Carbon

NFT sales – the digital ownership of unique assets such as audio clips and images – topped $17.6 billion in 2021, a 200-fold year-on-year increase _

NFT Market Report, Non-Fungible.com

Digital payment systems

68	79	14	55	66
Er	Cu	Si	Cs	Dy
Erbium	Copper	Silicon	Cesium	Dysprosium

Server farms

13	29	79	26	73
Al	Cu	Au	Fe	Ta
Aluminium	Copper	Gold	Iron	Tantalum

25

Digital economy

E-commerce and digital banking heralded the biggest disruption to financial systems in decades. While the days of physical cash might be numbered, the burgeoning digital economy, backed by faster internet speeds and enhanced internet security, is still in its infancy. Cryptocurrencies, blockchain and the mainstreaming of non-fungible tokens (NFTs) has captured the imaginations of everybody from tech billionaires to mum and dad investors. But it takes a brave soul to ride the volatile crypto waves – the market lost $2 trillion in the first half of 2022, and more than 40 countries have banned or restricted the use of cryptos. The only safe bet, it seems, is on the OG of strategic assets – gold – the safest haven of all in complex times.

THE FUTURIST EDITION

The world's first zero emissions hydrogen-powered passenger aircraft could be in service by 2035 _

Airbus

Hydrogen trucks

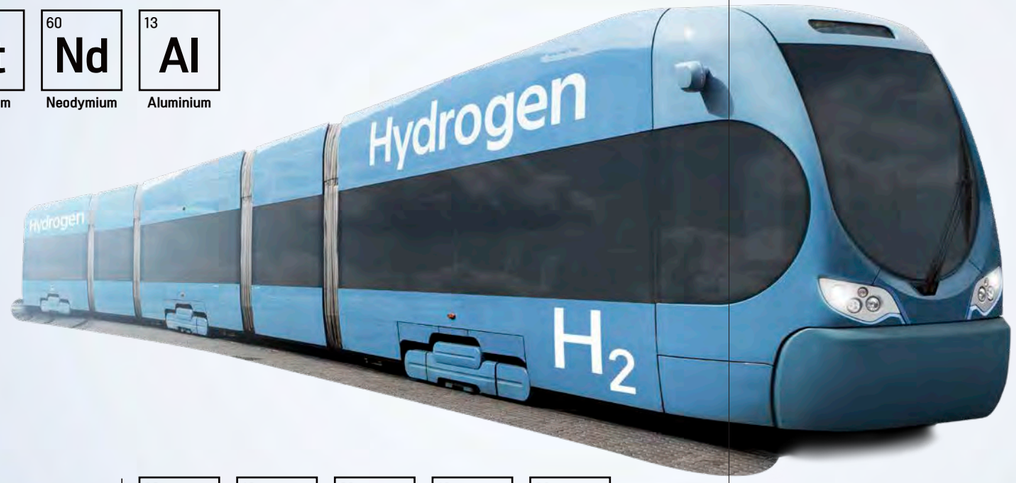
29	26	78	13	74
Cu	Fe	Pt	Si	W
Copper	Iron	Platinum	Silicon	Tungsten

Hydrogen aircraft

78	60	13
Pt	Nd	Al
Platinum	Neodymium	Aluminium

Hydrogen storage

26	13	6	24
Fe	Al	C	Cr
Iron	Aluminium	Carbon	Chromium

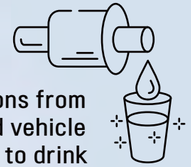


Hydrogen superpower

Australia is positioning itself as a hydrogen superpower. The Federal Government is investing $1.4 billion to establish a hydrogen industry, with the aim of becoming a major global player by 2030. Hydrogen production for export and domestic use could be worth more than $50 billion to Australia in 2050.

Refuelling stations

30	13	29	13	26
Zn	Si	Cu	Al	Fe
Zinc	Silicon	Copper	Aluminium	Iron



The only emissions from a hydrogen-powered vehicle is water clean enough to drink (although best you don't) _

Electrolyser (Hydrogen production)

78	77	27	28	25
Pt	Ir	Co	Ni	Mn
Platinum	Iridium	Cobalt	Nickel	Manganese

Hydrogen steel (Green steel)

26	13	28	30	29
Fe	Al	Ni	Zn	Cu
Iron	Aluminium	Nickel	Zinc	Copper

26

Hydrogen energy

Hydrogen is the wunderkind of future fuels, carrying the decarbonisation ambitions of the transportation and freight sectors, as well as energy-intensive industries, such as steel and cement production. The future of hydrogen production is electrolysis - the passage of an electrical current through water - which makes for an emissions-free energy source when electricity from wind, solar and nuclear is used. According to Wood Mackenzie, global demand for low-carbon hydrogen could rise six-fold by mid-century, while Deloitte estimates the market could be worth US$2 trillion. With energy demand set to climb almost 50 per cent by 2050, it seems a safe bet hydrogen will play a much larger role in the future energy mix.

Australia's Synchrotron produces a light beam a million times brighter than the sun to help unlock the sub-atomic secrets of materials _

ANSTO

Australian Synchrotron

79	74	60	72	28	78
Au	W	Nd	Hf	Ni	Pt
Gold	Tungsten	Neodymium	Hafnium	Nickel	Platinum

Dark matter detectors

29	32	14	11	70
Cu	Ge	Si	Na	Yb
Copper	Germanium	Silicon	Sodium	Ytterbium

International Linear Collider (Next gen collider)

50	26	47	29
Sn	Fe	Ag	Cu
Tin	Iron	Silver	Copper

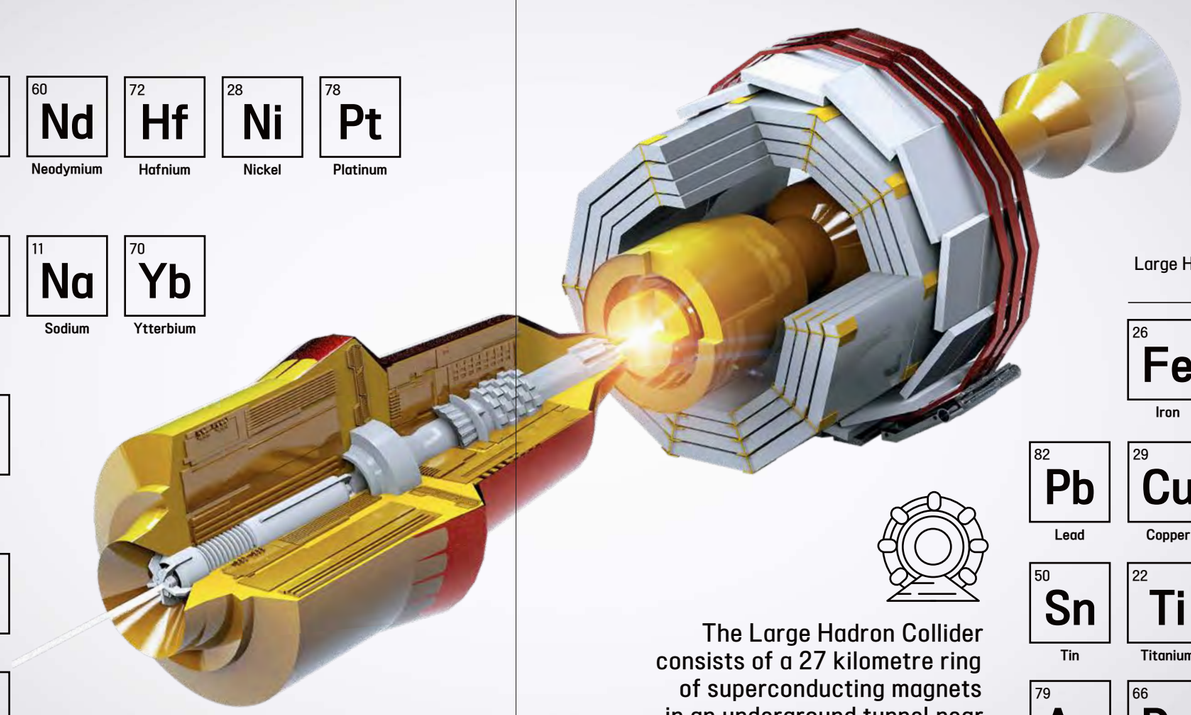
Medical isotopes

71	27	39	6	42
Lu	Co	Y	C	Mo
Lutetium	Cobalt	Yttrium	Carbon	Molybdenum

THE FUTURIST EDITION

Shining light on dark matter

Stawell Gold Mines is an unlikely partner in the global search for dark matter. An international team of scientists aim to unlock the secrets of the universe, and advance cutting-edge technologies, from an underground laboratory at the mine – the first of its kind in the southern hemisphere.



The Large Hadron Collider consists of a 27 kilometre ring of superconducting magnets in an underground tunnel near Geneva, Switzerland _

CERN

Large Hadron Collider

26	41
Fe	Nb
Iron	Niobium

82	29	74
Pb	Cu	W
Lead	Copper	Tungsten

50	22	13
Sn	Ti	Al
Tin	Titanium	Aluminium

79	66	14
Au	Dy	Si
Gold	Dysprosium	Silicon

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Particle physics

Particle physics is the study of sub-atomic particles and their properties. Particle physicists use machines called accelerators to propel subatomic particles at close to light speed – and then wait for the collision. What happens to these particles on collision helps physicists understand the physical laws that govern everything from matter and energy to space and time. But those at the helm of the world's biggest science experiments are consumed with more than just the origins of the universe (i.e. the Big Bang theory). Practical particle acceleration discoveries have delivered us everything from real time security scanning at airports to the diagnosis and treatment of certain cancers, and even shrink wrap!

From the internet to drones to GPS, the defence ecosystem has incubated some of the world's most recognisable technology _

Satellite communications

29	47	21	22	41
Cu	Ag	Sc	Ti	Nb
Copper	Silver	Scandium	Titanium	Niobium

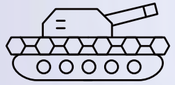
Naval sonar

65	26	66
Tb	Fe	Dy
Terbium	Iron	Dysprosium

Drone aircraft

3	29	28
Li	Cu	Ni
Lithium	Copper	Nickel

25	27
Mn	Co
Manganese	Cobalt



Invisibility cloak

Military vehicles fitted with BAE Systems' ADAPTIV technology can navigate enemy territory invisible to infrared systems. The futuristic honeycomb-shaped tech uses temperature to match the vehicle's thermal signature with its surrounds, and can even disguise itself to look like a cow, or a car.

Cyber security

14	73	31	68	32	79
Si	Ta	Ga	Er	Ge	Au
Silicon	Tantalum	Gallium	Erbium	Germanium	Gold

Missile defence system

62	27
Sm	Co
Samarium	Cobalt

13	39	74
Al	Y	W
Aluminium	Yttrium	Tungsten

Armoured personnel carrier

26	23
Fe	V
Iron	Vanadium

42	28	24
Mo	Ni	Cr
Molybdenum	Nickel	Chromium

THE FUTURIST EDITION

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Defence systems

Rapid advances in robotics, AI and IoMT will shape and reshape modern warfare this century. From unmanned vehicles to hypersonic missile defence systems to cyber warfare, the future of combat is hybrid in both the physical and digital realms. While military nations race to develop next gen tech – whether that be direct energy munitions, robotic armies (as horrifying as that prospect is) or even space munitions – governments are grappling with supply security of rare earth elements and other strategic minerals. The opportunity for Australia's resources is vast. Let's just hope that common interest and diplomacy are the first tools out of the defence kit to resolve future conflicts.

Sensor pods, called 'dragon eggs', have been developed that can be drone-dropped onto active volcanos to provide real-time monitoring of volcanic activity _

University of Bristol

Electric fire trucks

60	3	26	28	51
Nd	Li	Fe	Ni	Sb
Neodymium	Lithium	Iron	Nickel	Antimony

Fire fighting drones

3	28	27	25	60
Li	Ni	Co	Mn	Nd
Lithium	Nickel	Cobalt	Manganese	Neodymium

Emergency warning system

29	47	68	49	30
Cu	Ag	Er	In	Zn
Copper	Silver	Erbium	Indium	Zinc

Flood modelling

14	66	63	50
Si	Dy	Eu	Sn
Silicon	Dysprosium	Europium	Tin

Weather satellites

22	21	79	58	12
Ti	Sc	Au	Ce	Mg
Titanium	Scandium	Gold	Cerium	Magnesium

THE FUTURIST EDITION

Firefighting kit

Australia scientists have developed a fire retardent nanomaterial that could revolutionise firefighting uniforms, and one day even protect vehicles and buildings. The lightweight compound, made from titanium carbide, is the product of collaborative effort of ANSTO and the University of NSW.

Earthquake detection (Seismograph)

13	29	26
Al	Cu	Fe
Aluminium	Copper	Iron

74	41
W	Nb
Tungsten	Niobium

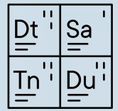
Predictive modelling that leverages AI and ML technologies will be able to better forecast low level tectonic motion before earthquakes _

Cornell University

29

Emergency management

Floods, bushfires, cyclones… natural disasters and extreme weather events exacerbated by climate change are testing populations around the world. From drones to GIS to IoT, technology is transforming the way frontline services coordinate to keep rescue personnel and communities safe. Predictive technologies leveraging AI and ML are used to forecast and simulate everything from earthquakes to heatwaves to flood events, while digital identity and facial recognition are increasingly being used to help survivors get back on their feet. In the future, sonic extinguishers may become part of the firefighter's arsenal – drone-delivered loud noises that use sound waves to disrupt and deny bushfires oxygen.



There were 246 elements known to Federation science in the 24th century. That's 128 more elements than exist on the periodic table today _

Star Trek: Voyager

Bridge

50	49	63	73
Sn	In	Eu	Ta
Tin	Indium	Europium	Tantalum

Mr Data

14	27	42	79	60
Si	Co	Mo	Au	Nd
Silicon	Cobalt	Molybdenum	Gold	Neodymium

Phasers

57	39	25	3	28
La	Y	Mn	Li	Ni
Lanthanum	Yttrium	Manganese	Lithium	Nickel

Alternate realities

Transporting ourselves into alternative realities via a holodeck is many moons away. Truly interactive holographic projections defy the laws of physics, which is a close to insurmountable problem. For impatient tech heads, the nearest approximation might eventually be found in the metaverse.

USS Enterprise (Hull)

22	13	12	21	6	120
Ti	Al	Mg	Sc	C	Du*
Titanium	Aluminium	Magnesium	Scandium	Carbon	Duranium

Warp propulsion is not completely beyond the realm of possibility with a team from NASA examing faster-than-light future intergallactic travel _

Warp drive (Engine)

78	74	41	67	87
Pt	W	Nb	Ho	Dt*
Platinum	Tungsten	Niobium	Holmium	Dilithium

Transporter room

29	51	26	66	47
Cu	Sb	Fe	Dy	Ag
Copper	Antimony	Iron	Dysprosium	Silver

* Dilithium and duranium are invented materials in the *Star Trek* fictional universe

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USS Enterprise

Live long and prosper. It was more than 50 years ago that Spock's immortal words captured the imaginations of sci-fi buffs everywhere, and Star Trek is still going strong today. Incredibly, many of the science fiction offerings from the enduring tv series are now a reality - from wireless communication to computer tablets and even universal translators. Numerous attempts have been made by fans to reproduce some of the advanced technologies (holodeck, anyone?), but one of the limitations is that many of the materials described in the show are yet to be discovered or produced. There is hope though - while we might not have dilithium crystals, scientists have managed to engineer transparent aluminium.

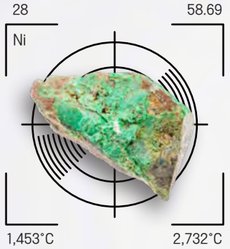
Rock stars of the future

Global demand for clean energy technologies could push production of future-critical minerals nearly 500 per cent higher by 2050 _

World Bank Group

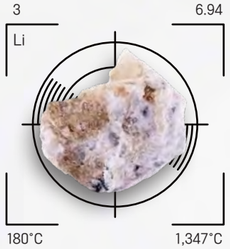
Copper _

World copper consumption has doubled on average every 25 to 30 years as a result of increased access to electricity, growing incomes and rapid advancements and take up of new technologies. This pattern will accelerate with copper-intensive goods and energy infrastructure set to play an increasing role in the global economy.



Nickel _

The market use of nickel will diversify over the next decade from high-grade steel required for skyscrapers and transportation networks to meet global demand for battery-grade nickel. The battery industry's market share of nickel consumption will rise to 26 per cent by 2030, according to analysts at Commodity Insights.

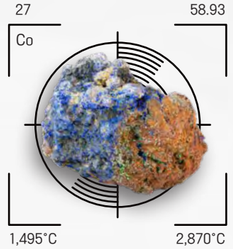


Lithium _

The main driver of the forthcoming surge in demand for lithium ion batteries will be car manufacturers releasing more electric vehicle models and the rising use of renewable energy requiring greater use of energy storage technology. Commodity Insights forecasts growth in lithium demand of 368 per cent to 2030.

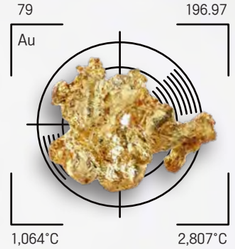
Uranium _

More than 30 countries rely on low cost, zero emissions nuclear-generated electricity to underpin baseload power requirements and tackle climate change. Commodity Insights forecasts global uranium demand to rise to 99.5 kt in 2030, driven largely by China, which has outlined plans to significantly increase nuclear generation.



Cobalt _

Cobalt is an important material in the cathode of many lithium-ion batteries as it boosts energy density and extends battery life. Rapid growth in the production of electric vehicles over the next ten years is set to significantly increase global demand for cobalt and will require new mines around the world to open.



Gold _

Gold has provided top notch investment returns over the past 20 years and looks set to hold its position for superior long-term returns compared to bonds and other asset classes given uncertain economic times. Its role in financial systems continues to grow with central banks and exchange traded funds increasing their holdings.

Silicon _

Often overlooked, silicon is the most consumed mineral commodity in the world. It is used to make concrete, glass, solar panels and importantly, the micro processors that power high tech consumer electronics. Rising urbanisation, solar PV production and emerging technologies will drive higher consumption of silicon.

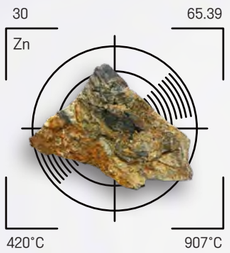
Rare earth elements _

Demand growth is expected for most rare earth elements over and beyond the next decade, mainly supported by the manufacture of permanent magnets used in offshore wind turbines and the drive trains of most EVs. The IEA forecasts global neodymium demand to increase between 73 per cent and 113 per cent to 2030.

Workhorses of the future

Iron_

Rising urbanisation rates and industrial expansion across Asia will drive growing steel demand into the future. The stock of steel in these highly populated Asian economies remains less than half that of OECD nations. High-grade iron ore, such as ores mined in Australia, produce fewer emissions during the steel-making process.



Zinc_

Zinc's primary use is galvanising steel to prevent rust from forming and its outlook is therefore linked to the fortunes of steel. Industrial expansion – the construction of bridges, factories, high-rise buildings and ships – will see zinc consumption rise 12 per cent to 2030, according to Commodity Insights.

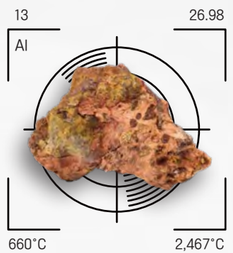
Manganese_

From the steel used in railway lines to the aluminium packaging in soft drink cans, manganese alloys are all around us. Manganese is also an important cathode material in electric vehicle batteries and grid storage devices. Manganese demand will rise as production capacity increases in Asia, Europe and North America.

Molybdenum_

Molybdenum is a critical component of the steel used to make railway lines. Mass urbanisation in developing economies will accelerate demand for the ductile and corrosion-resistant metal. 'Moly steel' alloys are also used in parts of engines, heating elements and saw blades where strength and hardness are important.

Rising urbanisation and industrial expansion in emerging economies across Asia will drive demand for steel and its alloys_



Aluminium_

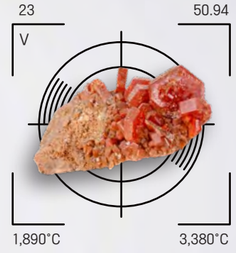
World consumption of aluminium has increased substantially over the last 20 years, underpinned by rapid demand from higher incomes, rising urbanisation and greater car ownership in Asia. Commodity Insights forecasts primary aluminium demand to rise rapidly to 94.7 Mt by 2030, representing overall growth of 45.5 per cent.

Metallurgical coal_

Steel demand for new high density housing, transport infrastructure and industrial machinery in emerging economies will see demand for metallurgical coal rise steadily to 2030, according to Commodity Insights. Global steel production is dependent on high quality metallurgical coal, with around 70 per cent of steel produced using coal.

Chromium_

Chromium is the essential alloying agent of stainless steel. Used in leather tanning, printing and catalysts, it is highly resistant to corrosion, even at high temperatures, and reflects about 70 per cent of light making it a fan-favourite with consumers. Much more than a one-trick pony, chromium is also used to colour ceramics and paint.



Vanadium_

Strength is the primary characteristic of vanadium, commonly used in steel alloys in nuclear reactors, space vehicles and aircraft carriers. The demand outlook for vanadium is expected to grow, particularly if the vanadium-flow battery, touted for its large-scale energy storage potential, gains momentum.

Mining makes the *imaginable* possible

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