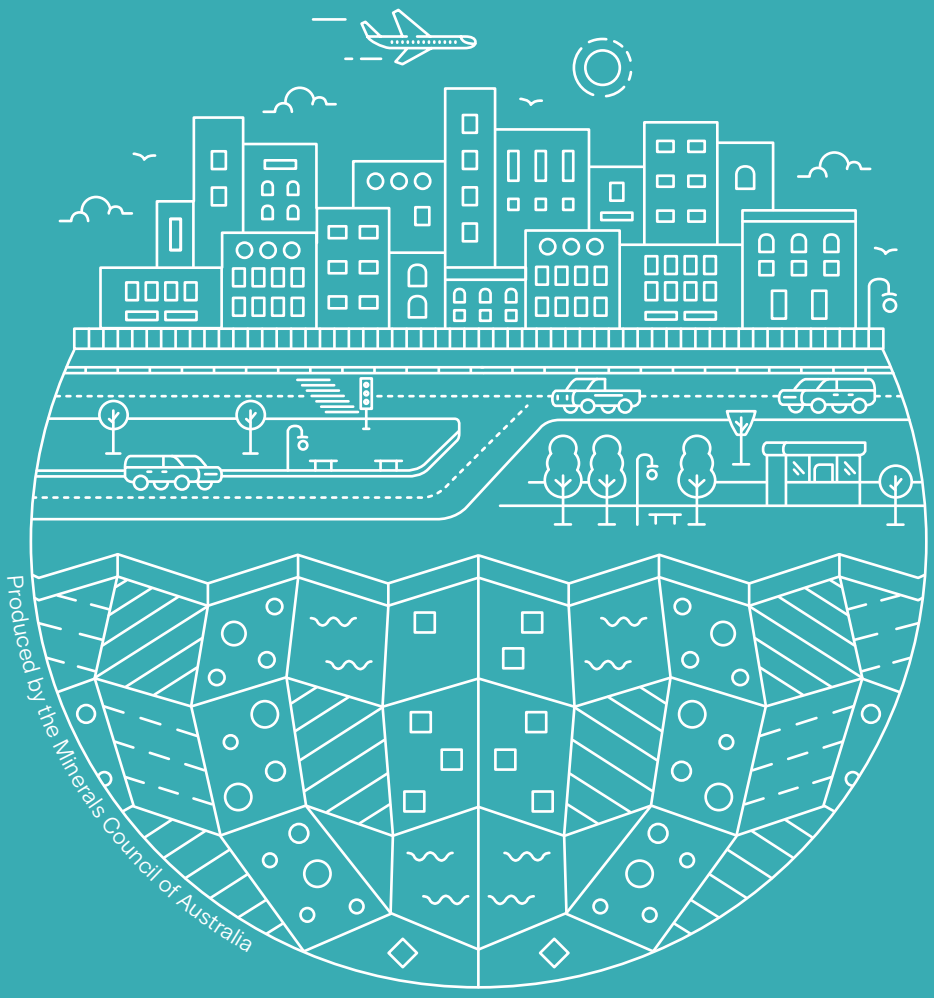
untapped potential



Produced by the Minerals Council of Australia

There's more to
Australian Mining

Part One

foreword

Australia has one-third of the world's uranium resource which will be increasingly critical for a power hungry world seeking to reduce greenhouse gas emissions.

As the third largest uranium exporter, the electricity produced by Australia's uranium is equivalent to 96 per cent of Australia's total annual electricity generation – and all with zero emissions.

Nuclear energy provides around 10 per cent of the world's electricity and last year resulted in about 2.2 billion tonnes of CO_2 not being released into the atmosphere. It is safe, reliable and affordable.

Yet in Australia outdated regulations in some states ban the exploration and mining of uranium, and under federal law nuclear energy is prohibited. The result is that Australians are denied a zero emissions 24/7 energy source that is not dependent on the weather.

Canada is like Australia in many ways. Yet it has chosen to embrace nuclear energy and uranium mining and is now a world leader in nuclear technology. Not only does Canada meet about 15 per cent of its electricity needs with zero emissions nuclear power, its citizens pay some of the lowest prices for residential electricity in the world.

There's more to Australian Mining

It's not too late for Australia.

With the next generation of nuclear technologies such as small modular reactors (SMRs) expected to be commercially available by the late 2020s, Australia should consider SMRs as an option to replace some of our ageing baseload coal-fired power generators.

Australia is already better placed than many countries to safely manage nuclear waste, both as one of the world's most geologically stable nations and the beneficiary of world-class health and safety and environmental protections.

Public support for nuclear energy is growing. Recent surveys show a majority of Australians support a role for nuclear in the nation's energy mix. This is also a position held increasingly by business and industry groups, including Industry Super Australia.

The Australian Workers' Union, the country's oldest and largest blue collar trade union, also recognises the potential of nuclear energy in supporting industry and households and has called for the immediate lifting of all legislative bans on uranium exploration, mining and nuclear power.

The benefits of a nuclear industry go far beyond energy generation. Nuclear medicine, for example, is literally life-saving, with around 50 per cent of Australians expected to benefit from nuclear medicine during their lifetime. **The irony is that the nuclear medicine saving lives in hospitals across the country is coming from uranium mining which is banned in the three most populous states and Tasmania, and limited to four mines in Western Australia.**

In spite of this, the completion of the Mo-99 (Molybdenum 99) Manufacturing Facility at Lucas Heights in Sydney means Australia will increasingly be a major player in international health care, supplying ever growing domestic and global demand for nuclear medicines.

So Australia has a clear choice – it can reconsider the role nuclear energy can play in a low carbon future and remove the obstacles prohibiting the development of a nuclear industry.

Or it can continue to help the rest of the world reduce its emissions through the export of our uranium and, as we've done for the past 40 years, allow domestic policy to be dictated by anti-scientific scare campaigns. This approach has achieved nothing but to deny Australians the benefits of this amazing natural resource.

The Minerals Council of Australia has produced this two-part booklet as part of its contribution to a mature national discussion about the future of energy generation and energy security in Australia.

Tania Constable
Chief Executive Officer
Minerals Council of Australia

Australia's rich endowment

Australia is endowed with the world's largest uranium resource but sits behind Kazakhstan and Canada as the third-largest producer.

Australia has 111 known uranium deposits accounting for 30 per cent of the world's known uranium resources, or 1.8 million tonnes.[1]

Yet Australia remains only the world's third largest producer.

Three operations are currently producing uranium in Australia: Olympic Dam in South Australia, Ranger in the Northern Territory and Four Mile in South Australia. Four Mile processes at the former Beverley mine.[2]

Around 80 per cent of Australia's known uranium resource is in South Australia, with 9 per cent in the Northern Territory, 7 per cent in Western Australia, 4 per cent in Queensland and 1 per cent in New South Wales.[3]

Australia has the opportunity to expand its role as a secure, reliable and sustainable uranium producer, but has not capitalised on it.

Kazakhstan, which has 14 per cent of global uranium resources is the world's largest producer, followed by Canada with 8 per cent.[4]

Federal regulation and state-based uranium mining bans, including in Queensland, Victoria, New South Wales and Tasmania continue to negatively impact uranium mining in Australia. Restrictions are also in place in Western Australia, with uranium mine development limited to four existing projects.

Australia's rich endowment

Minerals Council of Australia
minerals.org.au

URANIUM RESOURCE

Australia has the world's largest share of uranium resources but is 3rd biggest producer

30% **Australia** (1,818,300 t)

14% **Kazakhstan** (842,200 t)

8% **Canada** (514,400 t)

8% **Russia** (485,600 t)

7% **Namibia** (442,100 t)

Source: World Nuclear Association

PRODUCTION 2018

Tonnes U

1 **Kazakhstan** (21,705 t)
2 **Canada** (7001 t)
3 **Australia** **(6517 t)**
4 **Namibia** (5525 t)
5 **Niger** (2911 t)
6 **Russia** (2904 t)

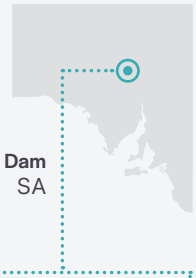
World Nuclear Association

STATE BY STATE

Around 80% of Australia's uranium is in SA

1.8 Mt
Australia's total uranium resource.
World Nuclear Association

80%
Of Australia's uranium is in **South Australia**.
Geoscience Australia



Share of uranium resources outside South Australia

Source: Geoscience Australia

OLYMPIC DAM [SA]

BHP's Olympic Dam is the world's largest uranium deposit with more than a million tonnes of uranium. It was the second-largest producing uranium mine in the world in 2018.

OPERATING MINES

At July 2019

Olympic Dam (SA)
Four Mile (SA)
Ranger (NT)

World Nuclear Association

URANIUM PRODUCTION

Production is down 23% since 2008

Tonnes U

8430 t
Uranium production in Australia in 2008.

6517 t
Uranium production in Australia in 2018.

Source: World Nuclear Association

RANGER MINE [NT]

Energy Resources Australia's Ranger mine is due to close in January 2021. A comprehensive rehabilitation program is already underway to return the mined area to a viable ecosystem.

AUSTRALIAN MADE

Strong oversight of uranium exports

Australian uranium can only be used for peaceful purposes such as civil nuclear power and nuclear medicine. This is enforced through stringent bilateral agreements in addition to International Atomic Energy Agency safeguards.

Safe production of uranium

Mining and processing uranium emits low levels of radiation which is strictly monitored and managed.

Australian standards for radiation protection are set by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

The unit to measure a dose of radiation is the Sievert (Sv). In Australia the annual average background radiation dose is 1.5 mSv – which is less than two one-thousandths of a Sv.[5]

Where a worker will be exposed to radiation the maximum dose permitted is 20 mSv per year averaged over five years, with no more than 50 mSv in any one year.[6]

The Australian National Radiation Dose Register reports that typical exposure to registered workers (i.e. miners, medical professionals and other occupations exposed to low level radiation) is significantly less than the prescribed limits.[7]

In 2018 95 per cent of exposed workers received an annual effective dose less than 3 mSv. 72 per cent of workers received a dose of less than 1 mSv.[8]

It is important to remember that radiation is all around us. It exists naturally in the world.

Cornwall in the United Kingdom, for example, has a background radiation level of 7.8 mSv per annum due to the presence of granite rock which has high natural levels of radiation.[9]

Safe working practices and regulation in Australia are based on internationally developed standards. These have been informed by scientific research developed over decades.

Safe production of uranium

Minerals Council of Australia
minerals.org.au

URANIUM WORKERS

Radiation safety regulations at Australian uranium mines

AUSTRALIAN MINERS

Miners who work with uranium ores receive an average of 2 to 5 mSv per year. The maximum dose permitted is 20 mSv per year averaged over five years, and not more than 50 mSv in any one year.

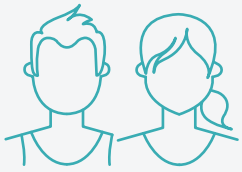
95% Occupationally exposed workers that recorded **an average annual dose of less than 3 mSv** in 2018.

72% Of this occupationally exposed group recorded **an average annual dose of less than 1 mSv** in 2018.

Source: Australian Radiation Protection and Nuclear Safety Agency

EVERYDAY AUSTRALIANS

Radiation exists in nature and everything around us



AVERAGE AUSTRALIAN

1.5 mSv

On average, Australians are exposed to 1.5 mSv of radiation from natural sources every year. This is about the same amount of radiation received from 75 chest x-rays.

10 mSv **CT scan** Single, full body

7.8 mSv **Cornwall UK** Annual, background

4.0 mSv **Flight crew** Annual, international

2.0 mSv **Uranium miner** Annual, average

0.29 mSv **Food** Annual dose

0.11 mSv **Return flight** Melb to London

Source: Australian Radiation Protection and Nuclear Safety Agency; Australia Nuclear Science and Technology Organisation

SAFE PASSAGE

Safe storage and transportation of uranium

Storage

Every 200-litre drum of uranium oxide concentrate produced in Australia is packed, sealed and locked in shipping containers before leaving the mine site.

Transportation

Around 300 containers of uranium are transported every year by road and rail to ports in Adelaide and Darwin and are not opened until they reach their final destination overseas.

Australian Safeguards and Non-Proliferation Office

BELIEVE IT OR NOT

Parliament House emits more radiation than a nuclear power plant

PARLIAMENT HOUSE AUSTRALIA

Source: World Nuclear Association

That's because of the large amount of granite and other natural stone used in its construction. These materials naturally emit radiation through trace amounts of uranium. But there's no need to panic. Levels emitted are minuscule, although – ironically – likely still higher than would be acceptable at a nuclear power station.

GRAND CENTRAL

New York's landmark train station emits a relatively high level of radiation. A typical worker might receive around 1.2 mSv a year from the granite used to build the terminal.

The economic opportunity

With 30 per cent of the world's uranium Australia should be a world leader in uranium mining and technology.

Australia is well positioned to expand its role as a secure, reliable and sustainable global producer and exporter of uranium.

It also has the opportunity to develop a high tech nuclear sector which would offer a broad range of employment, investment and research opportunities.

Australia exported 6227 tonnes of uranium in 2017-18 – just under 10 per cent of world demand – valued at $575 million.[10] Today the industry employs 3000 people.

Key markets such as the United States, France, Belgium, China, South Korea and Japan depend on uranium to generate affordable, reliable, low emissions electricity.

With growing international focus on the need for low emissions energy sources, global demand for uranium is expected to increase.

The International Energy Agency projects an increase in nuclear power generation of between 40 and 90 per cent by 2040.[11]

Based on this projection, and assuming Australia's global market share grows from 10 to 30 per cent, the uranium sector could employ up to 20,000 people and deliver $6 billion to $9 billion per annum.[12]

A modern and sensible nuclear policy would also revitalise Australia's nuclear engineering potential. This would encourage universities to develop specialist courses and partner with international universities.

State and federal bans have stopped the industry reaching its potential but it's not too late.

Australian uranium producers can meet increased global demand if they are allowed and Australia's world-class research and tertiary sectors could become global leaders in zero emissions energy and nuclear technology.

The economic opportunity

Minerals Council of Australia
minerals.org.au

THE ECONOMICS

If Australia realised its uranium potential

20,000

New jobs by 2040
If Australia increases its export share of uranium closer to 30 per cent.

$9 billion

Economic value by 2040
If Australia increases its exports of uranium closer to 30 per cent.

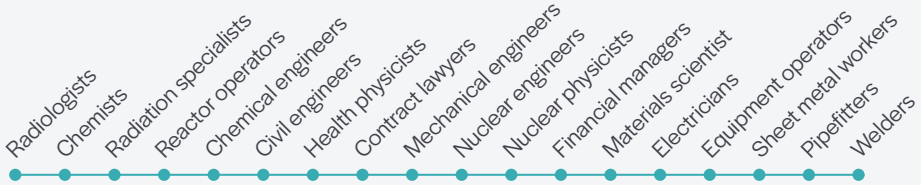
Source: Sinclair Davidson 2015

TRADING NATION

Australia could build on its preferred trading nation status with new partnerships and trade deals with nuclear energy nations if bans were removed and new uranium mines supported.

HIGH SKILLED CAREERS

More high skilled science and engineering career pathways



Source: Nuclear Energy Institute

NUCLEAR SCIENCE

Untapped opportunities in nuclear science and research

NUCLEAR JOBS

US nuclear industry provides secure, high paid jobs

JOBS

400-700

Power plant jobs
Workers required to operate a nuclear power plant.
Nuclear Energy Institute

3500

Construction jobs
Jobs during construction of a nuclear power plant.
Nuclear Energy Institute

36%

High wage jobs
Nuclear power plant salaries are 36 per cent higher than the local average.
Nuclear Energy Institute

SHIFTING VIEWS

More Australians support nuclear power today than ever before

44%

Essential poll
Australians who support nuclear power – up 4 points since the question was last asked in November 2015.

61%

SBS Viceland poll
Australians in favour of lifting the ban on nuclear energy (poll conducted in October 2018).

65%

9 News Facebook poll
Australians in favour of nuclear to prevent summer blackouts (25,300 votes, August 2019).

77

WORLD-LEADING CONSERVATION SCIENTISTS called for green groups in late 2014 to reconsider their historical opposition to nuclear power.
Brook & Bradshaw, Dec 2014

The Canadian example

Australia made a mistake when it banned nuclear power two decades ago. This is what a nuclear industry could have looked like today if it hadn't.

Canada is similar to Australia in many ways – a large country with a relatively small population and substantial mineral resources.

However Canada has taken a different approach to uranium and nuclear power and the result is a multi-billion dollar industry.

Canada is a global nuclear leader exporting uranium and advanced technology to nuclear-powered countries around the world.

As the world's second largest uranium producer, Canada exports 85 per cent of its production. This is worth A$1.3 billion (C$1.2 billion) per annum.[13]

In 2018 nuclear energy also provided 15 per cent of Canada's electricity – with zero emissions.[14]

60,000 Canadian jobs are directly and indirectly supported by its nuclear sector with many in high paying, high tech roles.[15]

With 5000 jobs in uranium mining, 25,000 in the nuclear power sector and another 30,000 indirect jobs, the industry generates annual revenues of over A$6.7 billion (C$6 billion).[16]

Other beneficiaries are the more than 200 Canadian companies that supply products and services to Canada's nuclear industry.[17]

The Canadian example

Minerals Council of Australia
minerals.org.au

AUSTRALIA VS CANADA

A side by side comparison of uranium industries

AUSTRALIA

Jobs **3000**

Value **A$600 million**

CO_2 from electricity **800 kg** per MWh

CANADA

Jobs **60,000**

Value **A$6.7 billion**

CO_2 from electricity **160 kg** per MWh

Source: Australian Bureau of Statistics; Australian Safeguards Non-Proliferation Office; compareyourcountry.org; Canadian Nuclear Association; MCA calculations

POWERED BY NUCLEAR

Canada's nuclear fleet can power more than 10 million homes

19

Nuclear reactors
Producing a combined net capacity of 13.5 GW.

14.6%

Nuclear share
Nuclear-powered share of Canada's energy mix.

30-35 yrs

Extension program
Average extra lifetime of old reactors after refurbishment.

Source: Canadian Nuclear Association

NUCLEAR INDUSTRIES

Nuclear technologies underpin other research and innovation

Nuclear research

Advanced manufacturing

Materials science

Nuclear medicine

Food safety

URANIUM MINING

Canada exported twice as much uranium as Australia in 2017

13,116 t

Uranium production*
Almost twice as much uranium as Australia.

85%

Uranium exports
Share of Canada's uranium exported in 2017.

A$1.3b

Value of exports
Value of Canada's uranium exports in 2017.

Source: World Nuclear Association

* Prior to temporary curtailment of McArthur River mine

NUCLEAR RESEARCH

Driving innovation

Canada is a pioneer of atomic energy. It developed its own nuclear reactor – the CANDU – more than 60 years ago.

The CANDU is a heavy water reactor that uses 15 per cent less fuel than a regular pressurised water reactor. It is also exceptionally safe, with multiple safety systems independent from the plant.

Canada has since exported its technology to the world, with 34 CANDU reactors operating in countries such as China, Pakistan, India, Romania and South Korea.

Canadian Nuclear Association

CANDU REACTOR

Canada's CANDU reactor can be powered with the recycled uranium from four light water reactors.

Canadian Nuclear Association

The way forward

Australia digs and ships uranium but its self-imposed nuclear ban prohibits the development of a high value, high tech nuclear industry.

The Canadian example shows what can be achieved if the decision is taken to treat uranium like any other resource.

However current federal and state policies limit Australia's ability to meet expected global energy demand or bolster energy security at home.

Federally the ***Environment Protection and Biodiversity Conservation Act 1999*** bans nuclear power under section 140A. It also includes uranium mining and milling as 'nuclear actions' under section 210. These clauses prohibit the development of a nuclear industry and shortchange Australia.

In Victoria the exploration and mining of uranium is prohibited; in New South Wales exploration is allowed but absurdly mining is prohibited. The Victorian ban was introduced in 1983 before climate change issues were a consideration; the NSW ban on uranium mining began in 1986.

This legislation is out of date.

The WA Government also took a backward step in 2017 when it banned the development of all but four uranium mines.

Beyond removing the legislative bans, Australia should work with other countries to harmonise the rules which apply to nuclear technologies. There is a great opportunity for Australia to ensure high standards for small modular reactors by taking the initiative and working with countries such as the US, Canada and the UK.

The way forward

Minerals Council of Australia
minerals.org.au

EPBC ACT

For the development of nuclear energy in Australia, Section 140A(1)(b) must be removed from the *Environment Protection and Biodiversity Conservation Act 1999*.

Environment Protection and Biodiversity Conservation Act 1999

Section 140A **No approval for certain nuclear installations**

The Minister must not approve an action consisting of or involving the construction or operation of any of the following nuclear installations:

a) a nuclear fuel fabrication plant;

b) a nuclear power plant;

c) an enrichment plant;

d) a reprocessing facility.

SA Nuclear Fuel Cycle Royal Commission 2016

RECOMMENDATION 8

... pursue removal at the federal level of existing prohibitions on nuclear power generation to allow it to contribute to a low-carbon electricity system, if required.

LEGISLATIVE INQUIRIES

The outcome of state-based uranium mining inquiries is critical

Victoria
The Victorian Legislative Council is considering the repeal of the state's 1983 ban on uranium exploration and mining. The 12-month inquiry will consider the feasibility of nuclear energy in Victoria.

New South Wales
NSW Legislative Council is considering legislation which would overturn the ban on uranium mining. NSW overturned its ban on uranium exploration in 2006 but still persists with a ban on mining.

THE HISTORY

Australia's nuclear timeline

50 years of missed opportunity

1969

Proposal to build Australia's first nuclear reactor at Jervis Bay. Tenders were called and land cleared but low cost coal and fiscal constraints saw the plan scrapped.

1980s-90s

Anti-nuclear movement gained traction against the backdrop of French nuclear testing in the Pacific, the Rainbow Warrior incident and leaked plans to commercially site international nuclear waste in Australia.

1998

ARPANS Act 1998 passed into law. The Australian Radiation Laboratory and Nuclear Safety Bureau merged and were renamed Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Political horsetrading resulted in the phrase 'prohibition on certain nuclear installations' included in the Act.

1999

A similar clause, but with greater effect, was written into the EPBC Act. Section 140A prohibits the minister approving the construction or operation of 'certain' nuclear installations, including a nuclear power plant.

2006

The Howard Government's review of nuclear power found the most compelling reason to adopt nuclear power was to reduce CO_2 emissions. The review also supported an expansion of uranium mining and an increase in uranium exports.

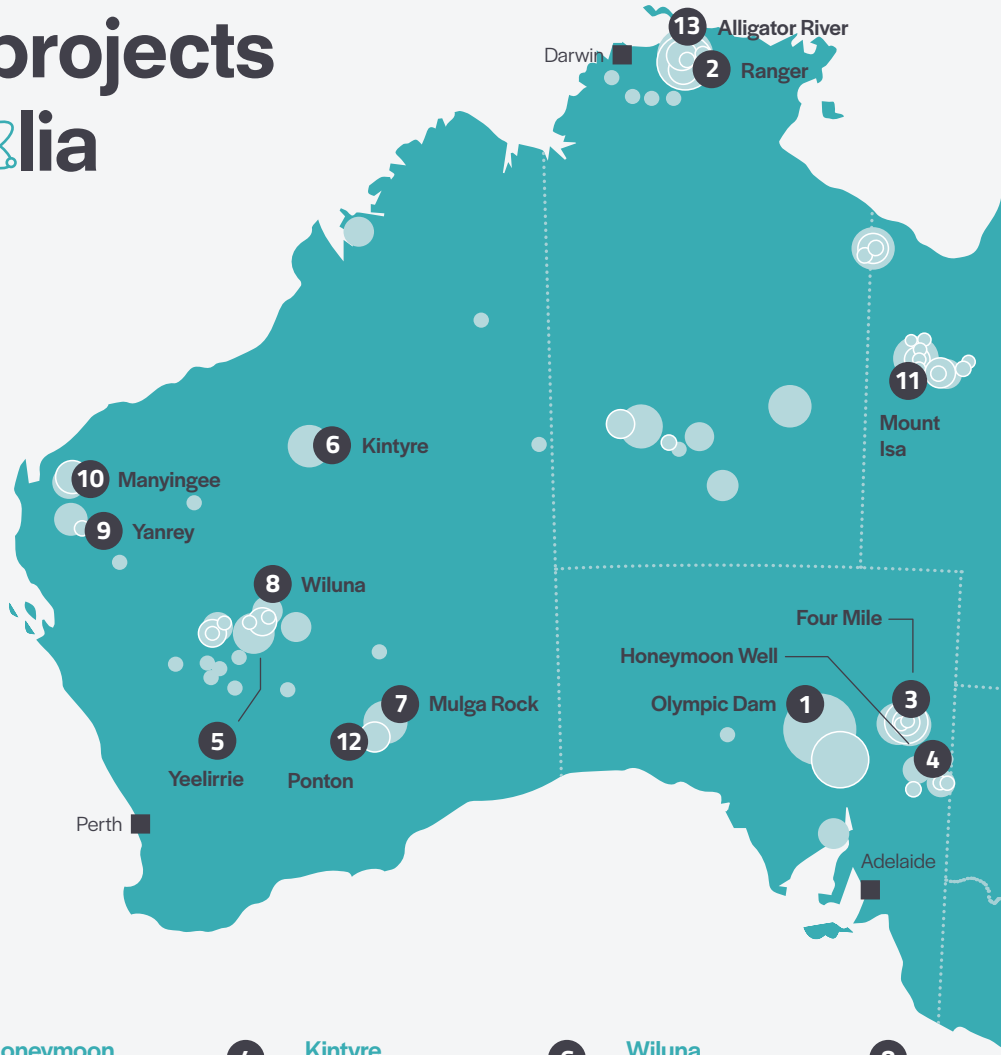
2019

Legislative inquiries are underway in two states to consider repealing bans on uranium mining (NSW and Victoria). A federal parliamentary inquiry is also considering nuclear energy as a potential low emissions energy solution.

Uranium projects in Australia

♣ Production (tonnes U)

♠ Total resource (tonnes)



Olympic Dam 1
SA

BHP

♣ 3159 t 2018

The world's largest uranium deposit with a resource of over 1 million tonnes.

Production

Ranger 2
NT

Energy Resources of Australia

♣ 1695 t 2018

A long time provider of fuel for the global nuclear power industry. Due to close 2021.

Production

Four Mile 3
SA

Heathgate Resources

♣ 1200 t (capacity)

Australia's newest uranium mine is supplying world nuclear markets.

Production

Honeymoon 4
SA

Boss Resources

♠ 28,000 t

Honeymoon can be fast tracked into production in a short 12-month time span.

Project

Kintyre 6
WA

Cameco

♠ 27,000 t

First deposit discovered in 1985. Project to be developed in line with market conditions.

Project

Wiluna 8
WA

Toro Energy

♠ 38,000 t

Has secured state and federal government environmental approvals to mine uranium.

Project

Note: Select projects and approximate locations shown. Resources have been rounded. Refer to company websites for more detailed information.

Yeelirrie 5
WA

Cameco

♠ 58,000 t

A world-class asset and one of Australia's largest undeveloped uranium deposits.

Project

Mulga Rock 7
WA

Vimy Resources

♠ 40,000 t

A long-life project with capacity to supply uranium to power 8 reactors per year.

Project

Yanrey 9
WA

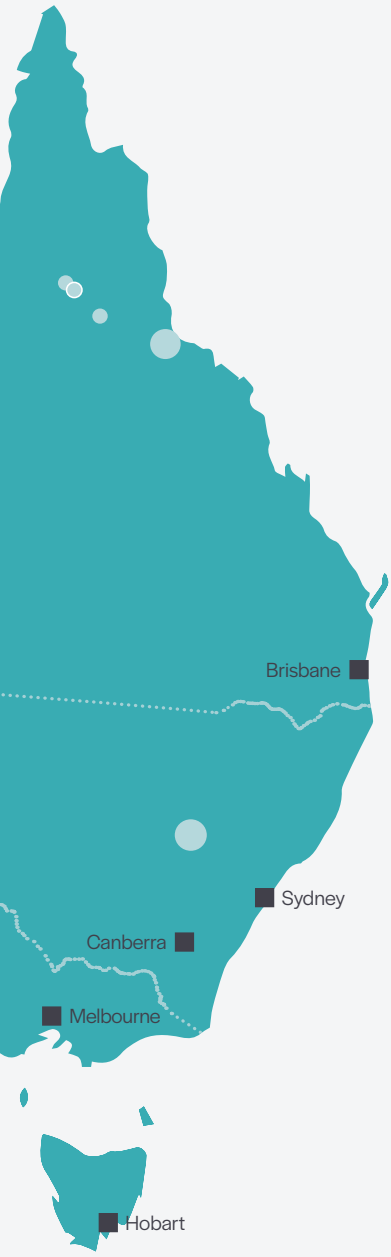
Cauldron Energy

♠ 9500 t

Prospective for large sedimentary uranium deposits amenable to in situ recovery.

Project

There's more to Australian Mining



IDENTIFIED (2017)

Uranium resources

- 1500 – 3000 (t)
- 3000 – 10,000 (t)
- 10,000 – 50,000 (t)
- 50,000 – 1,000,000 (t)
- >1,000,000 (t)

Source: Geoscience Australia

Mount Isa 11
QLD

Paladin

♠ 67,000 t

Largest uranium deposit in Queensland. Pre-development exploration underway.

Project

Ponton 12
WA

Manhattan Corporation

♠ 7800 t

Initial exploration has identified a promising inferred resource.

Project

Manyingee 10
WA

Paladin

♠ 18,000 t

Can be developed into an in situ recovery mining operation over a 4 to 5 year period.

Project

Alligator River 13
NT

Vimy Resources

♠ 11,700 t

The Alligator River province is one of the top three uranium regions in the world.

Project

- Clean energy
- Medicine
- Naval vessels
- Radiotherapy
- MRI scans
- Aerospace
- Diagnosis
- Research
- Industry

AROUND THE WORLD

Largest producing uranium mines (2018)

1 Cigar Lake
CANADA

Cameco/Orano

♣ 6924 t

13% of world production

2 Olympic Dam
AUSTRALIA

BHP

♣ 3159 t

6% of world production

3 Husab
NAMIBIA

Swakop Uranium (CGN)

♣ 3028 t

6% of world production

4 Inkai, 1-3
KAZAKHSTAN

Kazatomprom/Cameco

♣ 2643 t

5% of world production

5 Rössing
NAMIBIA

China National Uranium Corp.

♣ 2102 t

4% of world production

Source: World Nuclear Association

Did you know?

DID YOU KNOW?

2 billion years ago...

nature produced its own nuclear fission reactors in Gabon, West Africa. These 'reactors' produced heat in naturally occurring uranium and were active for around one million years. The radioactive by-product of fission has been safely contained ever since – proving long term geological storage works.

DID YOU KNOW?

Archeologists rely on...

radioactive isotopes to date rocks and bones by measuring the decay rate. Chemist Willard Libby won the 1960 Nobel Prize in Chemistry for discovering this method using carbon-14 in the 1940s. As well as radiocarbon dating, potassium-argon dating and uranium-lead dating are techniques used by archeologists, paleontologists and forensic scientists.

DID YOU KNOW?

Grandma's dinnerware...

could be hiding a radioactive secret. Uranium and thorium were commonly used to glaze and decorate ceramic dishes and pottery until the 1960s. The Homer Laughlin China Company discontinued its Fiestaware range in 1972 after using depleted uranium oxide and natural uranium for its red and white dishes.

DID YOU KNOW?

We are all radioactive...

because radiation exists all around us – in the air we breathe, the water we drink and the food we eat. This all leads to our bodies being slightly radioactive. The average Australian absorbs cosmic radiation equivalent to around 75 chest x-rays (1.5 mSv) every year.

DID YOU KNOW?

It took a woman...

to explain and name the process of nuclear fission. Lise Meitner was a physicist whose 1939 letter to science journal *Nature* described how atoms as large as uranium could be split in two. Female, Jewish and exiled in Sweden, Meitner was excluded from the 1944 Nobel Prize in Chemistry, which was awarded to her former male colleague, Otto Hahn, in Germany. This was only rectified in 1966 when US President Lyndon B. Johnson awarded her and members of her previous team the prestigious Enrico Fermi Award.

DID YOU KNOW?

Electric cars will...

drive demand for electricity in the future and for many countries that demand will need to be met by nuclear energy. That's because renewables generate insufficient energy during demand periods. According to AREVA, if 10 per cent of cars in France were electric powering them would require 10 per cent more electricity from nuclear sources.

DID YOU KNOW?

Brazil nuts would win ...

the award for Most Radioactive Food if there was such a thing. Containing high levels of radium and potassium, Brazil nuts emit over 6600 picocuries of radiation per kilogram. But that's no reason to skip the nut aisle. High levels of potassium and other nutrients, such as selenium, make the Brazil nut a nutritious snack. Other foods with a high radioactive content include lima beans, bananas, carrots and potatoes.

DID YOU KNOW?

Uranus inspired...

German chemist Martin Klaproth to name his newly discovered element after the planet in 1789. Klaproth was studing samples of minerals taken from all over the world when he identified uranium oxide in ore taken from a silver mine in Jachymov, Czech Republic.

There's more to

Australian Mining

Endnotes

Part One

Australia's rich endowment

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15 International Energy Agency, *Nuclear power in a clean energy system*, May 2019, p. 7
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17 Third Way, *Introducing the advanced nuclear industry*, June 2015, p. 4
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19 MCA calculation

High density, small footprint

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21 Australian Safeguards and Non-Proliferation Office, *Annual report 2017-18*, p. 25
22 ibid. p. 25
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29 Australian Nuclear Science and Technology Organisation, *ANSTO health services FAQs , ansto.gov.au* viewed 5 September 2019
30 Australian Nuclear Science and Technology Organisation, *ANSTO nuclear medicine project*, ansto.gov.au viewed 5 September 2019

So what are we afraid of?

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...on the record

Michael Liebreich

FOUNDER, BLOOMBERG NEW ENERGY FINANCE

“ My take on the nuclear debate: **wind and solar alone can’t provide enough zero carbon power to decarbonise the economy in the near term**; the overwhelming priority is to keep existing nuclear plants open; when it comes to new plants, the current generation of plant designs won’t cut it on economic grounds; and **for goodness sake, let’s get serious about developing SMRs and researching the generation of nuclear technologies that might even follow them.** ”

‘We need to talk about nuclear power’, BloombergNEF (bnef.com), 3.7.2019

Professor Geraldine Thomas

LONDON IMPERIAL COLLEGE
UNSCEAR COMMITTEE MEMBER ON THE HEALTH EFFECTS OF CHERNOBYL

“ If you want our planet’s future to be decided by scientific fact instead of urban myth, including using zero emissions nuclear energy, **it’s important to look at nuclear risks in a clear-eyed and objective way.**

In the interests of reducing risk for current and future generations, **it’s time to ditch the fear campaigns and get behind nuclear power.** ”

‘Let’s separate the urban myths from Chernobyl’s scientific facts’, *Sydney Morning Herald*, 10.7.2019

Dr Ben Heard

FOUNDER, BRIGHT NEW WORLD
ENVIRONMENTALIST

“ Climate change is real, serious and must be addressed with a controlled sense of urgency. **Yet here in Australia we have kept our doors closed to the possibility of nuclear with 20 years of prohibition.**

These newer reactors bring the vital benefit of high-temperature outputs to decarbonise industry, and excellent ramping capability to work with variable renewables. ”

‘The case for developing nuclear in Australia’, ***Energy*** (energymagazine.com.au), 22.8.2019

Dr James Hansen

FMR. HEAD OF NASA’S GODDARD INSTITUTE FOR SPACE STUDIES

“ While it may be theoretically possible to stabilise the climate without nuclear power, **in the real world there is no credible path to climate stabilisation that does not include a substantial role for nuclear power.** ”

Hansen, Caldeira, Emanuel, Wigley, ‘Top climate change scientists’ letter to policy influencers’, cnn.com, 3.11.2013

Carol Browner

FMR. DIRECTOR, OFFICE OF ENERGY AND CLIMATE CHANGE POLICY OBAMA ADMINISTRATION

FMR. ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY CLINTON ADMINISTRATION

“ I used to be anti-nuclear. But, several years ago I had to re-evaluate my thinking because **if you agree with the world’s leading climate scientists that global warming is real and must be addressed immediately then you cannot simply oppose clean, low-carbon energy sources.** ”

‘If you’re concerned about climate change, you should support nuclear power’, *Forbes*, 5.5.2014

James Lovelock

SCIENTIST, ORIGINATOR OF GAIA THEORY

“ **The Swiss did a study of the number of deaths per year in all the various power systems, and nuclear beats everything.**

[Speaking about Fukushima]
There is virtually no wildlife damage anywhere near Fukushima. Levels [of radiation] are much too low. Nobody was killed, nobody was even hurt, so what was all the fuss about? It’s all propaganda. People badmouth nuclear so nobody dares use it. ”

‘Lovelock: ‘Instead of robots taking over the world, what if we join with them?’, *The Guardian*, 31.3.2014

Michael Shellenberger

FOUNDER, ENVIRONMENTAL PROGRESS
THE BREAKTHROUGH INSTITUTE

“ **Only nuclear energy can lift all humans out of poverty while preventing dangerous levels of global warming...**

Sweden in 2017 generated a whopping 95 per cent of its total electricity from zero carbon sources [nuclear and hydro]... France generated 88 per cent of its total electricity from zero carbon sources. Now look at Germany. By 2025 Germany will have spent $580 billion on renewables and related equipment, while shutting down its nuclear plants. All that Germany will have gotten for its ‘energy transition’ is a 50 per cent increase in electricity prices, flat emissions, and an electricity supply that is 10 times more carbon-intensive than France’s. ”

‘Shellenberger: “Nuclear is the safest way to make electricity”’, Foro Nuclear (foronuclear.org), 25.2.2019

Noel Pearson

FOUNDER, CAPE YORK INSTITUTE FOR POLICY AND LEADERSHIP

“ If nuclear power is used in Europe, Asia and the Americas, and contributes to lower carbon emissions, **why is the debate on nuclear power not on the basis of science and the mitigation of risks associated with nuclear energy, instead of a green version of obscurantism?**

Proponents of safer nuclear waste disposal in Australia [which included the late Bob Hawke] have got a point that is worth subjecting to science rather than outright prohibition. ”

‘The environment is too important to be left to eco-warriors’, *The Australian*, 15.6.2019

Daniel Walton

NATIONAL SECRETARY
AUSTRALIAN WORKERS' UNION

“ In terms of global competitiveness Australia’s energy infrastructure has fallen off a cliff – from 29th in the world in 2009 to 55th today.

Continuing to adopt a position of ideological extremism on nuclear technology is an economic own goal we can’t afford to keep kicking.

If industry sees value in the Australian market it should be free to invest without being blocked by outdated fears. **Our energy debate should be about pragmatics, not 20th century ideology.** ”

‘AWU splits with Labor over nuclear power restrictions’, *The Australian*, 19.9.2019

Bill Gates

TECHNOLOGIST AND PHILANTHROPIST

“ **Nuclear is ideal for dealing with climate change, because it is the only carbon-free, scalable energy source that’s available 24 hours a day.**

The world needs to be working on lots of solutions to stop climate change. Advanced nuclear is one. ”

‘What I learned at work this year’, Gatesnotes: The blog of Bill Gates, (gatesnotes.com), 29.12.2018

Professor Corey Bradshaw

FELLOW IN GLOBAL ECOLOGY
FLINDERS UNIVERSITY

“ **Many so-called green organisations and individuals, including scientists, have avoided or actively lobbied against proven zero emissions technologies like nuclear because of the associated negative stigma.**

Our main goal was to show – through careful, objective scientific analysis – that on the basis of cost, safety, emissions reduction, land use and pollution, nuclear power must be considered in the future energy mix. ”

‘Nuclear power is the greenest option, say top scientists’, *The Independent*, 4.1.2015

Jessica Lovering

FELLOW, ENERGY FOR GROWTH HUB
RESEARCHER, CARNEGIE MELLON UNIVERSITY

“ **Advanced nuclear designs have the capability to be meltdown-proof, using a combination of coolants, fuels, and basic physics.** Reactors that are intrinsically safe can also be radically cheaper, especially by making much smaller, modular reactors in factory settings.

Australia is well-placed to be a major player in this nuclear future, if it takes the time now to pivot on legacy policies and invest in innovation. ”

‘Australian can play a big role in safer, cheap nuclear development’, *The Australian*, 29.5.2017

So what are we afraid of?

Nuclear energy is the world's safest source of electricity per kilowatt generated.

Energy can be a dangerous business – oil spills, gas explosions, dam breaks and manufacturing accidents. But only nuclear energy has been subject to a relentless scare campaign for 40 years.

With over 17,000 cumulative years of operation, nuclear energy is safe, reliable and affordable and yet Australian homes and businesses continue to be denied this amazing zero emissions 24/7 energy source.

Nuclear accidents are rare (three accidents in six decades) and while expensive to clean up have had a much lower public health impact than people feared decades ago.

While 30 deaths were recorded in the immediate aftermath of Chernobyl, the United Nations Scientific Committee on the Effects of Atomic Radiation concluded that apart from an increase in thyroid cancers, which have a very low mortality rate, 'there is no evidence of a major public health impact attributable to radiation exposure two decades after the accident.'[31]

In Fukushima 16,000 people died from the largest recorded earthquake to hit Japan and the following tsunami but there were no deaths from radiation exposure.[32]

New nuclear technologies such as small modular reactors which are close to commercialisation are even safer, cheaper and capable of meeting energy needs in the developing world and advanced industrial economies.

That's why organisations like the Australian Workers' Union have called on governments to remove bans on nuclear mining and for an assessment of SMRs as an energy source capable of meeting the needs of Australian industry.

If Australia is serious about addressing climate change while supporting jobs and industry, then nuclear energy should be considered in the energy mix.

So what are we afraid of?

Minerals Council of Australia
minerals.org.au

BEYOND THE FEAR

Three accidents in 6 decades (≃17,000 cumulative reactor years)

Three Mile Island
United States 1979

0.08mSv AVG. EXPOSURE
(EQUIV TO A CHEST XRAY)
0 INJURIES OR DEATHS

Numerous studies have concluded the small release of radiation had negligible effects on human health.

Chernobyl
Ukraine 1986

Approx. 200 DEATHS IN 30 YRS inc.
30 FIREFIGHTER DEATHS
19 RADIATION-RELATED DEATHS

No observed increase in solid cancers among clean up workers 33 years after the accident at Chernobyl.

Fukushima
Japan 2011

16,000 TSUNAMI DEATHS
2000 EVACUATION DEATHS
0 RADIATION-RELATED DEATHS

Cancer cases among workers and residents are expected to be smaller than lifetime baseline cancer risks.

SAFER BY THE TWh

Even including Chernobyl and Fukushima, nuclear power is as safe as renewable energy. This is in part because of the high energy density of uranium.

Source: World Nuclear Association; Prof. Geraldine Thomas; World Health Organisation; Nuclear Energy Agency, Organisation for Economic Co-operation and Development

ASK THE EXPERTS

Nuclear advocates often have first hand experience

> **I was anti-nuclear until I worked on the after effects of the Chernobyl accident.** Now I am very pro-nuclear as I realise that we have an unwarranted fear of radiation – probably due to all the rubbish about a nuclear winter we were fed during the cold war.

Professor Geraldine Thomas
UNSCEAR Committee Member on the Health Effects of Chernobyl

> Although the radiation dose to the public from Fukushima was relatively low, and **no discernible physical health effects are expected**, psychological and social problems, largely stemming from the differences in risk perceptions, have had a devastating impact on people's lives.

Dr Koichi Tanigawa
Fukushima Medical University

NUCLEAR WEAPONS

Nuclear energy & non-proliferation

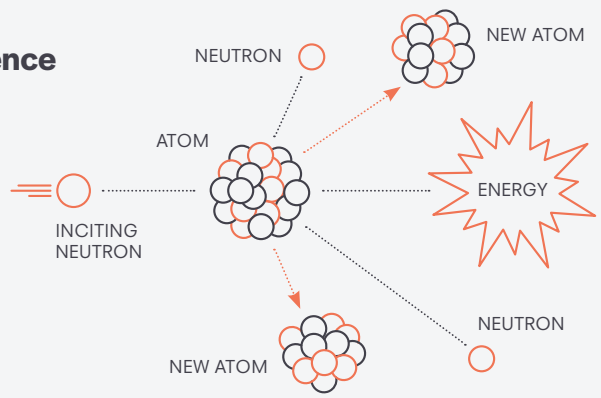
A 2017 Dartmouth study analysed the relationship between nuclear energy programs and proliferation between 1954 and 2000. It found proliferation is not more likely among countries with nuclear energy programs.

Nuclear energy programs do not increase likelihood of proliferation, Dartmouth 2017 (sciencedaily.com)

WHAT IS NUCLEAR FISSION?

A simple matter of science

Nuclear fission occurs when an atom is split in two, generating energy. Nuclear reactors harness this energy by creating a chain reaction of splitting atoms in the nuclear reactor core.



POST-COLD WAR

Nuclear reactors allow for the safe disposal of old nuclear warheads. Until 2013, 10% of US electricity came from Russian nuclear warheads. The Megatons to Megawatts Program, which ran from 1993 to 2013, eliminated 500 tonnes of highly enriched uranium after the break up of the Soviet Union.

Lifesaving medicine

One in two Australians will benefit from life-saving nuclear medicine during their lifetime.[27]

About one-third of all hospital procedures every year in Australia involve radiation or radioactivity. Nuclear medicine is central to the diagnosis, treatment and prevention of many diseases.

On average, one in two Australians will need a nuclear medicine scan during their lifetime. Scans are used to diagnose heart, thyroid, lung and kidney conditions along with tumours, fractures and sporting injuries.[28]

The Australian Nuclear Science and Technology Organisation (ANSTO) operates a medical research reactor at Lucas Heights in Sydney. ANSTO produces more than 10,000 nuclear medicine doses per week which are used by 250 medical facilities across Australia and New Zealand.[29]

Molybdenum 99 (Mo-99) is used in 80 per cent of nuclear medicines, particularly in the diagnosis of cancers, heart disease, muscular and skeletal conditions.

The recent completion of the Mo-99 Manufacturing Facility at Lucas Heights will further boost Australia's reputation as a major player in international health care.

Australia will soon have the capacity to supply 25 per cent of global demand for nuclear medicines in addition to meeting domestic needs.[30]

ANSTO's world-class Open Pool Australian Lightwater (OPAL) reactor uses low enriched uranium. Ironically the nuclear medicine saving lives in hospitals across the country is coming from uranium mining which is banned in the three most populous states and Tasmania.

Lifesaving medicine

Minerals Council of Australia
minerals.org.au

NUCLEAR DIAGNOSIS AND TREATMENT

X-rays and CT scans are widely used in Australian hospitals

Diagnosis
Heart, thyroid, lung and kidney conditions as well as infection, tumours, fractures and sports injuries.

Treatment
Hyperthyroidism, breast, prostate and lung cancers, lymphomas and associated bone pain.

Sterilisation
Medical equipment and single-use devices, i.e. knee implants, syringes, cotton tips and surgical gloves.

560k
Nuclear medicine
Procedures conducted across Australia every year.
World Nuclear Association

470k
Uranium-dependent
Of these procedures use nuclear isotopes generated from uranium.
World Nuclear Association

LIFESAVING NUCLEAR MEDICINE

1 in 2 Australians will benefit from nuclear medicine in their life

OPAL REACTOR
ANSTO's **OPAL reactor in Lucas Heights** is the centrepiece of Australia's nuclear medicine and research program.

Mo-99
The medical isotope produced by ANSTO. The decay product of Mo-99 is technetium-99m (Tc-99m), which is used in diagnostics.

45m
Around the world
Nuclear medicine procedures performed globally every year.
World Nuclear Association

10,000
Patient doses of ANSTO nuclear medicine delivered every week across Australia and New Zealand.
ANSTO

1 in 2
Australians will benefit from nuclear medicines produced by ANSTO at some point throughout their lives.
ANSTO

250
Research reactors in 55 countries around the world develop radioisotopes for medicine and industry.
World Nuclear Association

5%
Global demand ▲
Annual increase in demand worldwide for radioisotopes.
World Nuclear Association

OTHER INDUSTRIES

Nuclear applications are used widely across industry to benefit all Australians

Agriculture · Industry · River health · Airports · Detectors · Microwaves · Aerospace

Managing nuclear waste

The management of nuclear waste is tightly regulated nationally and globally.

Nuclear energy creates radioactive waste. This waste is classified as high, intermediate or low level and comprises everything from lightly irradiated tools and medical waste through to highly radioactive spent nuclear fuel.

Globally 90 per cent of all nuclear waste is classified low level which means it has a radioactive content of less than 1 per cent. A further 7 per cent of nuclear waste is classified intermediate. Only 3 per cent is classified high level. This waste is primarily spent reactor fuel.[24]

Spent reactor fuel is initially stored in cooling ponds before being placed in dry-ventilated concrete casks.

It can then be disposed in deep geological repositories or the spent fuel can be re-processed as happens in France.

According to the Nuclear Energy Institute all of the used fuel produced by the commercial nuclear industry since the late 1950s would cover a soccer field to a depth of less than 10 metres.

Emerging technologies such as Generation IV fast reactors can further reduce waste by using it as a fuel source.[25]

Radioactivity dissipates over time. After 40-50 years the radioactivity of spent nuclear fuel falls to 1/1000th of the level at its removal from the reactor. After 1000 years it has the same radioactivity as naturally occurring uranium ore.[26]

Nuclear power is the only large-scale energy-producing technology to take full responsibility for its waste.

Managing nuclear waste

Minerals Council of Australia
minerals.org.au

RADIOACTIVE WASTE

Nuclear waste production by type, volume and radioactivity

Low level waste

90% BY VOLUME

1% BY RADIOACTIVE CONTENT

Low level waste includes lightly irradiated items such as mops and work clothes from power plants and other nuclear facilities as well as medical waste and diodes found in electronics.

Intermediate level waste

7% BY VOLUME

4% BY RADIOACTIVE CONTENT

Intermediate level waste includes used filters and steel components from the reprocessing of reactor fuel or plant refurbishments as well as some materials used during radiation therapy.

High level waste

3% BY VOLUME

95% BY RADIOACTIVE CONTENT

High level waste is primarily spent reactor fuel. Fuel is removed when the uranium concentration becomes too low to sustain fission at the required level. Used fuel may be recycled and reused.

Source: World Nuclear Association

BY COMPARISON

Hazardous waste

400 Mt

Hazardous waste produced globally every year.

0.003%

Radioactive waste
High level radioactive waste comprises just 0.003 % of global hazardous waste.

Nuclear Energy Agency & OECD, *Radioactive waste in perspective*, 2010

HOW RADIOACTIVE WASTE IS STORED

Medium and long-term storage of radioactive waste from nuclear reactors

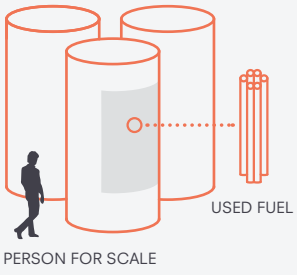
Cooling ponds

A nuclear plant replaces a third of its fuel every 18-24 months. Used fuel is stored in cooling ponds for 7-10 years during which it loses 99% of radioactivity before it is transferred to onsite storage and later, deep geological repositories.

Dry cask storage

Spent fuel bundles are encased in concrete and metal casks strong enough to withstand floods, cyclones and major impacts. Not even a train travelling at 130 kmh managed to demolish a dry cask in US safety tests.

Canadian Nuclear Association



Deep geological repository

Deep geological repositories allow long-term isolation and containment of nuclear waste. Used fuel is stored in secure containers in geologically-stable repositories around 500 metres underground.

Canadian Nuclear Association

WASTE MANAGEMENT IN PRACTICE

Reactor fuel is reprocessed and reused in France

France

France is a world leader in **nuclear fuel reprocessing.** Its Le Hague nuclear fuel reprocessing plant provides almost half the world's fuel reprocessing capacity.

World Nuclear Association

Finland

Finland is building the world's first **deep geological repository** three hours northwest of Helsinki. Onkalo repository will begin operations in the mid 2020s.

World Nuclear Association

Transport

More than 7000 shipments of used fuel have been transported by the nuclear industry worldwide since 1970 with zero incidents of leaks or personal injury.

Nuclear Energy Institute

RATE OF DECAY

The half life of nuclear waste is the time it takes for 50 per cent of the material to naturally decay. High level waste loses 99% of its radioactivity relatively quickly which enables safe, long term storage.

High density, small footprint

A golf ball-sized amount of nuclear material can provide a lifetime's amount of energy for one person.

A small amount of uranium contains a huge amount of energy.

One kilogram of uranium produces the same amount of energy as 11 tonnes of coal or 8500 cubic metres of natural gas. And it does so while emitting close to zero greenhouse gas emissions.[20]

In 2017-18 Australia exported 6227 tonnes of uranium – just under 10 per cent of world demand – valued at $575 million.[21]

Australia's uranium exports generated 246 TWh of zero emission electricity – equivalent to 96 per cent of Australia's total electricity production.[22]

With the equivalent energy of 3451 PJ, uranium represents about 18 per cent of Australia's total energy exports.[23] That means almost a fifth of Australia's energy exports are zero emissions.

By maintaining a prohibition on nuclear energy, Australia is supporting the emissions reduction targets of its customers but failing to benefit from its own natural endowment at home.

High density, small footprint

Minerals Council of Australia
minerals.org.au

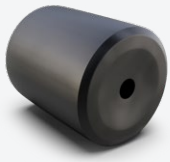
ENERGY CONTENT

Fuel type comparison

URANIUM FUEL

Uranium pellets are inserted into fuel rods which are used in a nuclear reactor to create the steam to drive the turbines that generate electricity.

A single uranium fuel pellet has the same amount of energy as:



ACTUAL SIZE

Oil	Coal	Natural gas
564 L	**1000 kg**	**481 m³**

Source: Nuclear Energy Institute

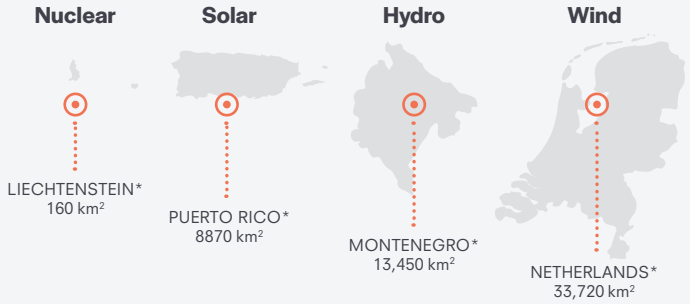
SMALL FOOTPRINT

Nuclear produces more power with a much smaller footprint

Land required to produce Australia's annual electricity generation (260 TWh)

Energy type	km²
Nuclear	150
Solar	8000
Hydro	14,000
Wind	33,000

Canadian Nuclear Association, Nuclear Energy Institute and MCA calculations



*APPROXIMATION

Source: worldometers.info

HIGH DENSITY

A lifetime supply of energy

Golf ball

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

THE NUCLEAR SCENARIO

Affordable, reliable, zero emissions electricity for Australian cities

3 Small modular reactors

1.08 million average Australian households

MCA calculation based on average household electricity consumption of <8000 kWh per year. Each SMR = 360 MW

ZERO EMISSIONS

Australia's uranium exports in financial year 2017-18 could generate 96 per cent of Australia's total electricity needs.

Australian Safeguards and Non-Proliferation Office

The future of nuclear energy

Nuclear power has come a long way since its beginnings in the 1950s. The future of nuclear energy is safer, cheaper and *much* smaller.

New technology is driving change in the nuclear energy space and the promise of safer, cheaper, zero emissions energy is now within reach.

Small modular reactors, for example, have been getting a lot of attention for good reason. SMRs are safer, cheaper, scalable and importantly for Australia, could replace some of the baseload power lost through rolling closures of our oldest power stations.

SMRs are also highly suited to Australia because they can be installed on brownfield sites, scaled up or down, and use existing infrastructure to send power to the grid.

SMRs are being developed by companies globally and are expected to be commercially available by the late 2020s. More than 40 companies in North America alone are developing SMRs supported by US$1.3 billion of private sector capital.[17]

SMRs are expected to deliver electricity for between A$60-$110 per MWh. This would likely make SMRs the cheapest zero emission power source capable of providing 24/7 electricity of any technology, including renewables with storage and coal with carbon capture and sequestration.[18]

The cost of NuScale's first 720 MW SMR is US$3 billion with costs expected to drop to US$2.5 billion as production ramps up. In the Australian context, NuScale's SMR could supply electricity for 700,000 homes. That's enough affordable, reliable and zero emissions electricity to power the whole of Adelaide.[19]

An international taskforce is also focused on the future of nuclear. The Generation IV Nuclear Reactors Forum, of which Australia is a member through ANSTO, is advancing six new types of reactors for deployment between 2020 and 2030. These Gen-IV designs feature advances in fuel efficiency, waste minimisation, production, safety and non-proliferation.

The future of nuclear energy

Minerals Council of Australia
minerals.org.au

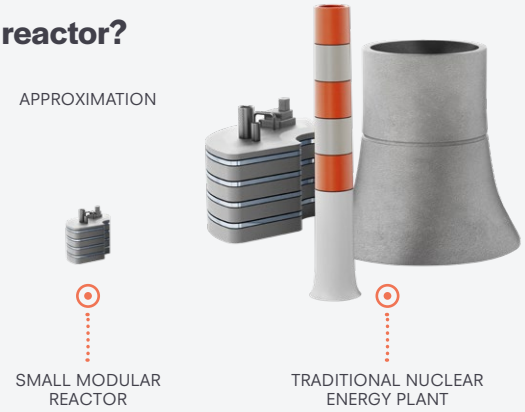
NEW NUCLEAR TECHNOLOGY

What is a small modular reactor?

‘Plug and play’

SMRs are small factory-built nuclear reactors that can be scaled up to meet a region's specific energy demands. Modular and highly mobile, SMRs can be integrated with renewables, and promise faster, cheaper construction and delivery.

Nuclear Energy Institute



Source: Idaho National Laboratory

SMR BENEFITS

How does a small modular reactor work?

Enhanced safety
Self-regulating system, auto fail safe and less maintenance.

Configurability
Customised for specific sites; can scale up by adding units.

Less waste
Produces less spent fuel which can be re-used.

Source: Idaho National Laboratory

SMR DEVELOPMENT

Private capital is driving innovation

40+

Private companies
Developing SMRs across North America.
Third Way (thirdway.org)

US$1.3b

Capital investment
Supporting development of SMRs in North America.
Third Way (thirdway.org)

2020s

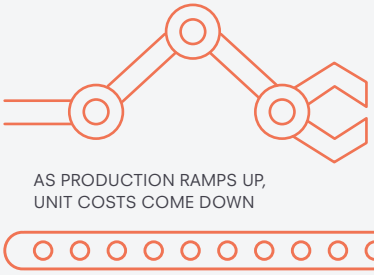
Commercially available
SMR technology to be commercially available.
Energy Innovation Reform Project

ECONOMIES OF SCALE

Mass production and advances in technology will drive down the cost of SMRs

US$3b
Initial build cost
Projected production costs of NuScale’s 720 MW SMR.

Source: NuScale Power



US$2.5b
Ongoing costs
Projected production costs of NuScale’s 720 MW SMR.

A$60/MWh

Cost of electricity
SMR-generated electricity could be as low as A$60.
Economics and Finance Working Group, *SMR Roadmap*, Dec 2018

Safe, reliable technology

Nuclear power has been operating safely for more than 60 years and continues to be one of the most reliable sources of energy generation available.

Electricity has been generated safely by nuclear energy since the first commercial reactor began operation in the UK in 1956.[12]

With more than 17,000 cumulative reactor years over the past six decades, nuclear energy generation has resulted in fewer accidents and many fewer deaths and worker injuries than other energy generation sources.[13]

Fukushima did nothing to change that. Although 16,000 deaths were attributed to the largest earthquake ever to hit Japan and the following tsunami, there were no deaths from radiation exposure in the immediate aftermath.[14]

The UK Friends of the Earth came to the same conclusion in a 2013 report by the Tyndall Centre: 'Overall the safety risks associated with nuclear power appear to be more in line with lifecycle impacts from renewable energy technologies.'

Nuclear is also the most reliable zero emissions energy source available. There are now 452 nuclear power generators operating in 31 countries, with another 55 new nuclear power stations being built in 17 countries.[15]

The US's almost 100 reactors have been operating on average at over 90 per cent of their rated capacity, such is the reliability of nuclear technology.[16]

Nuclear power generation technologies continue to evolve. Older technologies will be replaced by a range of new technologies including Generation IV technologies and small modular reactors.

These will offer more efficient and even safer ways of producing electricity to meet the future needs of energy consumers in developed and developing countries.

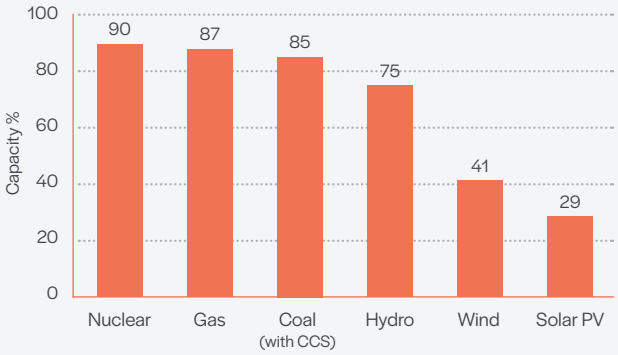
Safe, reliable technology

Minerals Council of Australia
minerals.org.au

RELIABLE ENERGY

Nuclear energy runs at capacity 90% of the time in the US

US capacity factors of various energy sources



Source: Energy Information Authority

IMPACT OF AGE

Although the capacity factor of most energy generation plant reduces with age, nuclear reactor performance shows no significant age-related capacity decline.

World Nuclear Association

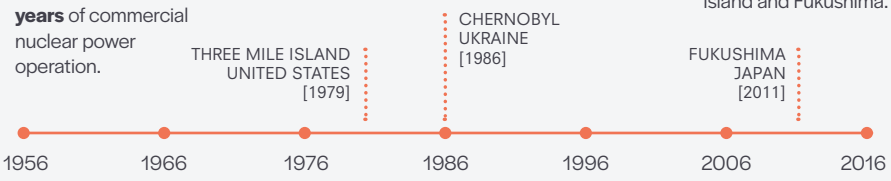
SAFE ENERGY GENERATION

Nuclear power is as safe as renewable energy

17,000
Cumulative reactor years of commercial nuclear power operation.

3 **Major accidents** in six decades.

0 **Radiation-related deaths** at Three Mile Island and Fukushima.



Source: World Nuclear Association

FUTURE PROOFING

Storage is not sufficient to back up peak demand in Australia

1 hour
Backup power requires..
Supplying 35 GW to the NEM during peak periods.

350
battery storage centres
Similar to the $90 million 100 MW Tesla battery in SA.

$32b
...at huge expense
That's enough to install a SMR that runs 24/7 in every state.

Source: MCA analysis

* Based on NuScale cost estimate for 720 MW SMR at US$2.5 billion.

PROVEN TECHNOLOGY

Reliable and affordable energy generation

24/7
Nuclear reactors generate electricity around the clock, every day of the week.
Nuclear Energy Institute

2.5-3x
Nuclear power plants are up to 3 times more reliable than solar energy.
US Department of Energy

18 mths
Refueling takes place every 1.5 to 2 years and involves replacing a third of the fuel.
US Department of Energy

MOST RELIABLE

Nuclear power stations can provide maximum output more than 90 per cent of the time because they are not reliant on the wind blowing, sun shining or the water flowing.

Affordable energy

High energy costs are driving the decline in Australia's international competitiveness.

Nuclear power generates 75 per cent of France's electricity.[5] As a result France pays 15 per cent less for electricity than the EU average and has close to half the power costs of its neighbour Germany.[6]

In the United States one fifth of electricity produced comes from nuclear. US nuclear power stations produce electricity at around US$33.50 per MWh (A$48 per MWh).

US electricity consumers pay less than half that which Australian consumers pay for electricity.[7]

Over the long term nuclear is the cheapest form of energy.[8] Once the initial capital is paid off, electricity can be generated for as low as US$28 per MWh. That's why France and Canada, which built nuclear fleets from the 1970s to the 1990s, have such cheap electricity today.

By further extending the operating life of existing reactors, electricity could be generated for US$40-US$55 per MWh (A$57-A$79 per MWh). This is cheaper than any new build power generation (renewables, gas and coal) in the US and EU.[9]

In contrast, the average wholesale price in Australia's National Electricity Market in the first six months of 2019 was over A$100 per MWh.[10]

New nuclear technologies, such as small modular reactors (SMR), could produce electricity for as low as A$60 per MWh.[11]

Australia exports cheap energy to the world but pays some of the world's highest electricity prices at home. This affects Australia's global competitiveness, hurting industry and costing jobs.

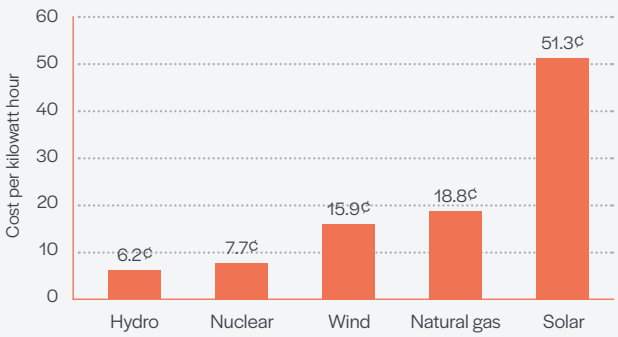
Affordable energy

Minerals Council of Australia
minerals.org.au

LOW COST POWER

Ontario is one of many regions benefiting from nuclear power

Cost of electricity by source in Ontario, Canada (C$, 2018)



Source: Ontario Energy Board, *Regulated Price Plan Supply Cost Report*, 2018

HALF THE COST

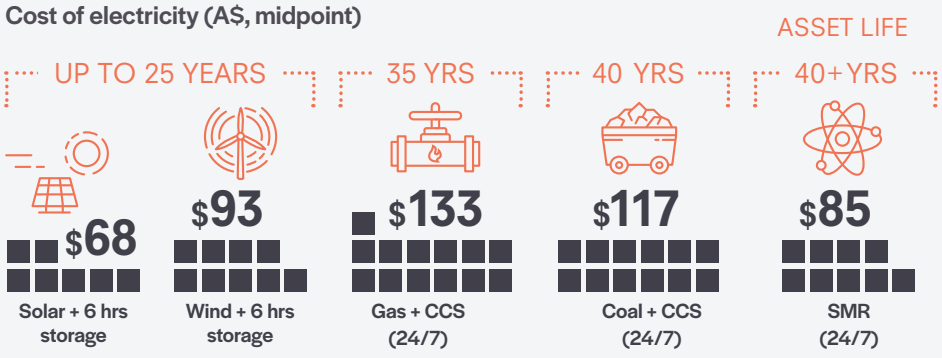
of nuclear energy is upfront construction. But with an asset life of 60 plus years, nuclear generates the cheapest electricity – as low as US$28 MWh – once the initial capital is paid off.

Canadan Nuclear Association; Lazard LCOE Nov 2018

ASSET LIFE AND AFFORDABILITY

SMRs deliver low cost energy with a long operating life

Cost of electricity (A$, midpoint)



Source: CSIRO, *GenCost 2018* (solar & wind); Solstice Development Services, *Prospects for a HELE USC coal-fired power station,* 2017 (gas and coal); Economic and Finance Working Group, *SMR Roadmap*, Dec 2018 (SMR). There is no single Australian study which accurately reflects actual operating lives of different technologies.

COST BENEFITS OF NUCLEAR

Source: Eurostat

Nuclear-powered European countries pay less for electricity

75% NUCLEAR

France
€0.18
per kWh

55% NUCLEAR

Slovakia
€0.14
per kWh

INTERMITTENT ENERGY

Denmark
€0.31
per kWh

Germany
€0.30
per kWh

Spain
€0.25
per kWh

BILL SHOCK

No end in sight to rising energy costs

89.2%

Industry consumption
of Australia's total electricity and gas output.
Australian Energy Regulator

90%▲

Cost to manufacturing
Electricity cost increase to manufacturing since 2009.
Australian Bureau of Statistics

98%▲

Household bills
Electricity bill increases over the past decade.
Australian Bureau of Statistics

POWER BILLS BY STATE

Cost change over 10 yrs

Sydney	106%▲
Adelaide	106%▲
Perth	105%▲
Melbourne	101%▲
Brisbane	85%▲

Australian Bureau of Statistics

Without low carbon baseload like nuclear integrated with other energy sources, prices are likely to be higher.

Zero carbon emissions

For 30 years nuclear energy has been the biggest low carbon source of electricity for developed countries, providing 18 per cent of all electricity.[1]

Nuclear power produces electricity with zero CO_2 emissions 24 hours a day, 7 days a week. Aside from run-of-water hydro power, which is geographically restricted, nuclear is the only energy source capable of producing electricity around the clock.

Nuclear energy has a low life cycle emissions profile which has been widely recognised. South Australia's Nuclear Fuel Cycle Royal Commission in 2015 found that nuclear energy's greenhouse emissions are comparable to solar PV and wind farms.[2]

Unlike weather dependent renewable energy sources, nuclear is a zero emissions energy source capable of meeting the needs of modern industrial economies.

According to the Intergovernmental Panel on Climate Change, at least 80 per cent of the world's electricity must be low carbon by 2050 if global warming is to be kept within 2°C. This will require a diverse mix of low carbon generation.

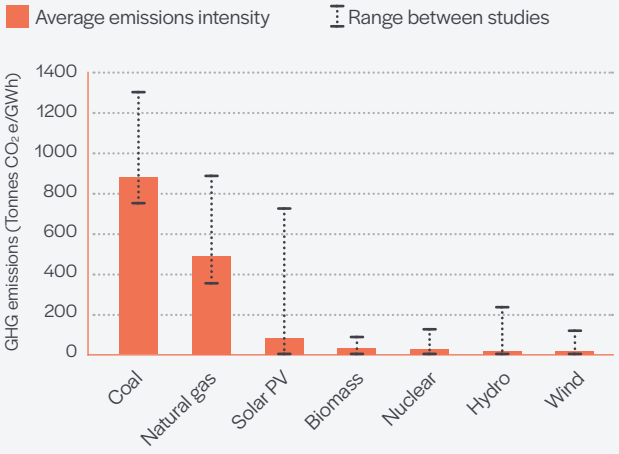
In 2018 nuclear power resulted in about 2.2 billion tonnes of CO_2 not being released into the atmosphere. Australian uranium fuelled about 10 per cent of that result.[3] This global saving is almost four times Australia's total greenhouse gas emissions. Without nuclear, global energy emissions would be 6 per cent higher.[4]

Zero carbon emissions

Minerals Council of Australia
minerals.org.au

LIFE CYCLE FOOTPRINT

Nuclear produces one quarter less CO_2 than solar farms



The World Nuclear Association reviewed the life cycle CO_2 emissions (construction, operation and decommissioning) of fuel sources, averaging the findings of 20-plus studies.

Source: WNA, *Comparison of lifecycle greenhouse gas emissions of various electricity generation sources*, 2011

GLOBAL ENERGY

CO_2 emissions

33 Gt

Global CO_2 emissions

Global emissions reached a record high in 2018.

International Energy Agency

14 Gt

Energy emissions

Global emissions from electricity production in 2017.

International Energy Agency

2.3% ▲

Energy demand

Fastest growth in global energy demand this decade.

International Energy Agency

2.2 Gt

Emissions saved

Global emissions saved through nuclear energy in 2018 .

MCA calculation

THE US STORY

1 in 5 households and businesses in the US are nuclear-powered

98

US nuclear reactors

Operated in 30 states by 30 different power companies.

Nuclear Energy Institute

92.6%

Nuclear capacity

US reactors run more than 92 per cent of the time.

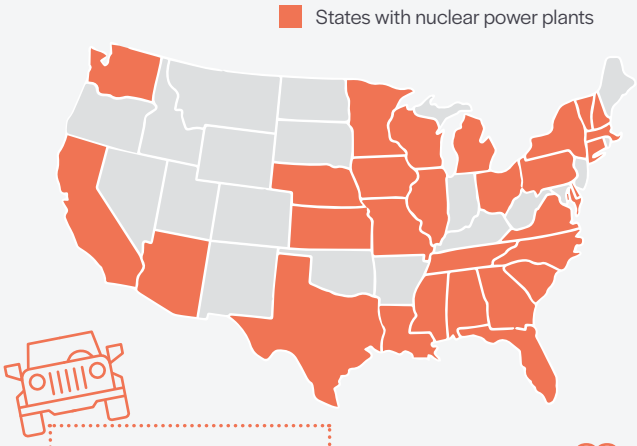
Nuclear Energy Institute

808 TWh

Nuclear electricity

US nuclear electricity generation in 2018.

World Nuclear Association



3 BILLION CARS

Nuclear power in the US reduced CO_2 emissions by more than 16,331 Mt between 1995 and 2018. That's equivalent to taking 3 billion cars off the road.

Nuclear Energy Institute

55%

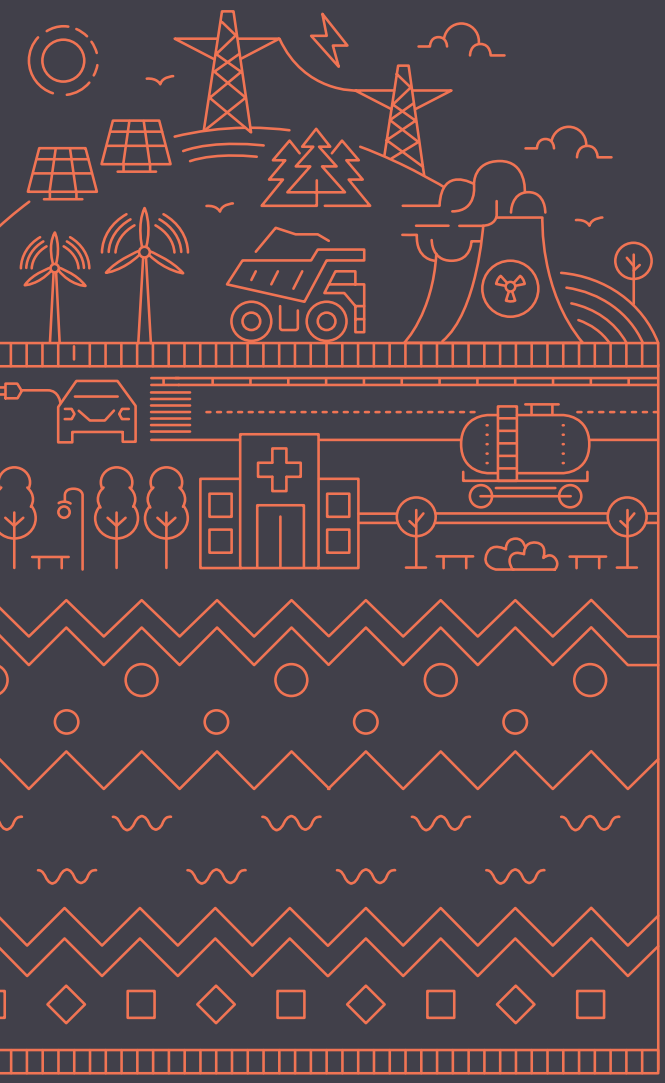
Clean energy

Nuclear's share of US clean energy generation in 2018.

Nuclear Energy Institute

WITHOUT NUCLEAR

Global energy emissions would be 6 per cent higher without the world's nuclear energy fleet. That's more than four times Australia's 2018 CO_2 emissions.



Global snapshot

GLOBAL ENERGY

Electricity generation mix 2018

Coal	38 %
Oil	3 %
Gas	23 %
Nuclear	10 %
Solar PV and wind	7 %
Hydro and other	19 %

Source: International Energy Agency

GLOBAL NUCLEAR

Nuclear power generation

10 %

Nuclear power share

Electricity generated by nuclear power in 2018.

International Energy Agency

2700 TWh

Nuclear energy

Global electricity generated by nuclear power in 2018.

International Energy Agency

GLOBAL ENERGY

Record energy demand in 2018

2.3 % ▲

Energy demand

Fastest growth in global energy demand this decade.

International Energy Agency

33 Gt

Global CO_2 emissions

Energy emissions reached a record high in 2018.

International Energy Agency

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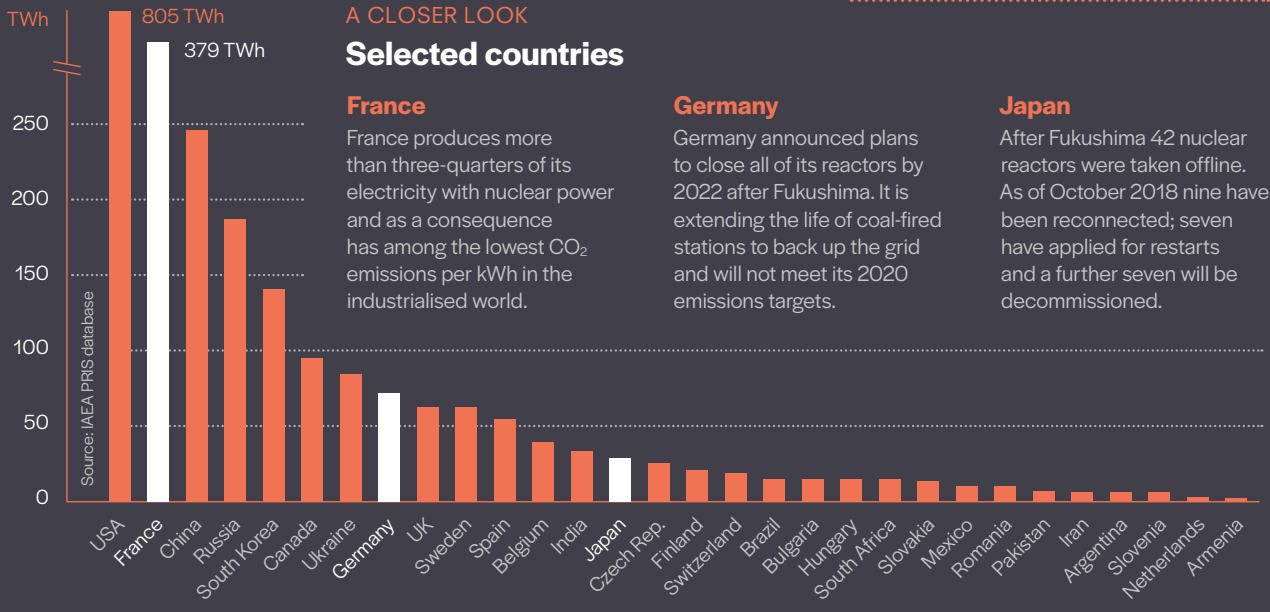
NUCLEAR POWER

Nuclear generation by country

Nuclear-powered France pays 15 per cent less for electricity than the EU average.



A CLOSER LOOK

Selected countries

France

France produces more than three-quarters of its electricity with nuclear power and as a consequence has among the lowest CO_2 emissions per kWh in the industrialised world.

Germany

Germany announced plans to close all of its reactors by 2022 after Fukushima. It is extending the life of coal-fired stations to back up the grid and will not meet its 2020 emissions targets.

Japan

After Fukushima 42 nuclear reactors were taken offline. As of October 2018 nine have been reconnected; seven have applied for restarts and a further seven will be decommissioned.

NUCLEAR REACTORS

Nuclear power reactors

452

Nuclear reactors

Operating in 31 countries and saving 2.2 billion tonnes of global CO_2 emissions.

World Nuclear Association

495

New nuclear reactors

Plants under construction, planned or proposed, with many in China and India.

World Nuclear Association

AROUND THE WORLD

Nuclear research reactors

225

Research reactors

Used for research, training and production of medical and industrial isotopes.

World Nuclear Association

55

Countries worldwide

With research reactors including Australia's OPAL reactor in Lucas Heights.

World Nuclear Association

POWER HUNGRY

Top 20 electricity consuming countries 2017

Australia is the only G20 country that prohibits nuclear power

● Nuclear consumer ● Nuclear under construction ○ Nuclear permitted ● Nuclear power prohibited

1 ● China	6 ● Korea	11 ● United Kingdom	16 ● Taiwan
2 ● US	7 ● Germany	12 ● Italy*	17 ● Turkey
3 ● India	8 ● Brazil	13 ● Saudi Arabia	18 ○ Indonesia
4 ● Japan	9 ● Canada	14 ● Mexico	19 ● Spain
5 ● Russia	10 ● France	15 ● Iran	20 ● Australia

* More than 80 per cent of electricity imported by Italy comes from nuclear powered countries

Source: International Energy Agency

the case for nuclear

Produced by the Minerals Council of Australia

There's more to Australian Mining

Part Two