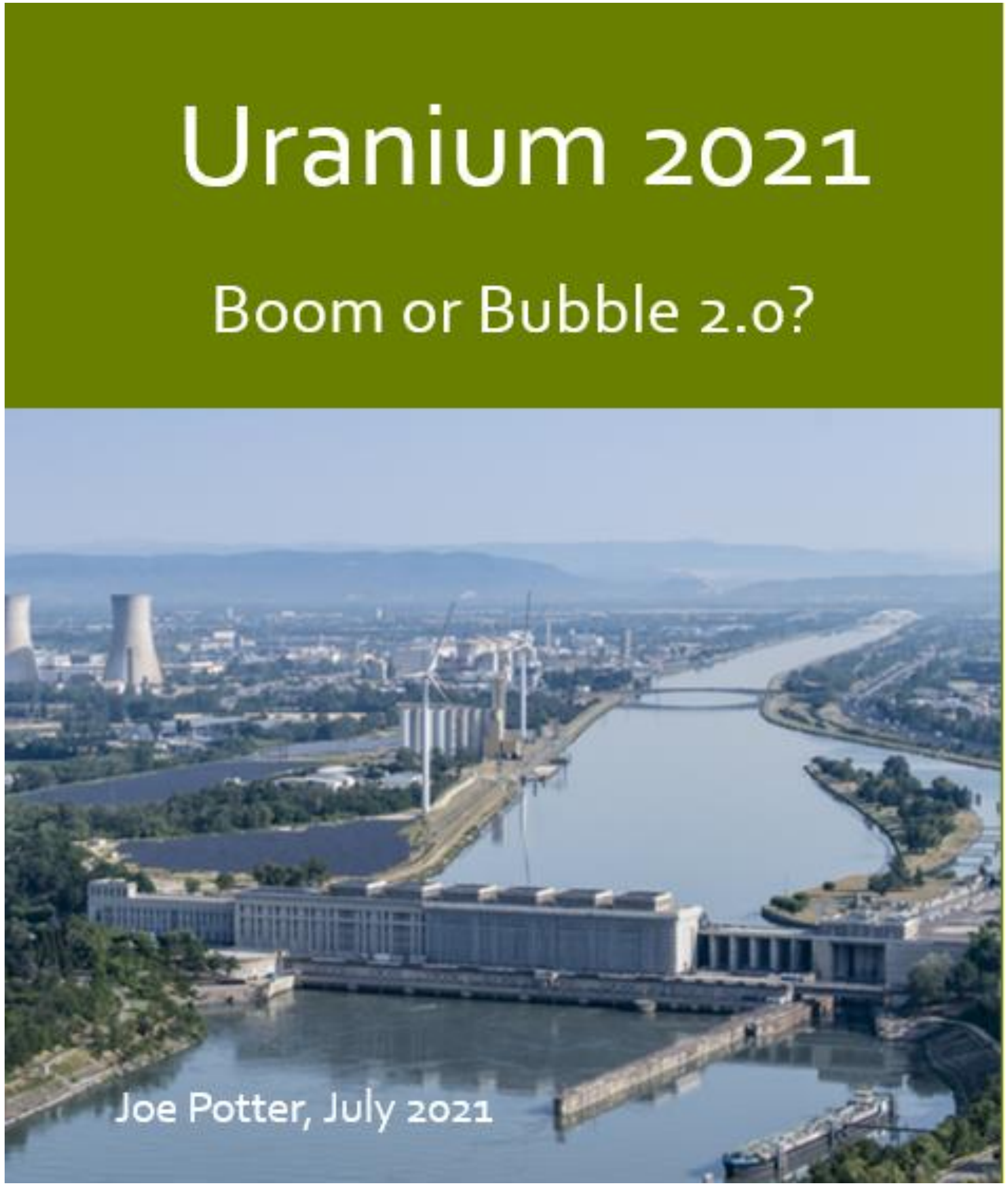



July 21, 2021
11:00 AM AEST
Last Updated 10 hours ago

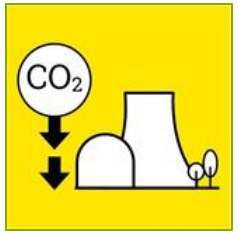
Energy

Japan goes nuclear in bid to stay cool during Summer Olympics

4 minute read

Yuka Obayashi

https://www.reuters.com/business/energy/japan-goes-nuclear-bid-stay-cool-during-summer-olympics-2021-07-20/

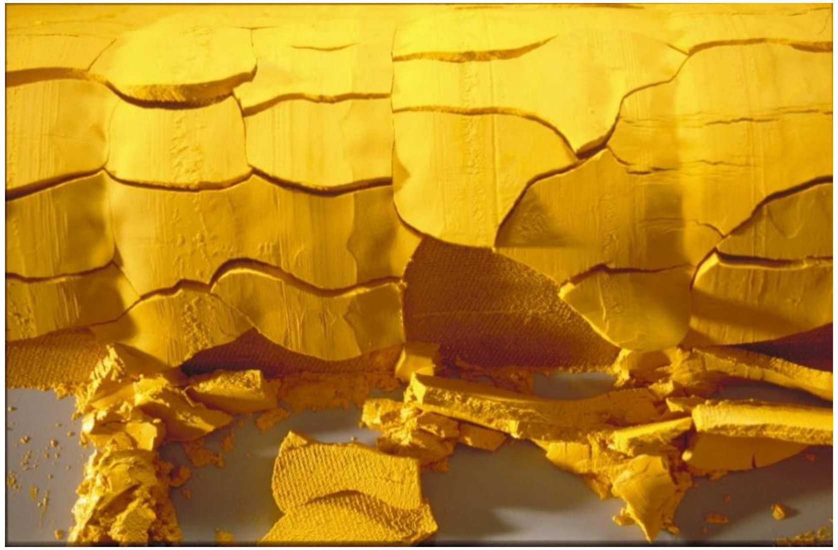


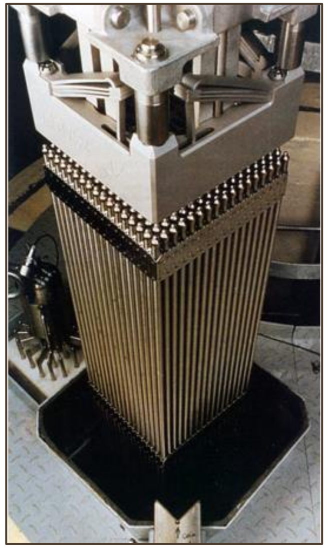
Contents

Factoid 1: Energy Density

A kilogram of coal can run a 100W lightbulb for about 4 days while a kilogram of natural uranium can run it for 182 years! If you enrich uranium up to weapons grade, a kilogram can then run the lightbulb for over 24,000 years! Put in better perspective, that kilogram of rock can power the entire USA for 177 seconds (almost 3 minutes!). Discussion of energy density

https://whatisnuclear.com/factoids.html





Factoid 2: Recycling Nuclear Waste

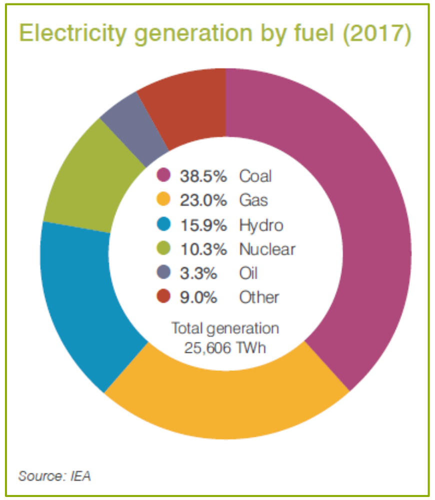
If we took all the nuclear waste that was sitting around in the USA today from the past 50 years of running reactors and recycled it, we could use it to power the entire USA for about 93 years without mining anything else. Discussion of recycling waste

https://whatisnuclear.com/factoids.html

Overview

- Uranium used primarily as **fuel for nuclear reactors**
- **443 reactors** operating across the globe (Jan 2019)
- **55 reactors** under construction (Jan 2019)
- 59, 200 tonnes U global **demand** 2019
- 54,000 tonnes U global **production** in 2019
- Australia exports ~ 5,000 tonnes U per annum (Olympic Dam & 4-Mile/Beverley)
- U-spot price and equities have risen significantly since 2019
- **What's going on?**

Source WNA, IAEA, ASX



World production–53.7 kilotonnes, 2019

Rank	Country	Percentage of Total
1	Kazakhstan	43%
2	**Canada**	**13%**
3	Australia	12%
4	Namibia	10%
5	Niger	6%

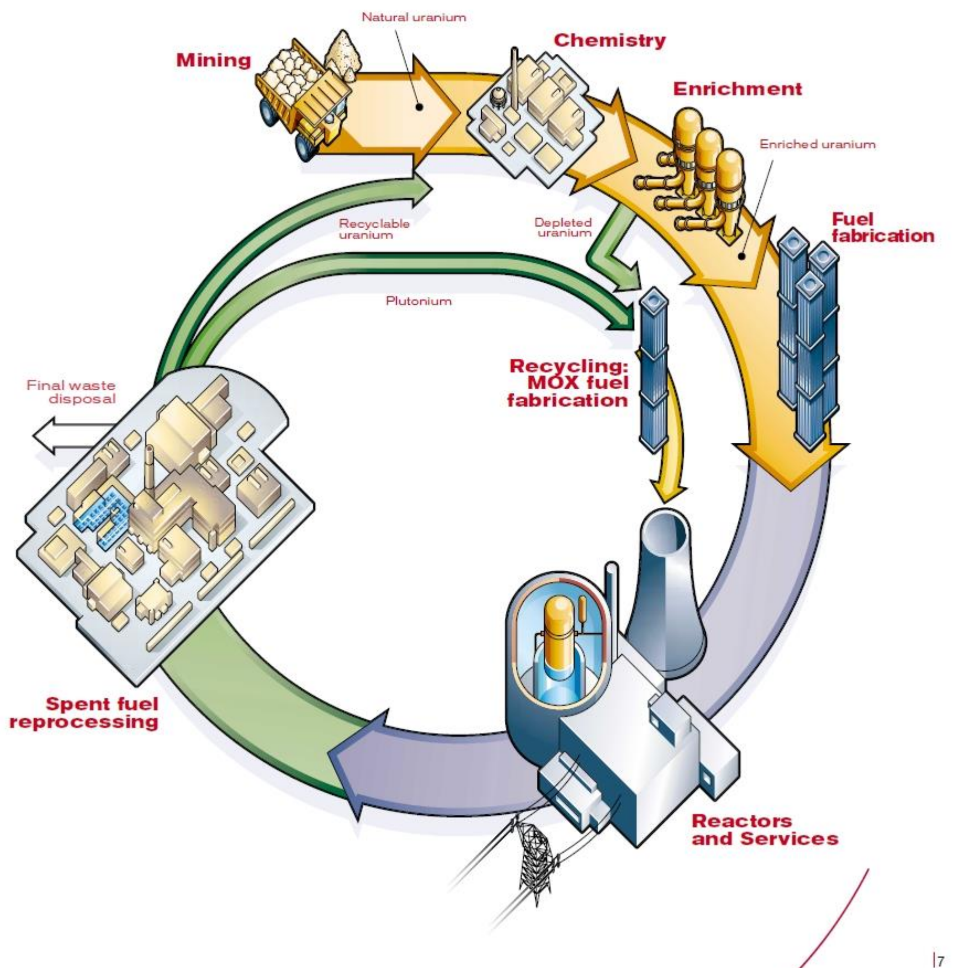
Countries with nuclear electricity

Location	Nuclear capacity MWe	% share of electricity, 2019
USA	96,772	20
France	62,250	71
China	45,498	5
Japan	31,679	8
Russia	29,203	20
South Korea	23,231	26
Canada	13,553	15
Ukraine	13,107	54
Germany	8052	12
UK	8883	16
Sweden	7738	34
Spain	7121	21
India	6255	3
Belgium	5930	48
Czech Republic	3932	35
Switzerland	2960	24
Finland	2764	35
Bulgaria	1926	38
Brazil	1884	3
Hungary	1902	49
South Africa	1830	7
Slovakia	1816	54
Argentina	1641	6
Mexico	1600	5
Pakistan	1355	7
Romania	1310	19
Iran	915	2
Slovenia	696	37
Netherlands	485	3
Armenia	375	28
Total*	390,382	10.2

* Includes four reactors on Taiwan with total of 3844 MWe.
Sources: World Nuclear Association, IAEA
as of 07.07.2020

Nuclear Fuel Cycle

- Exploration
- Mining
- Processing – U_3O_8
- Conversion – $U_3O_8 \longrightarrow UF_6$ (Gas)
- Enrichment – to 3-5% U_{235}. $UF_6 \longrightarrow UO_2$ (solid)
- Fuel Fabrication & Use (96% of U is not used)
- Spent Fuel Processing
- Recycling into MOX fuel
- Waste storage
- Waste disposal



Nuclear Fuel Cycle (Orano 2020)

Natural uranium consists primarily of two isotopes: 99.3% is U_{238} and 0.7% is U_{235}

[Handy Reference: The Nuclear Fuel Cycle - IAEA]

Global Uranium Supply & Key Players

- Orano (France)
- Cameco (Canada)
- Rosatom/ARMZ (Russia)
- Kazatomprom (Kazakhstan)
- CNNC (CHINA)
- CGN (CHINA)
- CNGC (CHINA)

Uranium output by producer*

Company	2019 production	
	Actual (tU)	World share (%)
Kazatomprom	13,291	25
Orano (AREVA)	5809	11
Cameco	4754	9
Uranium One	4624	9
CNNC	3961	7
CGN	3871	7
BHP	3364	6
ARMZ	2904	5
Navoi Mining	2404	4
Energy Asia	2122	4
General Atomics/Quasar	1764	3
Sopamin	1032	2
Rio Tinto	1016	2
VostGok	801	1
Other	**3001**	**6**
Total**	**53,656**	**100**

** based on ownership share*

*** Kazatomprom owns 50% share of Energy Asia, as a result, some quantity is double counted. Percentage figures do not add up to 100% due to rounding.*

Uranium production and resources

Country	2019 production (tU)	Uranium resources (tU)* <US$260/kg
Australia	6613	2,055,000
Canada	6938	846,000
China	1885	290,000
India	308	157,000
Kazakhstan	22,808	905,000
Namibia	5476	541,000
Niger	2983	426,000
Russia	2911	657,000
South Africa	346	449,000
Ukraine	801	219,000
USA	67	101,000
Uzbekistan	2404	139,000
Other	116	1,203,000
Total	**53,656**	**7,988,000**

Example: Orano/EDF – 87% French State- owned – 103 reactors built globally

Track Record:

98 nuclear reactors delivered

4 ongoing EPR™ Construction Projects:

Olkiluoto 3 (Finland)

Flamanville 3 (France)

Taishan 1 (China)

Taishan 2 (China)

Support to Plant Completion:
Engineering, Procurement & Safety Upgrade

Angra 3 (Brazil)

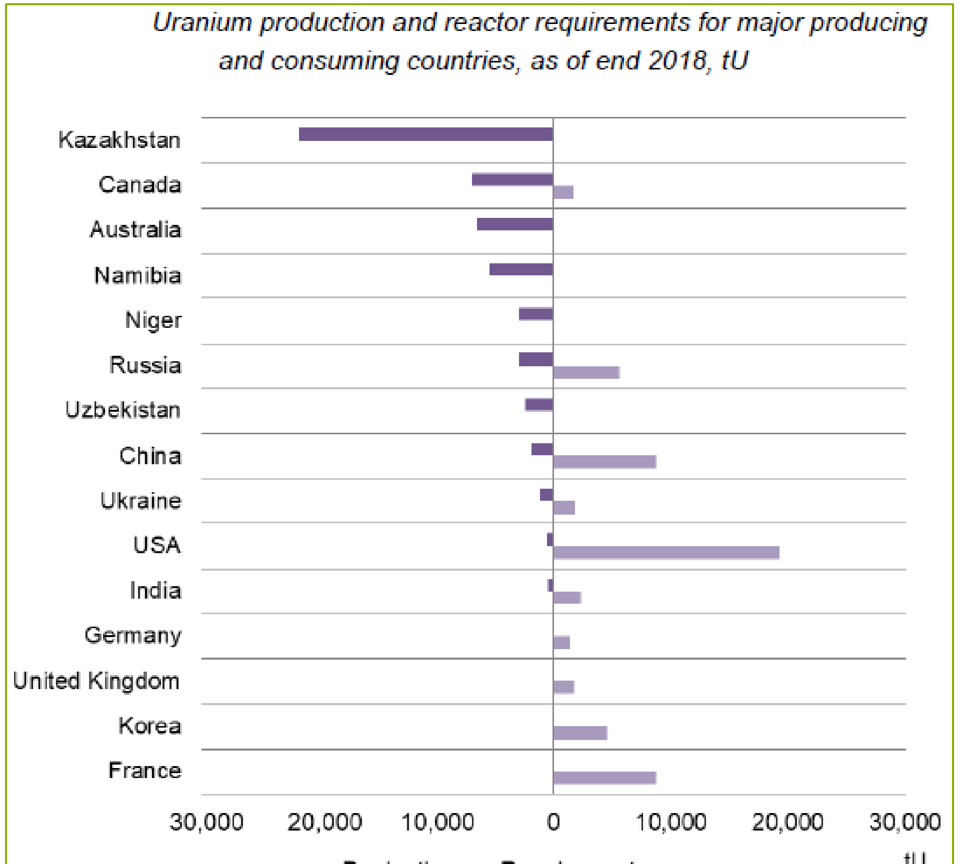
Next EPR™ Project:

Hinkley Point (U.K.)

ORANO provided services to 353 reactors worldwide in 2014

Uranium Supply and Demand - 101

- **443 operating reactors globally drives underlying Uranium demand fundamentals**
- 59, 200 tonnes U global demand 2019
- 54,000 tonnes U global production in 2019
- Annual mine production = 90-95% of demand
- Balance met from secondary sources:
  - U stockpiles (traders, utilities, miners)
  - Low and High Enriched Uranium inventories
  - Re-enrichment of depleted U tails
  - MOX fuel (recycled mixed U and P oxide)

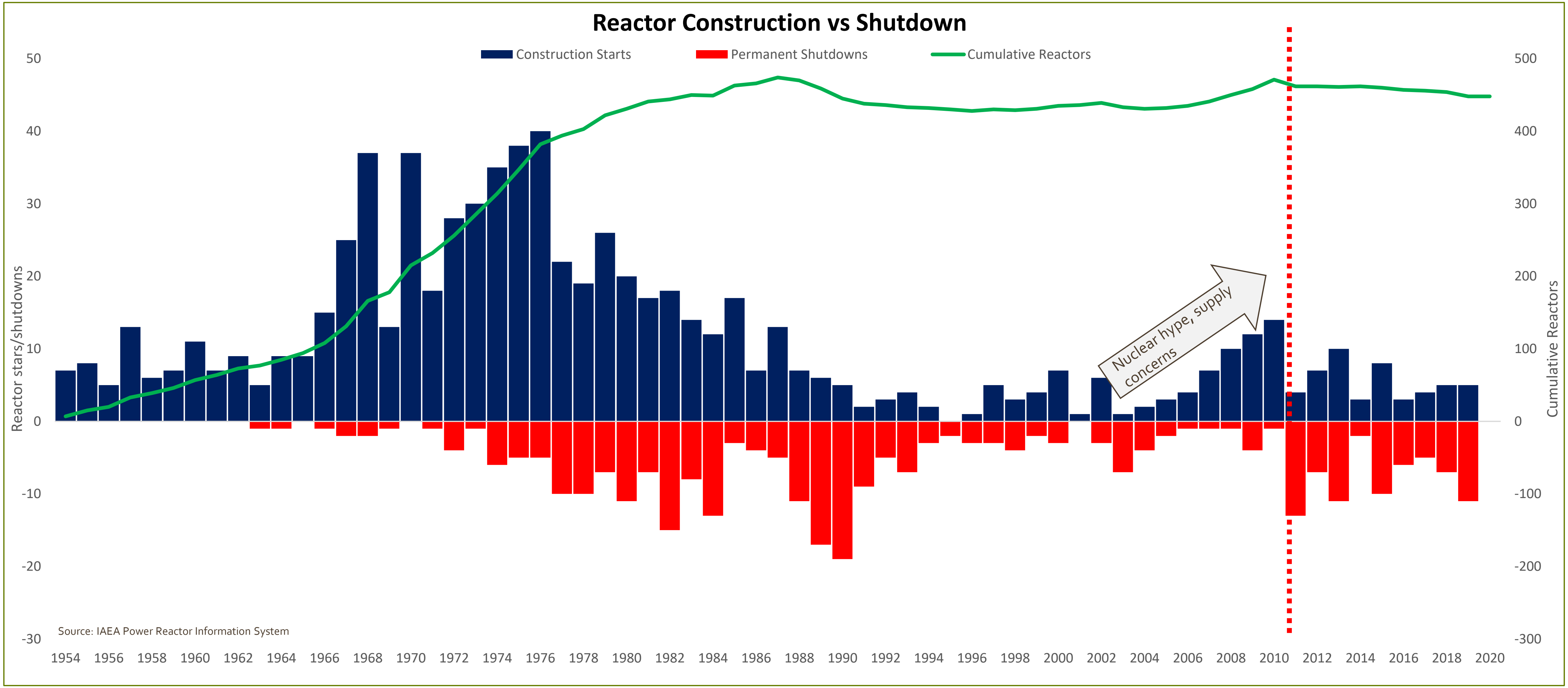


Source: WNA 2021

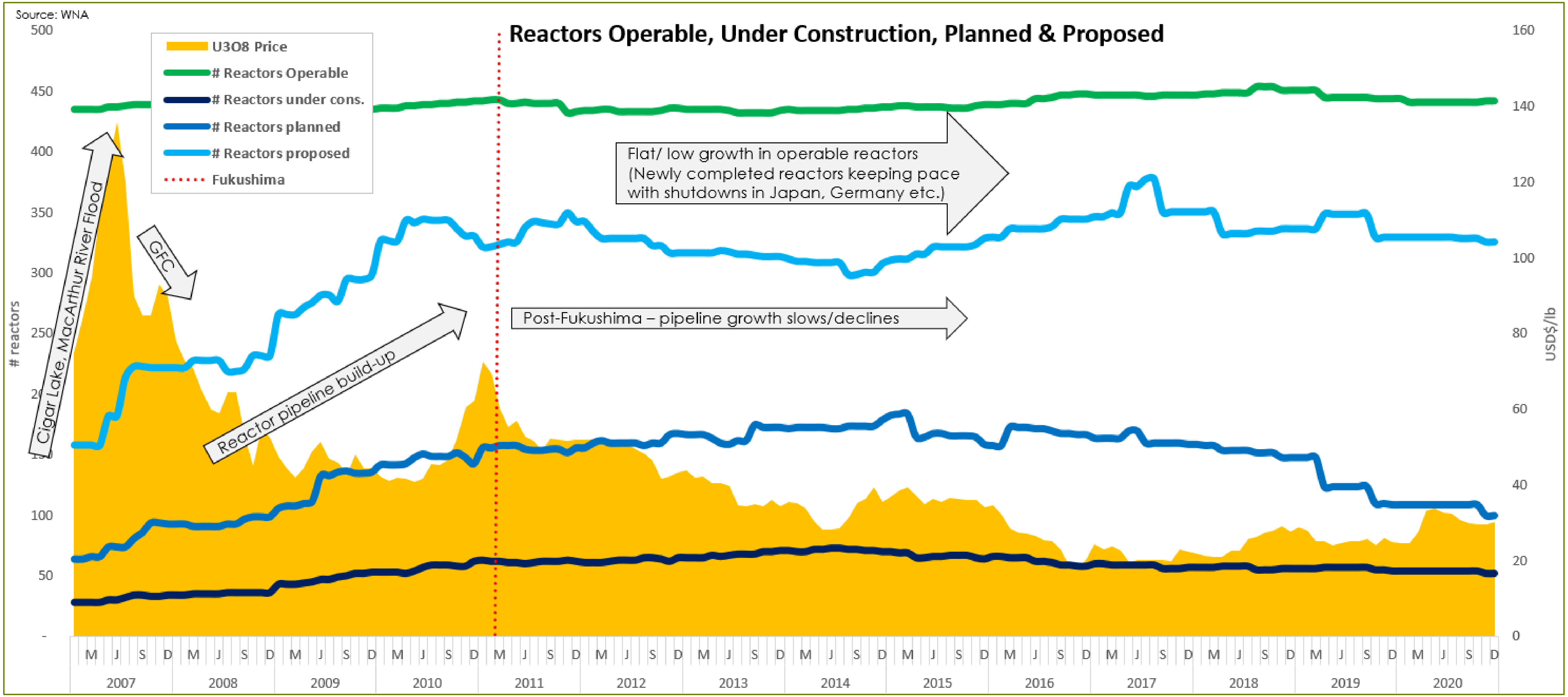
Overcapacity in the enrichment market since the Fukushima Daiichi accident has provided incentive to operators to "underfeed" enrichment facilities by extracting more 235U from the uranium feedstock. This reduces the amount of uranium required to produce contracted quantities of enriched uranium and, in turn, creates a stockpile of uranium. (Red Book 2020)

Highest Consumers of U are not Producers – Energy Security?

Long Term Trends in Reactors



Reactor Activity Post 2007 Bubble



Future Demand for Uranium - Global Reactor Fleet

- 443 operational reactors at end 2019
- In 2019:
  - 6 reactors connected to the grid
  - 13 reactors were shut down
  - 5 reactors started construction
- 54 reactors presently under construction globally
- **Long lead time to construct and connect**

World Nuclear Power Reactors & Uranium Requirements

July 2021

The World Nuclear Association's Country Profiles, linked to below, provide more detail of what is tabulated here.

COUNTRY (Click name for Country Profile)	NUCLEAR ELECTRICITY GENERATION 2020		REACTORS OPERABLE June 2021		REACTORS UNDER CONSTRUCTION June 2021		REACTORS PLANNED June 2021		REACTORS PROPOSED June 2021		URANIUM REQUIRED 2021
	TWh	% e	No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross	tonnes U
WORLD*	2553	c 10.1**	443	394,282	54	61,219	100	102,437	325	353,812	68,269
	TWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
	NUCLEAR ELECTRICITY GENERATION		OPERABLE		UNDER CONSTRUCTION		PLANNED		PROPOSED		URANIUM REQUIRED

WORLD NUCLEAR ASSOCIATION

https://world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

Home / Information Library / Facts and Figures / World Nuclear Power Reactors and Uranium Requirements

World Nuclear Power Reactors & Uranium Requirements

July 2021

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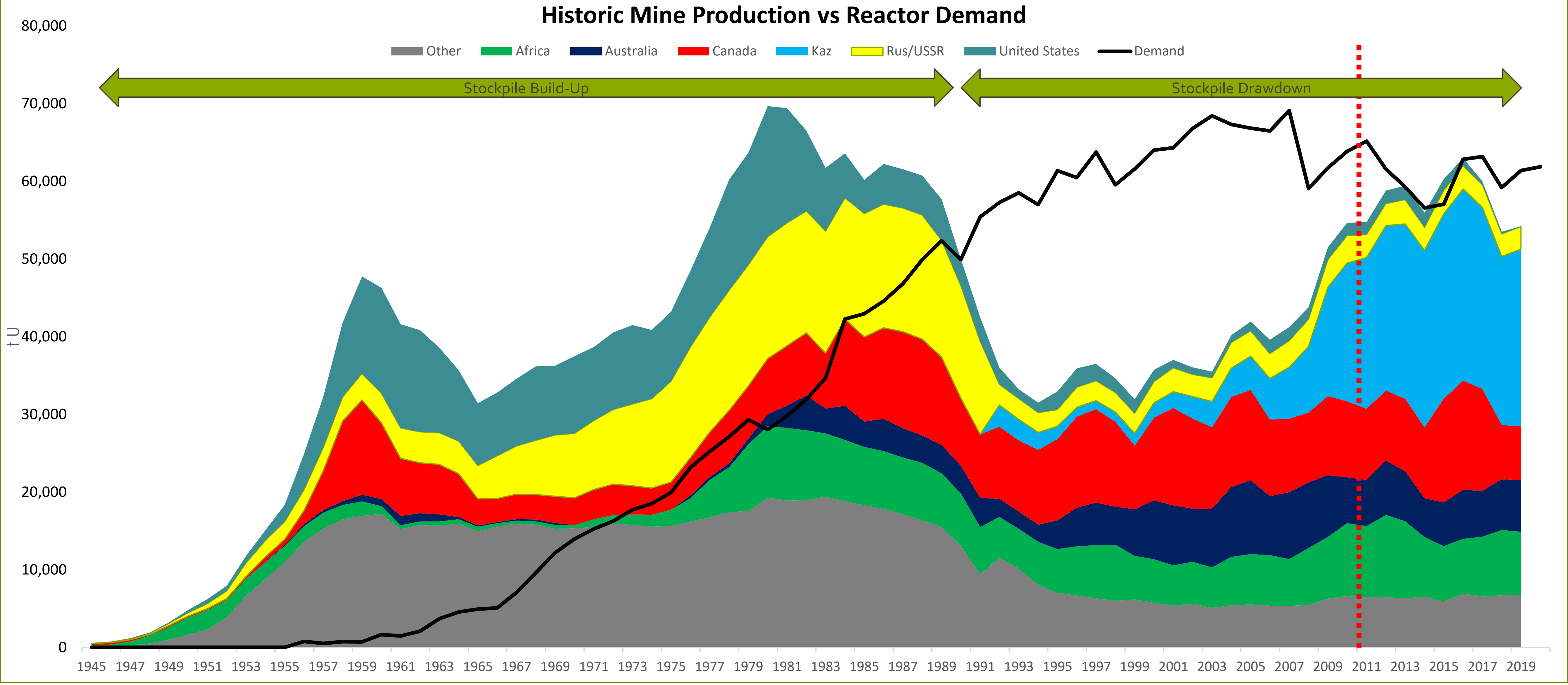
COUNTRY (Click name for Country Profile)	NUCLEAR ELECTRICITY GENERATION 2020		REACTORS OPERABLE June 2021		REACTORS UNDER CONSTRUCTION June 2021		REACTORS PLANNED June 2021		REACTORS PROPOSED June 2021		URANIUM REQUIRED 2021
	TWh	% e	No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross	tonnes U
Argentina	10.0	7.5	3	1641	1	29	1	1150	2	1350	206
Armenia	2.6	34.5	1	415	0	0	0	0	1	1060	77
Bangladesh	0	0	0	0	2	2400	0	0	2	2400	0
Belarus	0.3	1.0	1	1110	1	1194	0	0	2	2400	146
Belgium	32.8	39.1	7	5942	0	0	0	0	0	0	898
Brazil †	13.2	2.1	2	1884	1	1405	0	0	4	4000	358
Bulgaria	15.9	40.8	2	2006	0	0	1	1000	2	2000	334
Canada	92.2	14.6	19	13,624	0	0	0	0	2	1500	1409
China	344.7	4.9	51	49,569	17	18,616	38	41,785	168	196,860	10,814
Czech Republic	28.4	37.3	6	3934	0	0	1	1200	3	3600	694
Egypt	0	0	0	0	0	0	4	4800	0	0	0
Finland	22.4	33.9	4	2794	1	1720	1	1170	0	0	758
France	338.7	70.6	56	61,370	1	1650	0	0	0	0	8701
Germany	60.9	11.3	6	8113	0	0	0	0	0	0	587
Hungary	15.2	48.0	4	1902	0	0	2	2400	0	0	360
India	40.4	3.3	23	6885	6	4600	14	10,500	28	32,000	1080
Iran	5.8	1.7	1	915	1	1057	1	1057	5	2760	161
Japan †	43.0	5.1	33	31,679	2	2756	1	1385	8	11,562	2344
Jordan	0	0	0	0	0	0	0	0	1	1000	0
Kazakhstan	0	0	0	0	0	0	0	0	2	600	0
Korea RO (South)	152.6	29.6	24	23,150	4	5600	0	0	2	2800	5121
Lithuania	0	0	0	0	0	0	0	0	2	2700	0
Mexico	10.9	4.9	2	1552	0	0	0	0	3	3000	239
Netherlands	3.9	3.3	1	482	0	0	0	0	0	0	74
Pakistan	9.6	7.1	6	2332	1	1100	1	1170	0	0	636
Poland	0	0	0	0	0	0	0	0	6	6000	0
Romania	10.6	19.9	2	1300	0	0	2	1440	1	720	187
Russia ‡	201.8	20.6	38	28,578	2	2510	25	23,890	21	20,100	6227
Saudi Arabia	0	0	0	0	0	0	0	0	16	17,000	0
Slovakia	14.4	53.1	4	1837	2	942	0	0	1	1200	428
Slovenia	6.0	37.8	1	688	0	0	0	0	1	1000	141
South Africa	11.6	5.9	2	1860	0	0	0	0	8	9600	294
Spain	55.8	22.2	7	7121	0	0	0	0	0	0	1217
Sweden	47.4	29.8	6	6882	0	0	0	0	0	0	985
Switzerland	23.0	32.9	4	2960	0	0	0	0	0	0	446
Thailand	0	0	0	0	0	0	0	0	2	2000	0
Turkey	0	0	0	0	3	3600	1	1200	8	9500	0
Ukraine †	71.5	51.2	15	13,107	2	1900	0	0	2	2,400	1879
UAE	1.6	1.1	1	1345	3	4200	0	0	0	0	877
United Kingdom	45.9	14.5	15	8923	2	3440	2	3340	2	2300	1820
USA	789.9	19.7	93	95,523	2	2500	3	2550	18	8000	18,295
Uzbekistan	0	0	0	0	0	0	2	2400	2	2400	0
WORLD*	2553	c 10.1**	443	394,282	54	61,219	100	102,437	325	353,812	68,269
	TWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
	NUCLEAR ELECTRICITY GENERATION		OPERABLE		UNDER CONSTRUCTION		PLANNED		PROPOSED		URANIUM REQUIRED

Sources:

Reactor and electricity data: International Atomic Energy Agency Power Reactor Information System (PRIS); US Energy Information Administration; company data; World Nuclear Association estimates
World Nuclear Association, *The Nuclear Fuel Report* (published September 2019, reference scenario forecast) – for uranium requirements
68,269 tU = 80,506 t U_3O_8

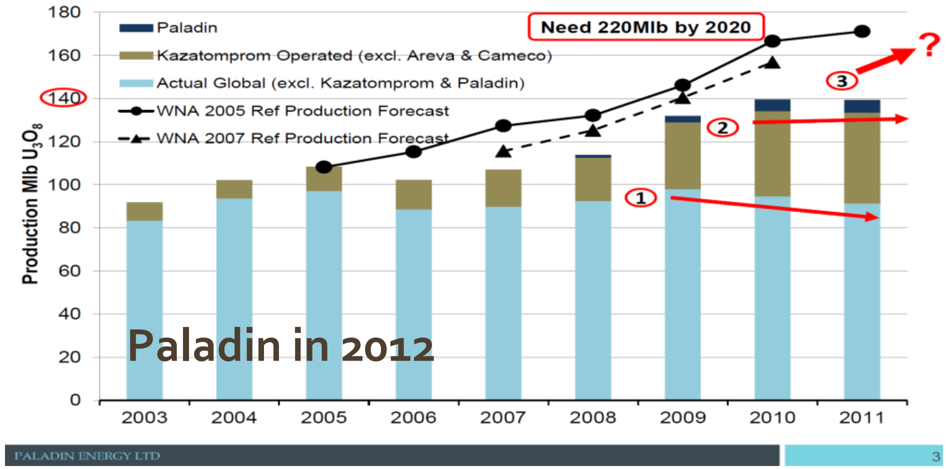
Uranium Supply and Demand – 101 (cont'd)

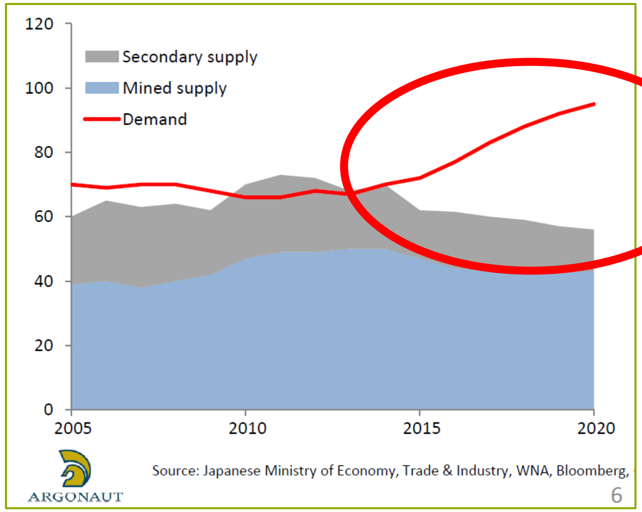


Source: WNA/IAEA Red Books, S&P

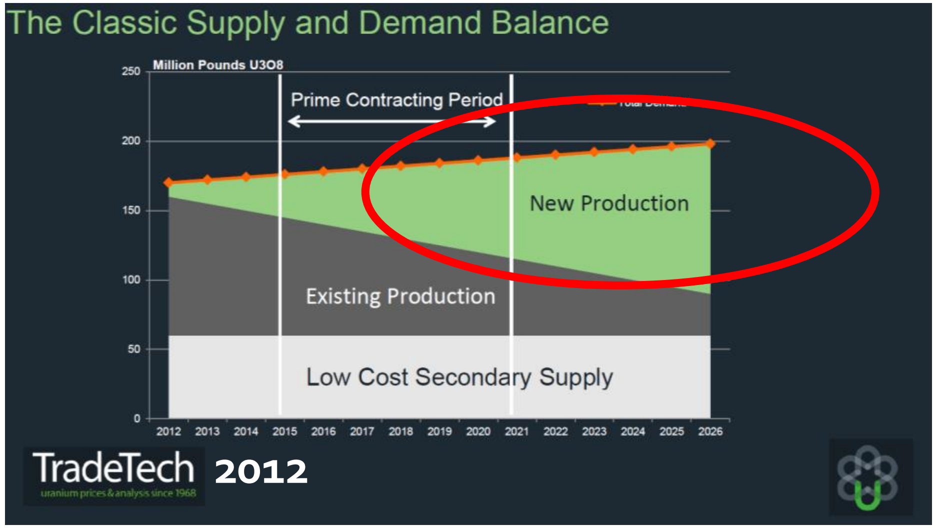
Uranium Supply and Demand – Forecasting…

Paladin in 2004





Argonaut, 2005

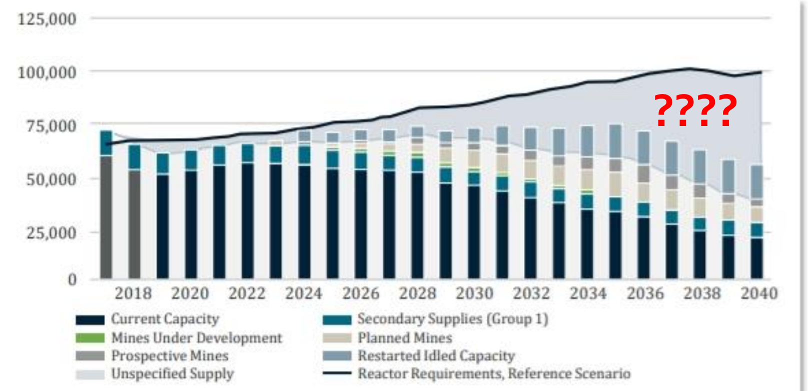


Future Supply and Demand Scenarios

Structural supply deficit

World Nuclear Association Supply Shortage Graph

Tonnes U



Source: World Nuclear Association

- Current uranium supply unable to meet current demand
- 285 new nuclear reactors forecast to be built by 2040, further increasing demand
- Re-start of idled mine capacity and the development of Planned & Prospective mines requires incentive prices US$40-80/lb

PALADIN ENERGY LTD 2021

Exhibit 12. TD Securities Uranium Supply/Demand Model

	2017	2018	2019	2020	2021E	2022E	2023E	2024E	2025E
Mine Supply - Western World (Mlb U3O8)									
Total Mine Supply - Western World	100	83	85	81	73	80	85	88	86
Net Eastern Mine Supply (lbs U3O8)	54	54	55	44	52	53	60	66	72
Total World Mine Supply (Mlb U3O8)	**154**	**138**	**140**	**125**	**126**	**132**	**145**	**154**	**158**
YoY % change	*-7.6%*	*-10.2%*	*1.7%*	*-10.9%*	*0.7%*	*5.3%*	*9.1%*	*6.8%*	*2.6%*
Secondary Supply									
Global underfeeding and tails re-enrichment*	19	18	18	16	16	15	15	14	14
Mixed Oxide Fuel (MOX)*	5	5	6	6	6	6	6	7	8
US government sales (DOE Proposed)*	3	2	2	1	0	0	0	0	0
Additional Russian secondary supply*	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
Total Secondary Supply (Mlb)	**27**	**24**	**26**	**24**	**22**	**21**	**21**	**21**	**21**
Secondary supply as % of global reactor demand	16%	14%	15%	13%	12%	12%	12%	11%	11%
Mobilization of Commercial Inventory	7	7	7	7	7	7	7	7	7
Total Supply	**187**	**169**	**173**	**156**	**155**	**161**	**173**	**183**	**187**
Total World Demand									
Total World Nuclear Generating Capacity (MWe) *	358,819	368,571	372,978	374,420	384,508	385,211	389,242	394,906	398,885
Uranium requirements per MWe	472	472	472	472	472	472	472	472	472
Uranium demand (mmlb)	169	174	176	177	181	182	184	186	188
First Core Requirement (2 year lead)	-	-	-	-	-	-	-	-	-
Total World Demand (Mlb U3O8)	**169**	**174**	**176**	**177**	**181**	**182**	**184**	**186**	**188**
YoY % change	*1.7%*	*2.7%*	*1.2%*	*0.4%*	*2.7%*	*0.2%*	*1.0%*	*1.5%*	*1.0%*
Supply / Demand Balance (Mlb)	**18**	**-5**	**-3**	**-21**	**-27**	**-21**	**-11**	**-4**	**-2**
Spot Uranium Price (US$/lb U3O8)	**$22.12**	**$24.82**	**$25.94**	**$29.52**	**$32.99**	**$36.00**	**$38.00**	**$40.00**	**$45.00**

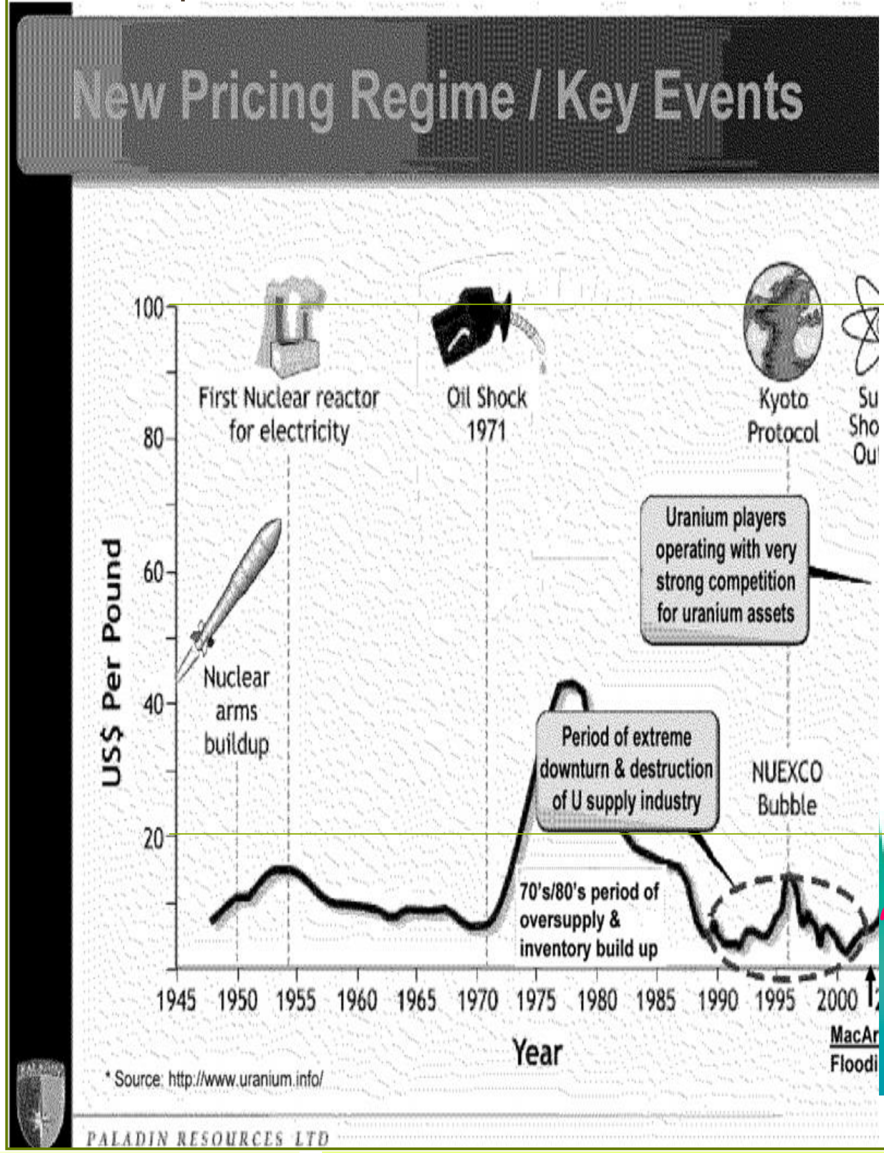
** Source: World Nuclear Association - Nuclear Fuel Report 2019-2040 Reference Case*

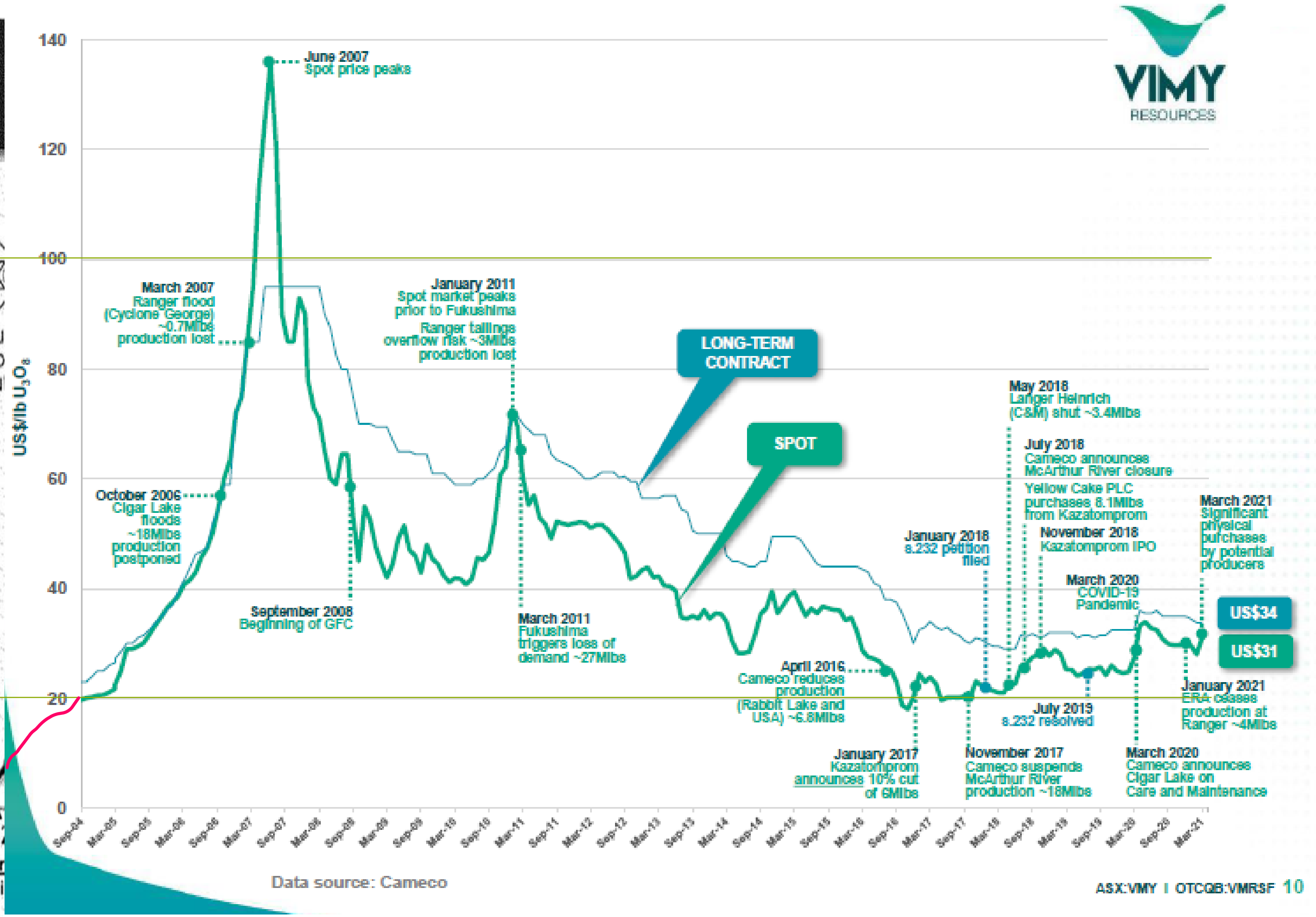
Note - TD LT price assumption starts in 2025; a flat US$45/lb price is assumed for 2025 and beyond.

Source: UxC, Bloomberg, World Nuclear Association, TD Securities Inc.

Historical Uranium Spot Price

Paladin 2004:

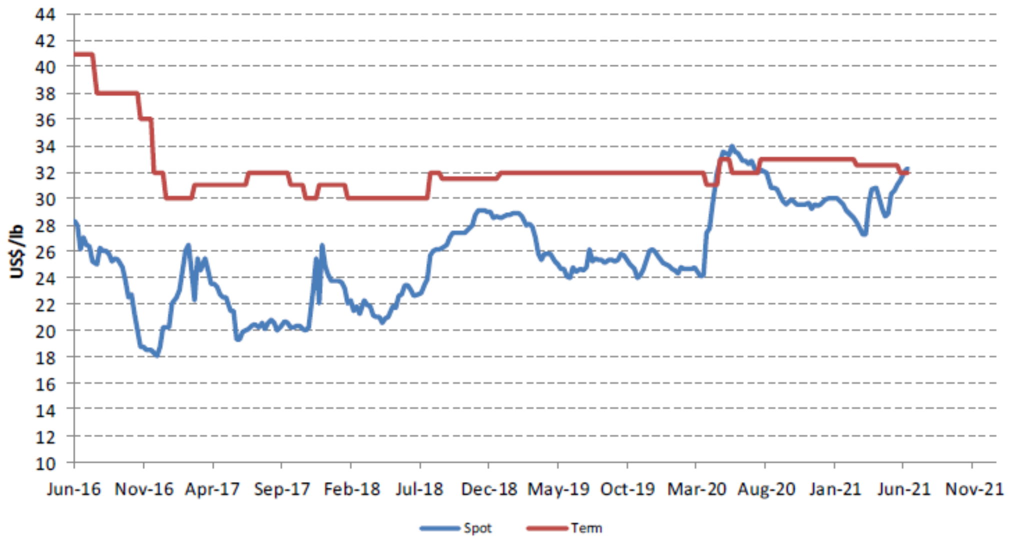




Uranium Short Term and Long Term Prices

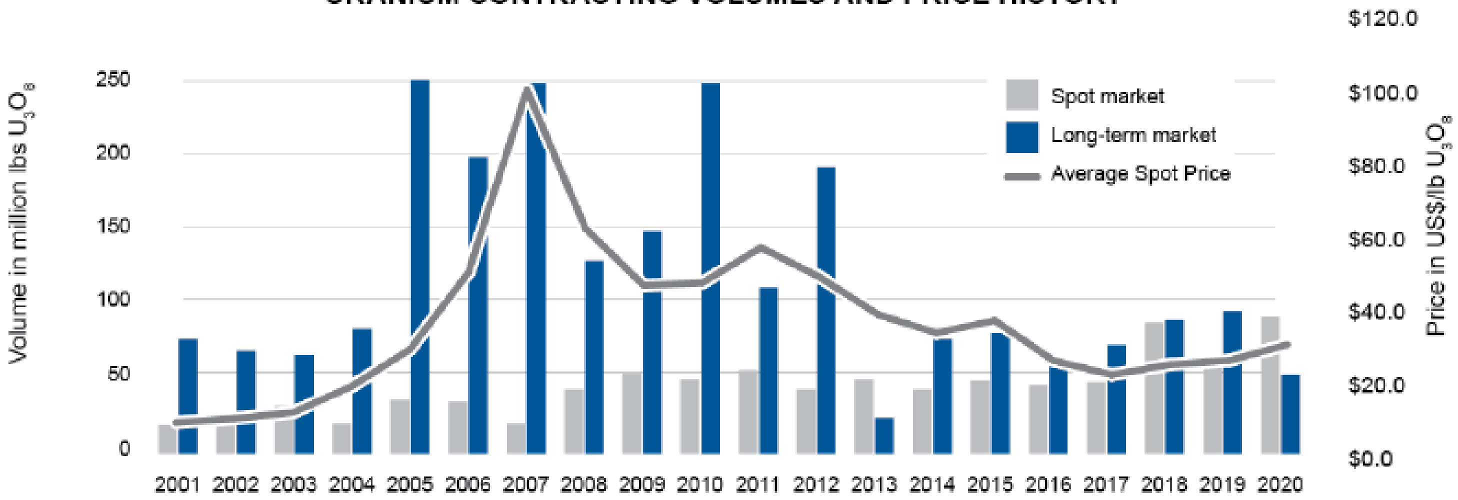
- Nuclear utilities require ~3 years of fuel in stock
- 2005 - long term contracts were 90% U market
- 2021 – long term contracts are <10% U market
- Spot – Term pricing is merging

Exhibit 2. Spot and Term Uranium Prices (US$/lb)



Source: UxC; TD Securities estimates

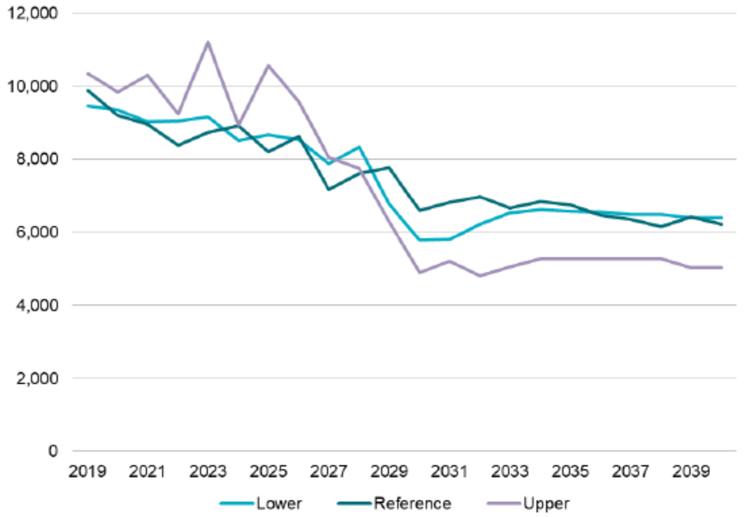
URANIUM CONTRACTING VOLUMES AND PRICE HISTORY



Source: UxC estimates

Secondary supply scenarios for uranium, *tU*

Source: WNA 2021



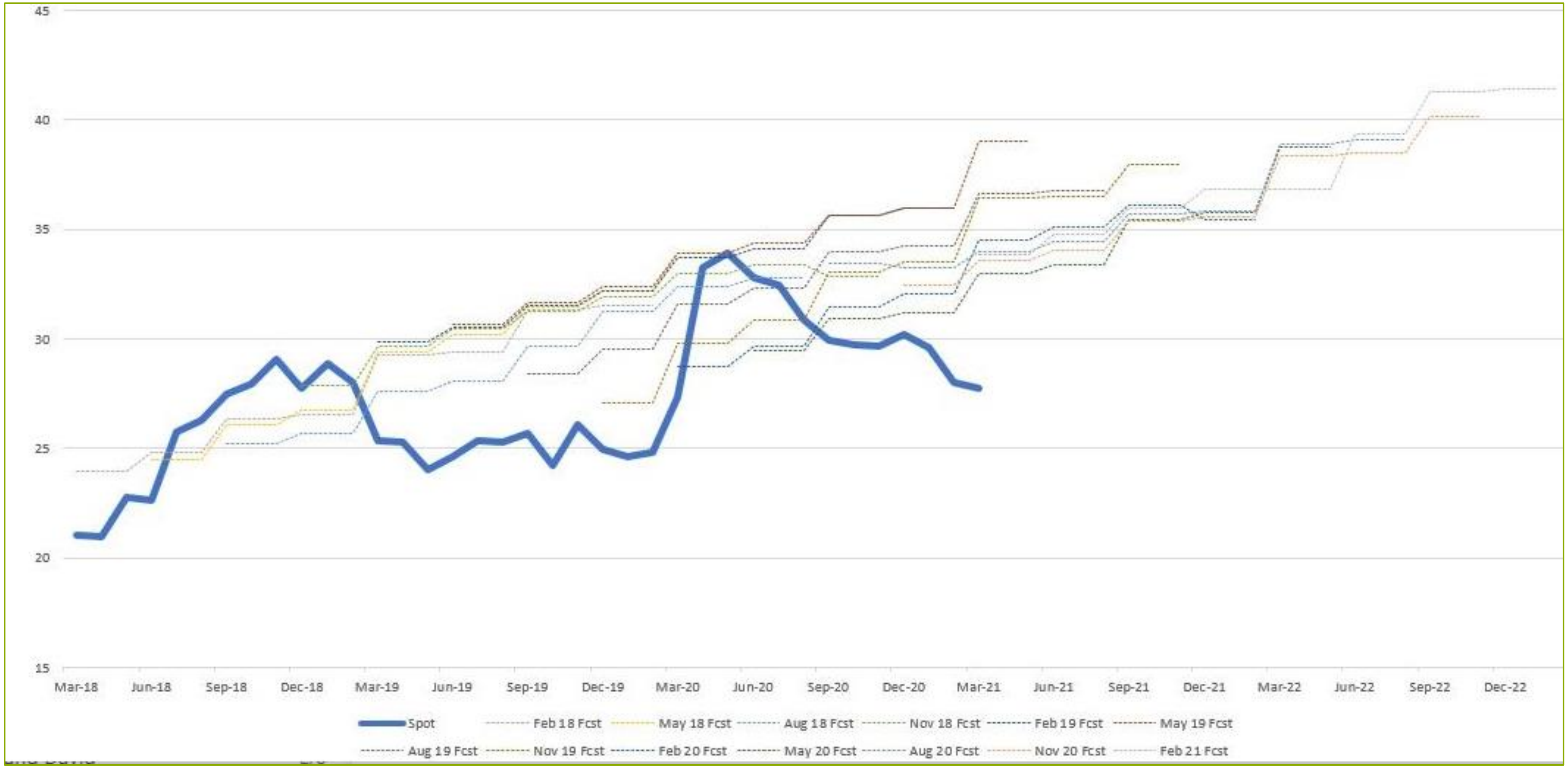
Spot Market Purchasing by Juniors/Traders

Exhibit 3. Uranium company equity offerings and uranium purchases

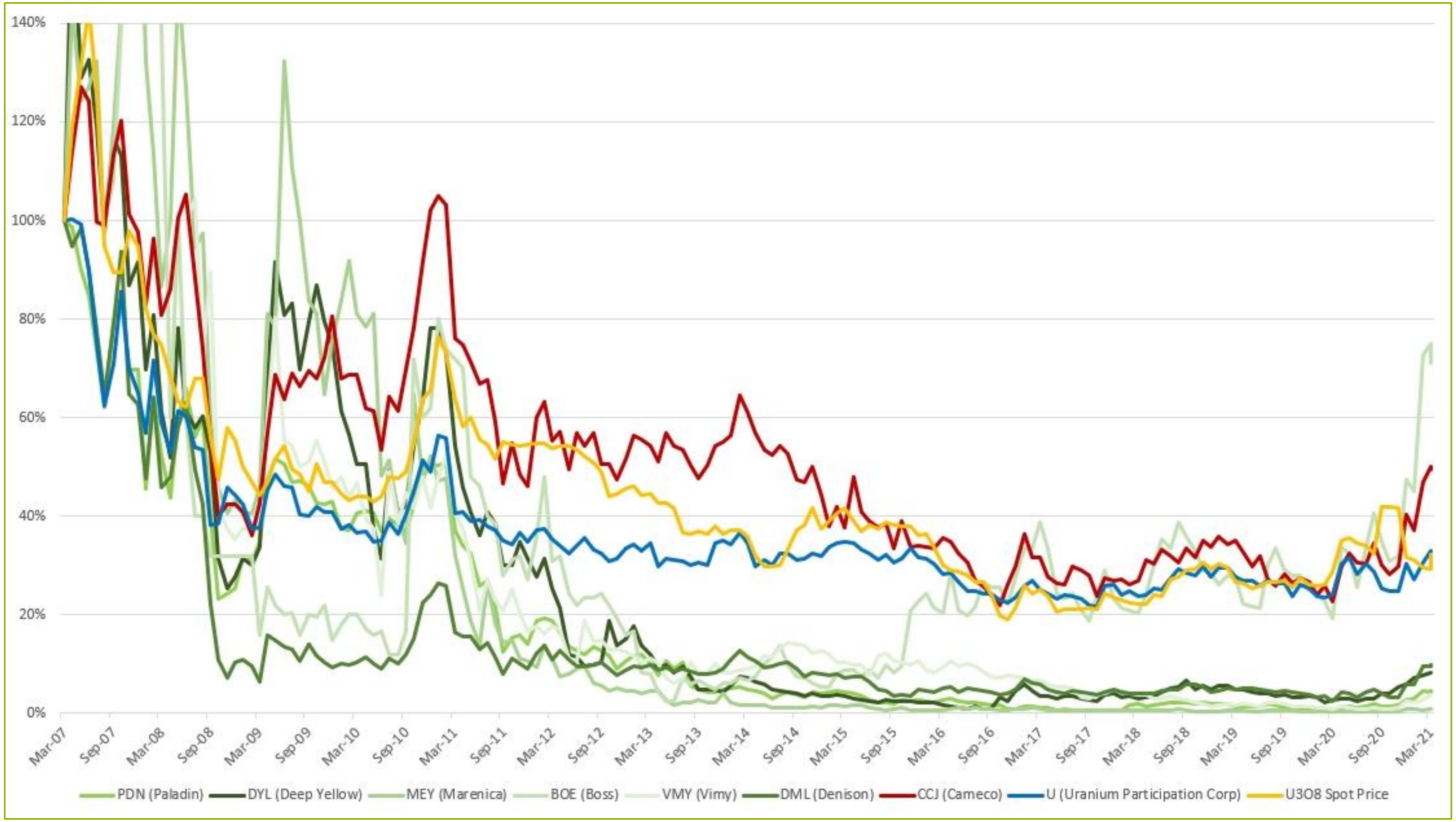
Company	Date Equity Offering and/or Uranium Purchase Announced	Equity Offering (US$ millions)	Uranium Purchased or Planned to Purchase (million pounds)	Estimated Average Price of Uranium Purchases (Planned or Actual) (US$/lb)
Yellow Cake	25-Feb-21	140.0	3.90	28.78
Denison Mines	15-Mar-21	86.3	2.50	29.61
Uranium Energy	17-Mar-21	30.5	1.40	29.00
Boss Energy	29-Mar-21	46.0	1.25	30.15
Uranium Energy	6-Apr-21	12.0	0.71	31.70
Uranium Participation Corp.[1]	3-May-21	66.4	1.78	30.50
Yellow Cake	11-May-21	n/a	0.34	29.15
Western Uranium & Vanadium	2-Jun-21	n/a	0.13	31.50
Total/Average		**381.2**	**12.00**	**29.59**

Source: Company reports; TD Securities estimates

Crystal Ball - Spot Price Forecasts vs Actual: 2018-



ASX Uranium Equities Performance 2007-2021



The uranium recovery is on hold

U-bugs, not to be confused with Gold-bugs, have been pestering investors for at least the past 12-months with a claim that uranium is poised to reclaim a price of US$72 a pound, last seen in early 2011, or even the stratospheric $140/lb of mid-2007.

Energy Minerals > Energy-minerals-news

14 July 2021

Sadly for the uranium cheer squad, the future is not playing out as forecast, with the nuclear fuel seemingly stuck at $33/lb when measured in its most commonly traded form of triuranium octoxide

Nuclear remains the Cinderella of the clean energies.....

bright new world

[Bright New World](#)

1 April 2021

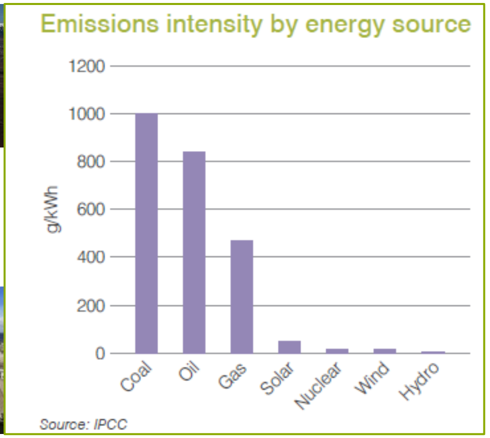
Energy Policy in Australia - Article for International Journal for Nuclear Power

Last month Bright New World was asked to provide a general overview of energy policy in Australia and how nuclear fits into that picture. Below is the overview of that article and following the link will open up a PDF of the whole article.

FROM FOSSIL FUEL SUPER POWER TO NET ZERO – CAN AUSTRALIA DELIVER AN ORDERLY ENERGY TRANSITION?

For example comparing materials per megawatt hour for the Spanish Andasol I solar thermal farm in comparison to a Westinghouse AP1000 nuclear reactor shows the solar farm uses 15 times more concrete (and 75 times more steel, not to mention 2,530 times more land). And this is a generous comparison, because the reactor will last twice as long, so you'll be building the solar farm twice.

[Brave New Climate Blog](#)



The Future – Small Modular Reactors? (SMRs)

This is MONEY.co.uk
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Consortium led by Rolls-Royce on hunt for orders for its £2bn nuclear reactors after redesign that means each will power 100,000 more homes

By ALEX LAWSON, FINANCIAL MAIL ON SUNDAY
PUBLISHED: 06:51 AEST, 16 May 2021 | **UPDATED:** 20:40 AEST, 16 May 2021

Cameco, GE Hitachi and Global Nuclear Fuel to Examine Potential Collaboration

Saskatoon, Saskatchewan, Canada, July 7, 2021

Cameco (TSX: CCO; NYSE: CCJ), GE Hitachi Nuclear Energy (GEH) and Global Nuclear Fuel-Americas (GNF-A) have entered into a Memorandum of Understanding to explore several areas of cooperation to advance the commercialization and deployment of BWRX-300 small modular reactors (SMRs) in Canada and around the world.

"Nuclear power will play a massive role in the global shift to zero-carbon energy, generating a lot of momentum for emerging SMR and advanced reactor

Downloads

News Release
(PDF, 109 KB)

Share

NuScale Power SMR
Image: NuScale Power SMR, 12 x 77 MWe modules, 924 MWe total on a 18 hectare site.
US Nuclear Regulatory Commission (NRC) Final Safety Evaluation Report issued in August 2020 - first SMR to achieve NRC design approval.

Australia's Role Beyond 2021?

- Stable supplier of uranium: U mining – friendly states……
- SA: Olympic Dam, 4-Mile
- NT: Ranger, Jabiluka, Koongarra……
- ~~QLD, WA, NSW, VIC~~
- Enrichment and Conversion/Fuel supply
- Waste Management: SA (domestic/international) NFCRC, SA 2015
- Recycling opportunity
- Fuel leasing (life cycle concept from mining to waste disposal)
- SMRs within Australia's energy mix [The Case for SMR's in Australia]

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- **Information Library - World Nuclear Association:** https://world-nuclear.org/information-library.aspx
- **NUCLEAR FUEL CYCLE ROYAL COMMISSION (SA)** http://nuclearrc.sa.gov.au/#fndtn-external-commission-visits
- **Australia's Uranium, WNA website**: https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx
- **Canadian Nuclear Association**: https://cna.ca/
- **Cameco**, https://www.cameco.com/about
- **Orano – Unpacking Nuclear:** https://www.orano.group/en/unpacking-nuclear
- **Bright New World (Ben Heard):** https://decarbonisesa.com/
- **Brave New Climate (Barry Brook):** https://bravenewclimate.com/category/nuclear/
- **The WISE Uranium Project Calculators** http://www.wise-uranium.org/calc.html
- **In situ Recovery links:**
  - Beverley Mine: http://www.heathgate.com.au/thebeverleymine_uraniumeducation.html
  - ISR U-Mining Best Practice Guide: https://www.nrc.gov/docs/ML1024/ML102440222.pdf

Uranium 2021

Boom or Bubble 2.0?

Joe Potter, July 2021

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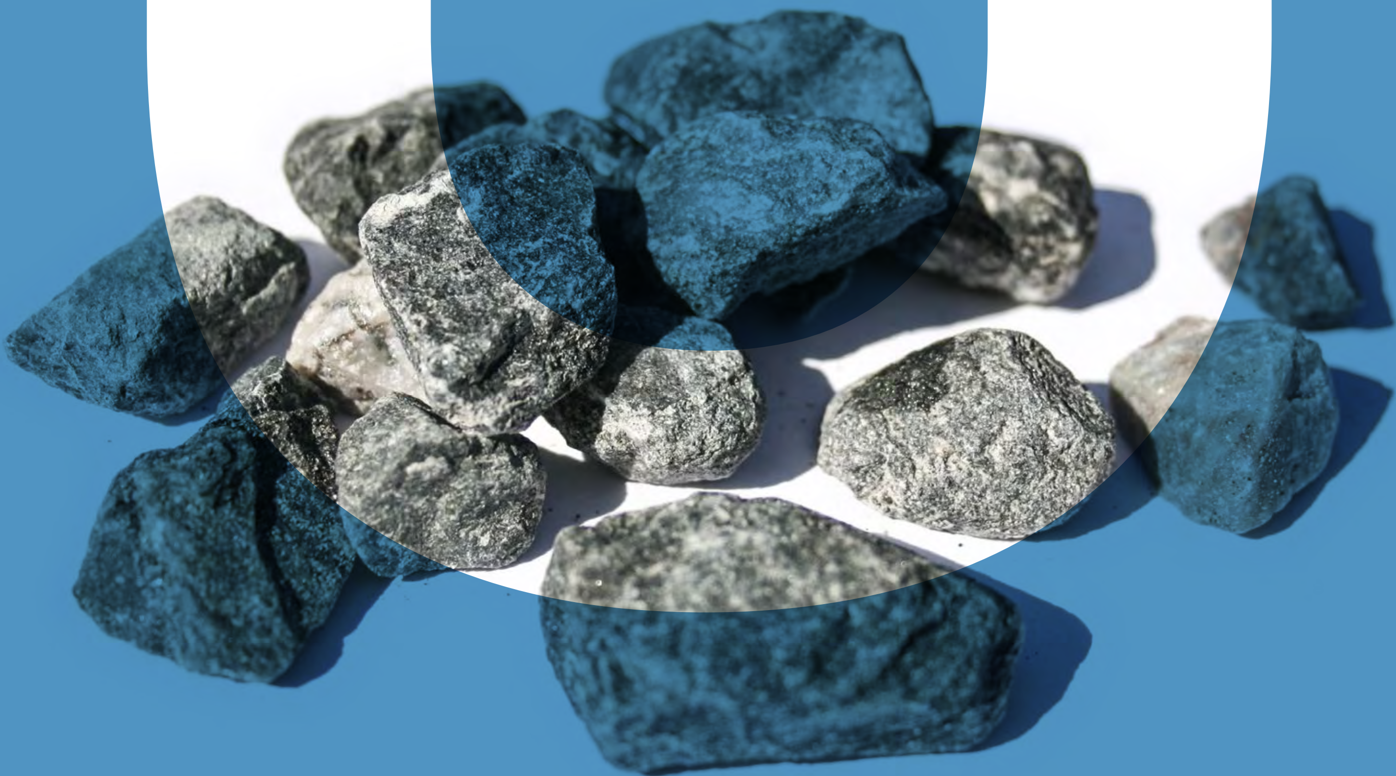


URANIUM

Natural Energy

Minerals Council of Australia

URANIUM
Natural Energy

Contents

$622m
EARNINGS
Australian uranium export earnings in 2013-14

$1.1b
FORECAST
BREE forecast value of Australia's uranium exports in 2018-19

5710t
PRODUCTION
Australia's production of uranium in 2013-14

8900t
FORECAST
BREE forecast for Australian uranium production in 2018-19

32%
RESOURCES
Australia has 32 per cent of global uranium resources – the largest in the world

437
REACTORS
Operable nuclear power reactors in the world

WORLD 11% PRODUCTION
Australia is the world's 3rd biggest producer

70 NEW REACTORS
The number of new nuclear reactors under construction

4200
EMPLOYED
Many in remote areas

487 PLANNED REACTORS
The number of planned or proposed new nuclear reactors

■ Underground mining, Olympic Dam, South Australia *(BHP Billiton)*

URANIUM: AUSTRALIA’S NEXT BILLION DOLLAR INDUSTRY

AUSTRALIA IS ENDOWED WITH THE WORLD’S LARGEST RESOURCES OF URANIUM AND IS THE WORLD’S THIRD BIGGEST EXPORTER.[1]

The Bureau of Resources and Energy Economics (BREE) forecasts that uranium will be a billion dollar Australian export industry by 2018-19[2], fuelled by the world’s growing demand for energy and rising interest in nuclear energy as a low emissions energy source.

BREE predicts that the combination of nuclear energy’s ability to provide reliable base load power, relatively cheap operating costs and low carbon emissions will see ‘substantial expansion in nuclear power generating capacity, particularly in emerging economies’.[3]

Beyond energy production, uranium will continue to support the use of nuclear technology in medicine for life saving diagnosis and treatment.

Australia is well placed to capitalise on this demand growth and expand its role as a secure, reliable and sustainable uranium producer. While it possesses approximately a third of the world’s low-cost uranium, Australia has claimed only 11 per cent of the world uranium market.[4]

A substantial opportunity awaits. ■

HIGH DENSITY ENERGY

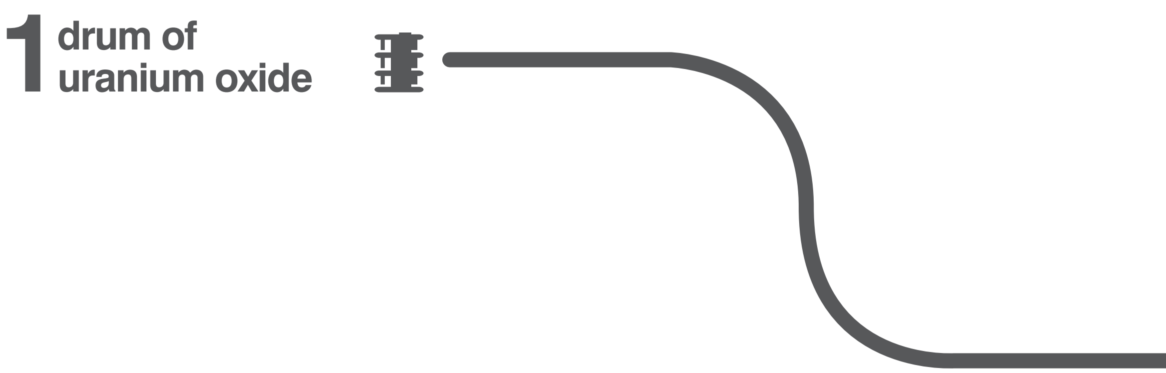
URANIUM IS THE HEAVIEST NATURALLY OCCURRING METAL IN THE EARTH'S CRUST.

Uranium is mildly radioactive in its natural form and is present in most rocks as well as in rivers, streams and oceans. It is about as common as tin and is more abundant than gold, silver or mercury.[5]

Generally speaking, uranium mining is no different to other mining.

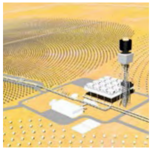
Uranium ore is mined in open cut or underground operations (sometimes with other metals such as gold and copper) or through in-situ recovery from boreholes drilled into the deposit. It is processed into uranium oxide (U_3O_8).

The energy content of uranium oxide[6]



The annual output of the world's largest solar farm or the southern hemisphere's largest wind farm can come from approximately just two shipping containers of uranium oxide.[7]

Ivanpah Solar Electric Generating System (SEGS)



Location:	Mojave Desert, California
Footprint:	3,500 acres
Build cost:	$2.2 billion
Capacity:	392 MW

Macarthur Wind Farm

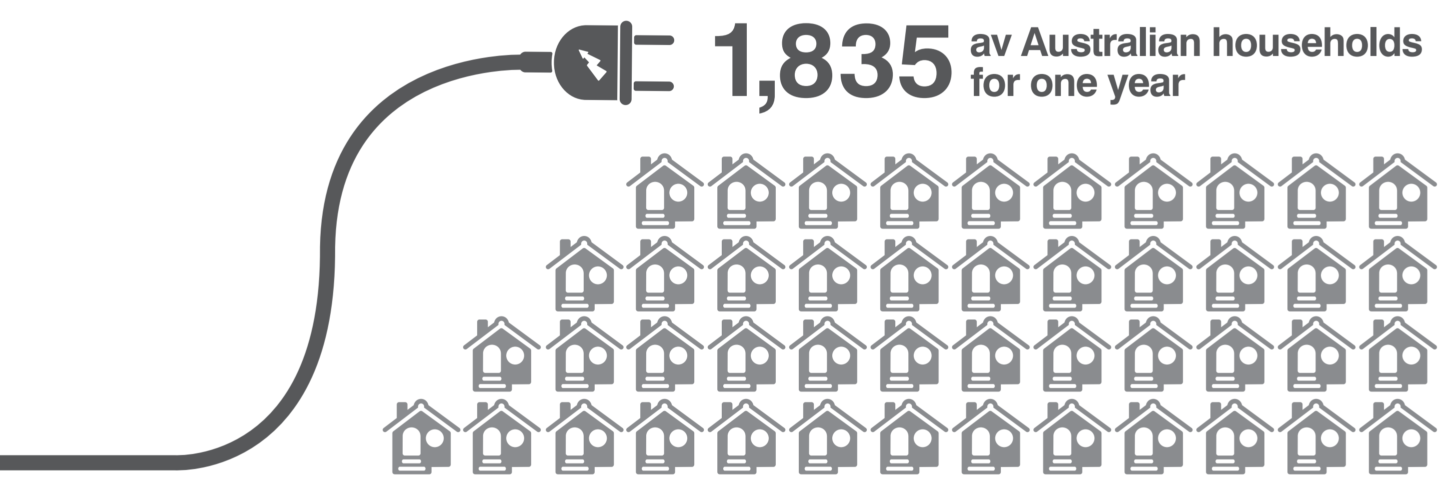
Location:	Victoria, Australia
Footprint:	5,500 acres
Build cost:	$1 billion
Capacity:	420MW (140 x 3MW turbines)

Uranium oxide has a uranium content of more than 80 per cent. It is sometimes referred to as yellowcake, though it is usually khaki in colour. This is the form in which Australia exports its uranium.

Uranium has extremely high energy density meaning a small amount of uranium can generate a large amount of energy. One kilogram of uranium produces the same energy as 11 tonnes of coal or 8,500 m^3 of natural gas.[8] Wind has low energy density – less than 1/10th that of wood. Wood has half the density of coal. Coal has half the density of octane.

The release of energy from splitting a uranium atom is 2 million times greater than breaking the carbon-hydrogen bond in molecules of wood, coal or oil.[9]

In 2012-13, Australia exported 8,391 tonnes of uranium oxide. This amount of uranium generated the same amount of electricity as Australia's total annual electricity production of 253TWh, and in energy units, was more than a quarter of Australia's exported energy. ■



AUSTRALIA'S RICH ENDOWMENT

AUSTRALIA HAS 90 KNOWN URANIUM DEPOSITS AND THE WORLD'S LARGEST URANIUM RESOURCE.

Australia's uranium resource accounts for 32 per cent (1,174 kt) of global Reasonably Assured Resources (RAR).[10]

South Australia hosts 80 per cent of Australia's resources. The Northern Territory has 10 per cent, Western Australia 6 per cent, Queensland 3 per cent and New South Wales 1 per cent.

Around 9 per cent of Australia's economic demonstrated resources of uranium are inaccessible for mining:

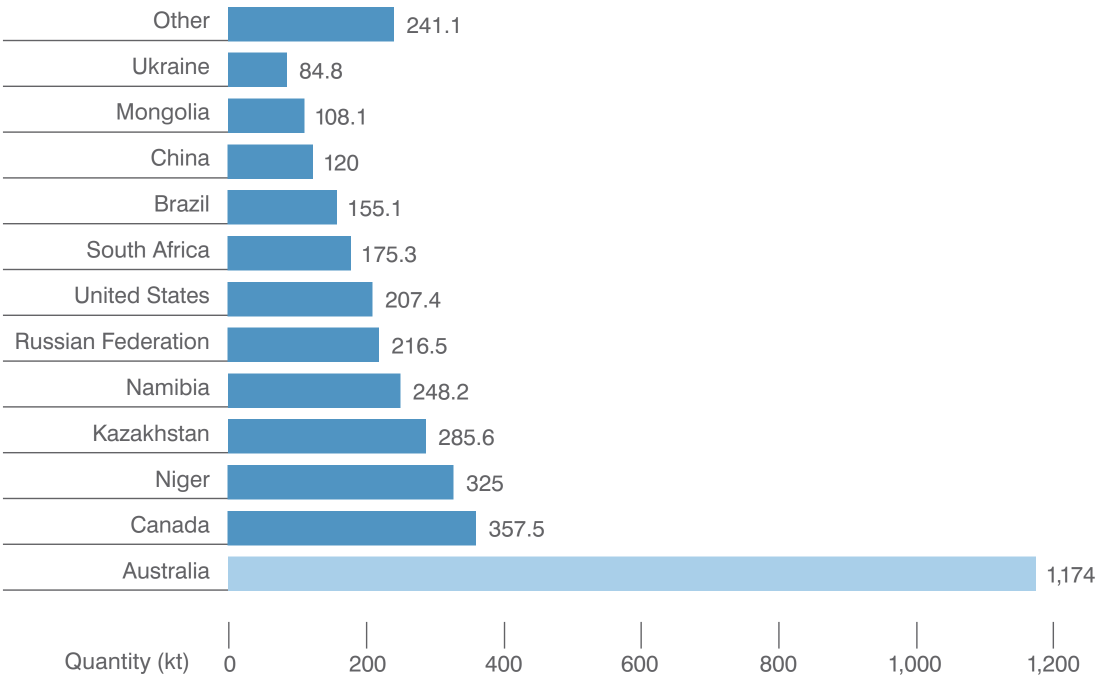
- The Jabiluka deposit is under a long-term care and maintenance agreement and will not be mined without agreement from the Traditional Owners
- The World Heritage Committee added the Koongarra Project Area to the Kakadu World Heritage Area in 2011 and the Australian Government incorporated the deposit into Kakadu National Park in 2013.[12]

Nevertheless, Australia's uranium resources have increased in recent decades, mainly as a result of ongoing drilling and evaluation of known deposits including Olympic Dam, Ranger 3 Deeps, the Beverley-Four Mile deposits, and deposits at Wiluna, Yeelirrie, Carnarvon and Westmoreland.

■ Ranger uranium mine, Northern Territory *(Energy Resources of Australia)*

CHART 1 **World Reasonably Assured Resources (RAR)**

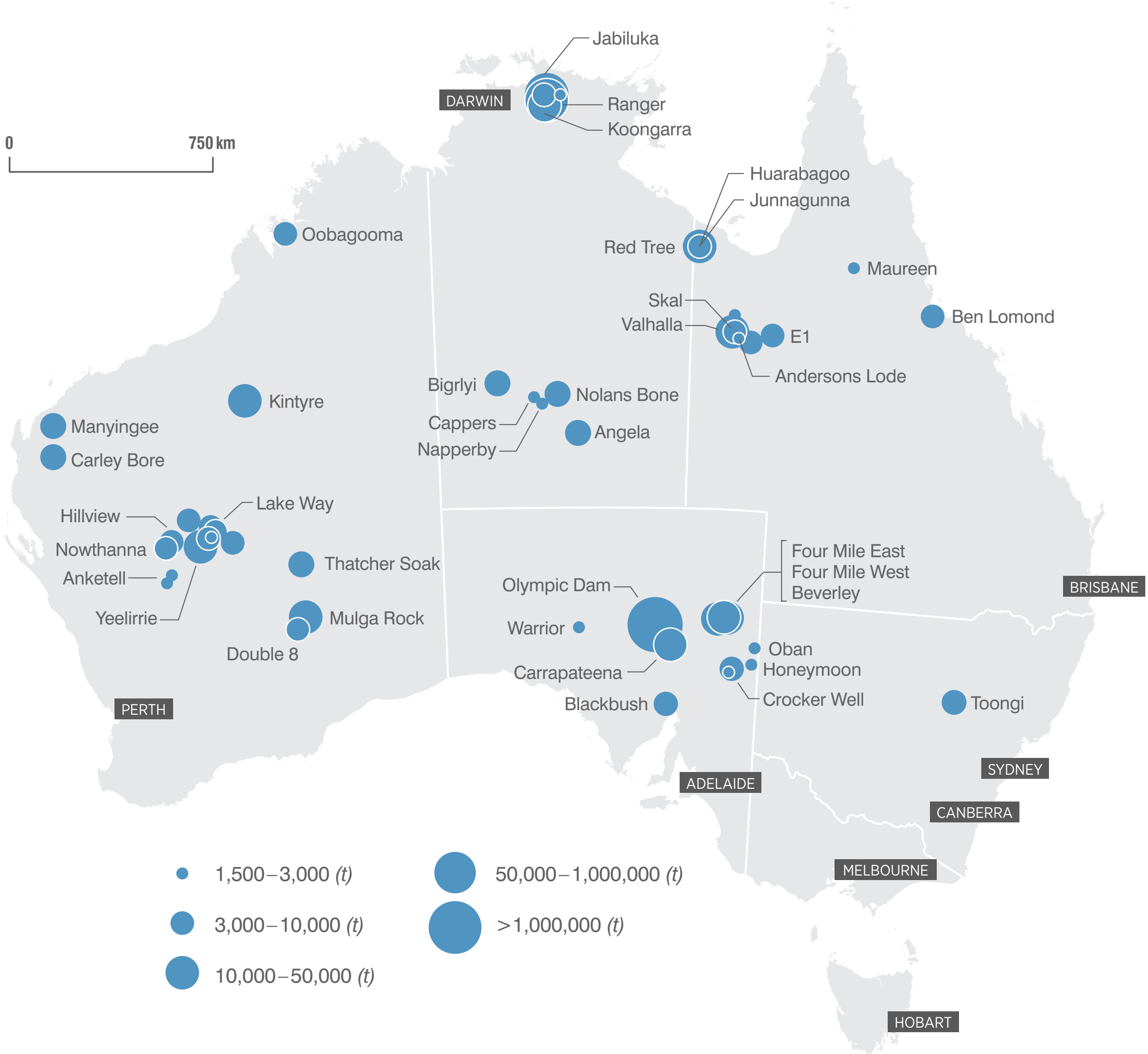
Source: Joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency[11]



Note: Recoverable resources as of 1 January 2013, tonnes U RAR < USD 130/kgU (i.e. approx. US$59/lbU).

CHART 2 **Uranium resource range (tonnes U)**
Total identified resources (RAR + Inferred)

Source: Geoscience Australia



Uranium resources by state

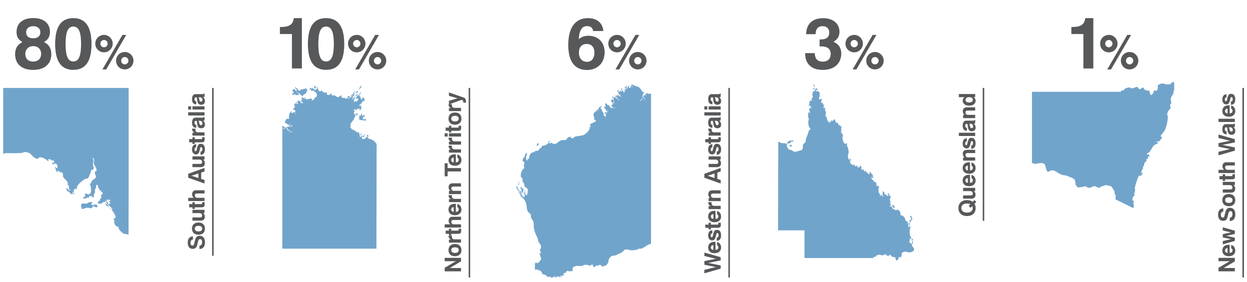
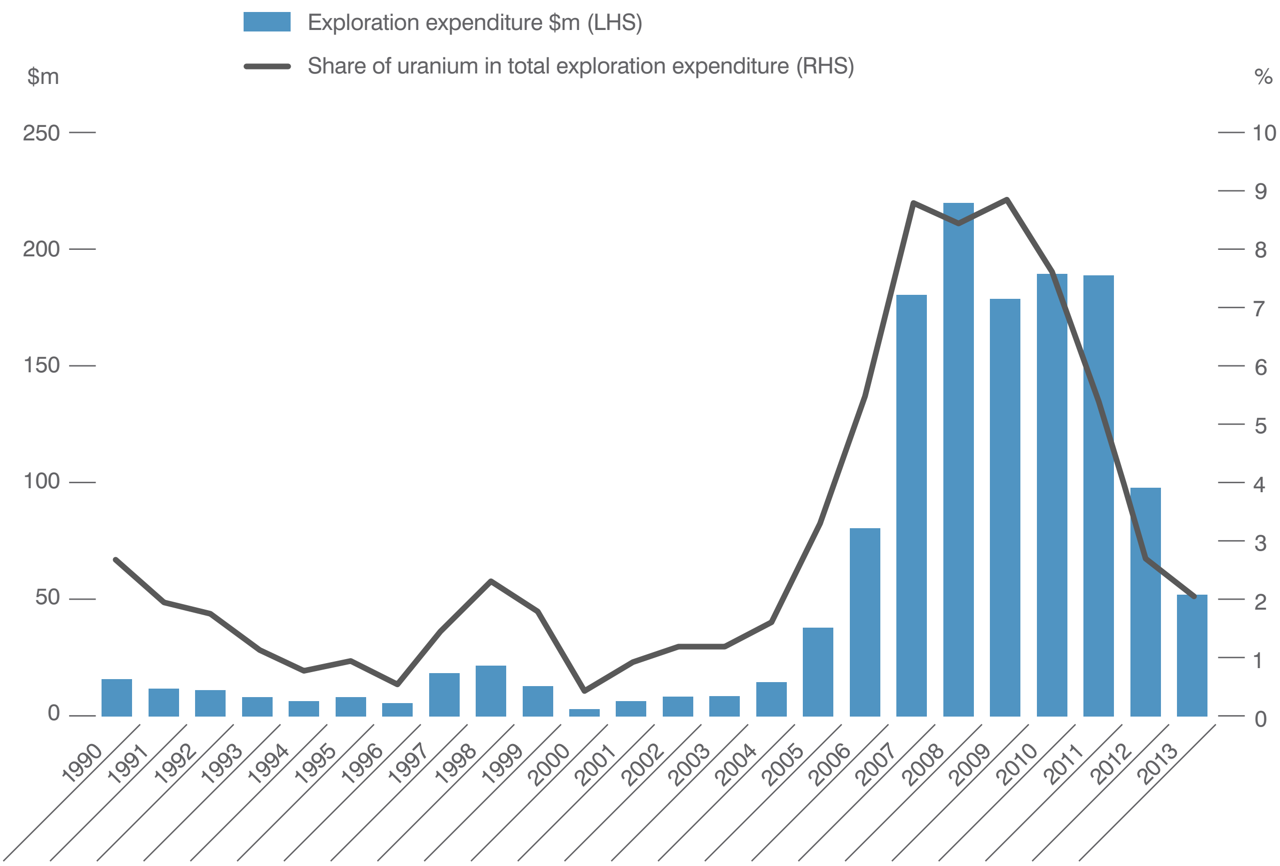


CHART 3 **Uranium exploration expenditure in Australia**

Source: Australian Bureau of Statistics



Exploration

Uranium exploration in Australia has been focused in four main areas:

- South Australia's Gawler Craton/Stuart Shelf and Frome Embayment
- Western Australia's Paterson Province, North Yilgarn and the Carnarvon and Canning Basins
- Northern Territory's Pine Creek and Arnhem Land regions
- Queensland's Mt Isa and Gulf of Carpentaria regions.[13]

According to the Australian Bureau of Statistics, uranium exploration expenditure in Australia was $52.3 million in 2013.[14]

The potential for new uranium discoveries in Australia is high. Geoscience Australia and the Bureau of Resources and Energy Economics reported in the most recent *Australian Energy Resource Assessment*:

> New pre-competitive data released by Geoscience Australia – notably the radiometric map of Australia and regional electromagnetic survey data – are providing a further stimulus to uranium exploration and discovery.[15] ■

AUSTRALIA: A SECURE AND RELIABLE SUPPLIER

AUSTRALIA HAS MINED URANIUM FOR THE PAST 70 YEARS.

In the 1930s uranium was a by-product of radium mining for medical purposes at Radium Hill and Mount Painter in South Australia.

In the period from the 1950s to early 1970s, uranium was mined primarily at Radium Hill, Mary Kathleen (Queensland), Rum Jungle (Northern Territory) and two sites in the South Alligator Valley (Northern Territory). They operated in accordance with the standards of the day either until ore reserves were exhausted or contracts completed.

In 1973, Australia ratified the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Australia supplies uranium solely for peaceful purposes such as civil nuclear power and nuclear medicine.

The development of civil nuclear power internationally stimulated a wave of activity and accelerating energy demand saw Australia become the world's second largest uranium producer from the mid-1990s to 2007. Production reached an all-time peak of 10,064 tonnes in 2004-05.

Although eclipsed by the rapid development of Kazakhstan's uranium industry since that time, Australian uranium production has been consistent and reliable over the past decade in response to export demand.

■ Stockpile ore, Ranger uranium mine, Northern Territory *(Energy Resources of Australia)*

CHART 4 **Global uranium production, 2013 (tU)**

Source: World Nuclear Association

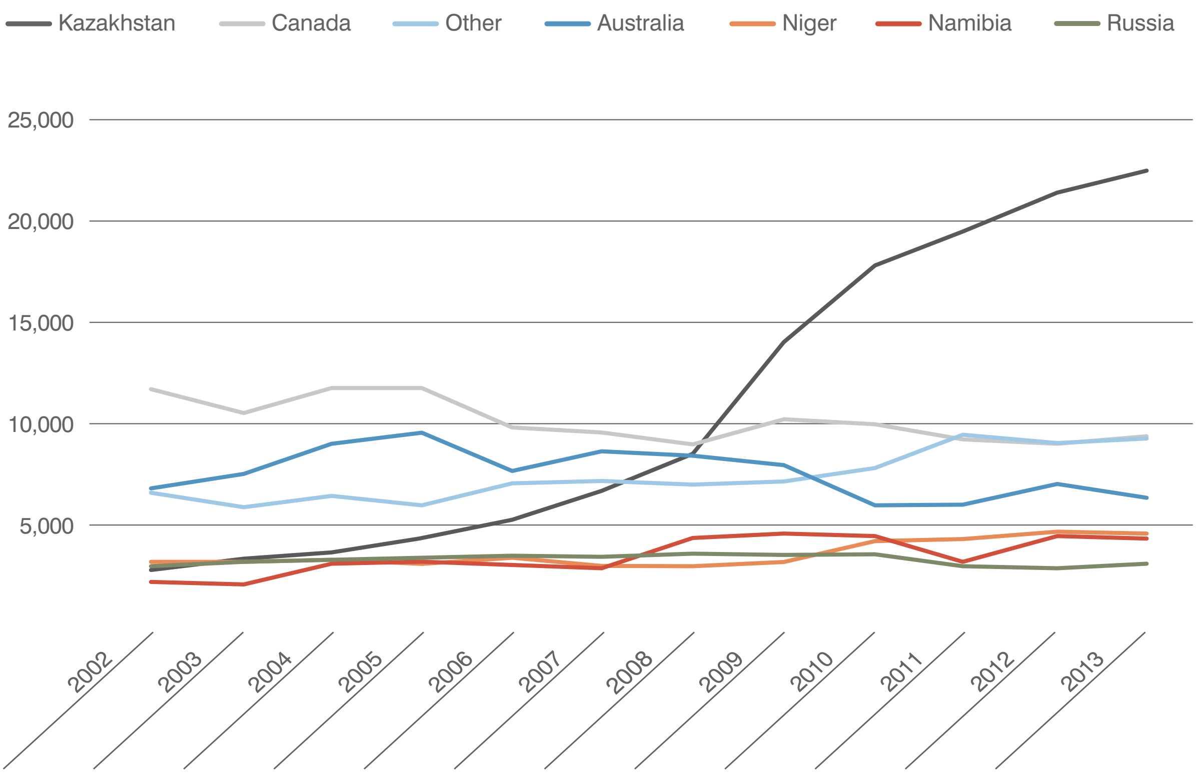


TABLE 1 **Australian mines**

Source: Australian Bureau of Agriculture and Resource Economics and Bureau of Resources and Energy Economics

Projects	Company	State	Start-up	Production capacity (kt/U_3O_8/year)	Capital expenditure ($A million nominal)	Current status
Olympic Dam 1999 expansion	BHP Billiton	SA	1999	4.3	1940[a]	Operating
Beverley ISR mine	Heathgate Resources	SA	2001	1.0	30	Not producing but processing loaded resin from Four Mile ISR well fields
Ranger radiometric sorting plant	Energy Resources of Australia	NT	2008	1.1	19	Operational
Ranger laterite plant	Energy Resources of Australia	NT	2009	0.4	44	Operating
Beverley North satellite ISR operations	Heathgate Resources	SA	2011	b	b	Not currently operating. The Pannikan Satellite Plant is currently used to load Four Mile uranium on resin for processing at Beverley
Honeymoon ISR mine	Uranium One	SA	2011	0.34	146	Care and Maintenance 1 April 2014
Four Mile ISR	Quasar Resources and Alliance Craton Explorer Joint Venture	SA	2014	c	120	Operating

a Capital expenditure covers total expansion of copper-gold-uranium-silver mining.
b Uranium-bearing resins from Beverley North ISR operations was processed at the Beverley plant to recover uranium.
c Uranium-bearing resins from Four Mile ISR operation is processed at the Beverley plant to recover uranium.

Uranium is Australia's second largest primary energy fuel type produced.[16] Production operates under a best practise regulatory framework reflecting modern expectations of environmental, employee and public safety standards.

Geoscience Australia projects that in the medium to long term, Australia's uranium production is expected to increase significantly.[17] The Bureau of Resources and Energy Economics and Geoscience Australia attribute this growth to Australia's 'stable commercial environment' and 'large low cost uranium resources, proposed new mines and increasing export demand'.[18]

The Australian uranium industry is assessing the feasibility of significant capital investment to expand existing mines and develop new projects. This investment is outlined in Table 2.

TABLE 2 **Uranium development projects**

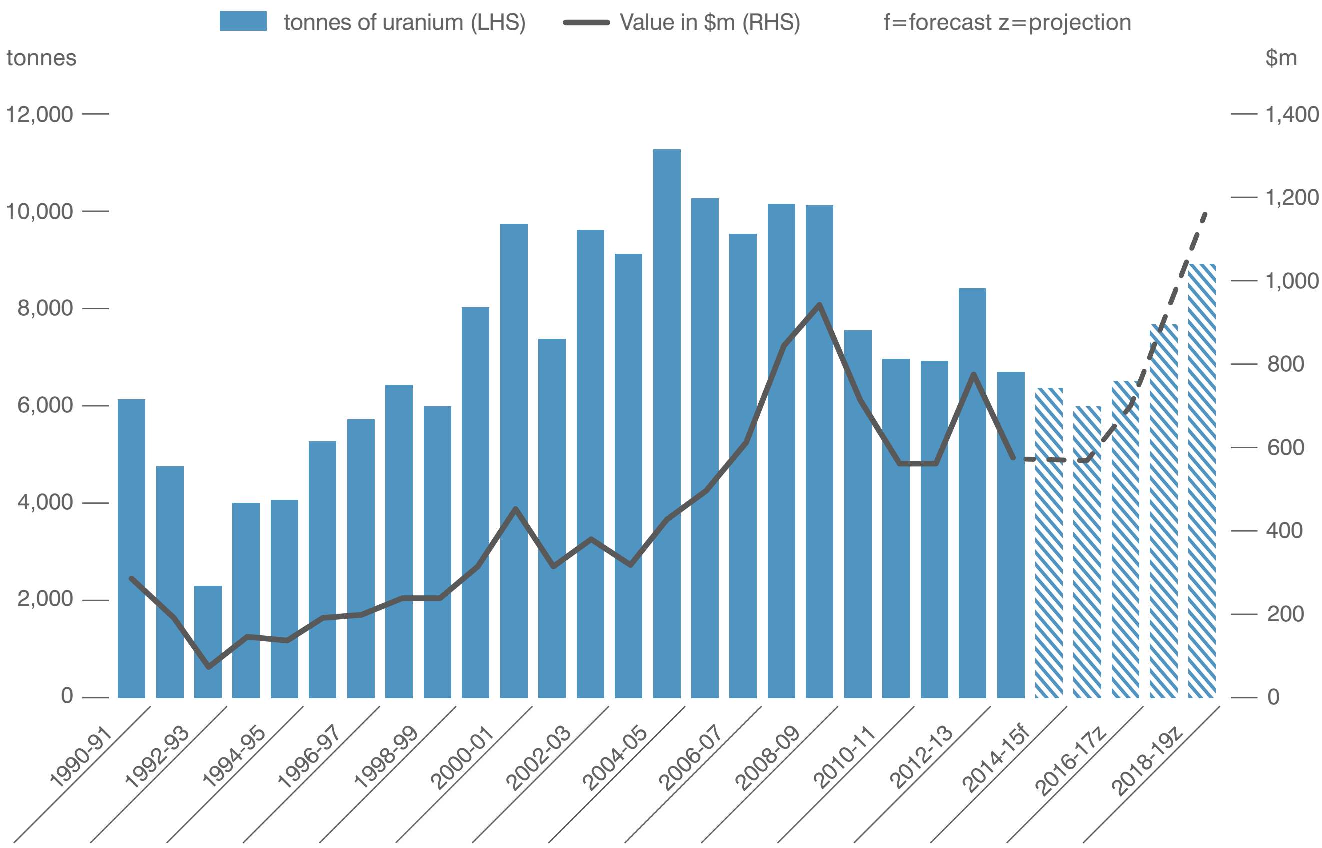
Source: Australian Bureau of Agriculture and Resource Economics and Bureau of Resources and Energy Economics, Draft EIS Energy Resources of Australia, Toro Energy Ltd ASX Release 31 Jan 2014, Energy and Minerals Australia Limited (Vimy Resources Limited) company presentation June 2013, Energy and Minerals Australia Limited (Vimy Resources Limited) company presentation Oct 2014

Project	Company	Location	Status	Potential production start	Capacity (kt/U_3O_8/year – nominal)	Capital ($A million – nominal)
Ranger 3 Deeps	Energy Resources of Australia	East of Darwin, NT	Pre-feasibility study underway, application for EIS underway	2015	2.5 – 3.6 (incl. production from stockpiled LG ore)	250 – 500
Wiluna	Toro Energy	South-east of Wiluna, WA	Feasibility study completed, environmental approvals granted	2017	1.0	315
Yeelirrie	Cameco	North of Kalgoorlie, WA	Under evaluation	2020+	3.5	NA
Kintyre	Cameco/ Mitsubishi Development	North-east of Kalgoorlie, WA	Recommended approval by WA EPA, under appeal awaiting Ministerial decision	2018+	3.6	500 – 1,000
Mulga Rock	Vimy Resources	North-east of Kalgoorlie, WA	Feasibility study underway	2017+	1.4	<300
Valhalla	Summit Resources/ Paladin Energy	North of Mt Isa, QLD	On hold, QLD Government recently removed the ban on uranium mining	2018+	4.1	250 – 500
Westmoreland	Laramide Resources	North-west of Burketown, QLD	On hold as for Valhalla	2018+	1.4	250 – 500
Olympic Dam Expansion	BHP Billiton	Roxby Downs, SA	Pre-feasibility study completed. Company announced that it would delay the expansion and investigate an alternative less capital-intensive design	NA	NA	NA

In the medium to long term, Australia's uranium production will increase significantly, reflecting Australia's large low cost uranium resources, proposed new mines and increasing export demand.

CHART 5 **Australia's uranium exports – volume and value**

Source: Bureau of Resources and Energy Economics



Exports

All of Australia's uranium production is exported. Stringent bilateral agreements specify that Australian uranium may only be used for peaceful purposes in civilian nuclear power reactors to generate electricity, and in other peaceful applications such as the manufacture of radioisotopes for medical applications.

These safeguards agreements ensure the countries to which Australia exports are committed to International Atomic Energy Agency (IAEA) requirements and international nuclear security standards.

Australian mining companies supply uranium under contracts to electricity utilities in the United States, Japan, China, the Republic of Korea, Taiwan and Canada as well as members of the European Union including France, Germany, Sweden and Belgium.

The latest country to sign a civil Nuclear Cooperation Agreement with Australia was India in September 2014, following agreements with Russia in 2010[19] and the United Arab Emirates in 2012. The UAE's civil nuclear power program is expected to begin operation in 2017.

Permits to export uranium are issued by the Department of Industry.

The Australian Safeguards and Non-Proliferation Office (ASNO) within the Department of Foreign Affairs and Trade (DFAT) ensures the effective operation of the Australian safeguards system, the physical protection and security of nuclear material and items in Australia. It carries out Australia's obligations under Australia's nuclear cooperation agreements with other countries and Euratom, and operates Australia's bilateral nuclear

In the past decade, uranium mining has contributed more than $6.5 billion in export revenue to the Australian economy.

cooperation agreements and monitors compliance with the provisions of these agreements.[20]

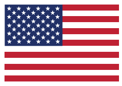
Australia's uranium exports totalled 6,701 tonnes in 2013-14. Export values totalled $622 million.[21] These results reflected production disruption at Ranger in the Northern Territory and lower global uranium prices.

In the past decade (2003 to 2013), uranium mining has contributed more than $6.5 billion in export revenue to the Australian economy.

Supported by growing production and world demand, Australia's uranium export volumes are projected to increase at an average annual rate of 10 per cent to total 8,900 tonnes in 2018-19. Export values are projected to increase at an average annual rate of 17 per cent to total $1.1 billion in 2018-19 (in 2014-15 dollars).[22] ■

Exporting uranium to the world

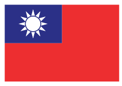
Australian mining companies supply uranium to electricity utilities in:


United States

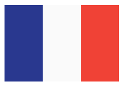

Japan


China


Republic of Korea


Taiwan


Canada


France


Germany

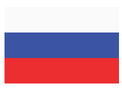

Sweden

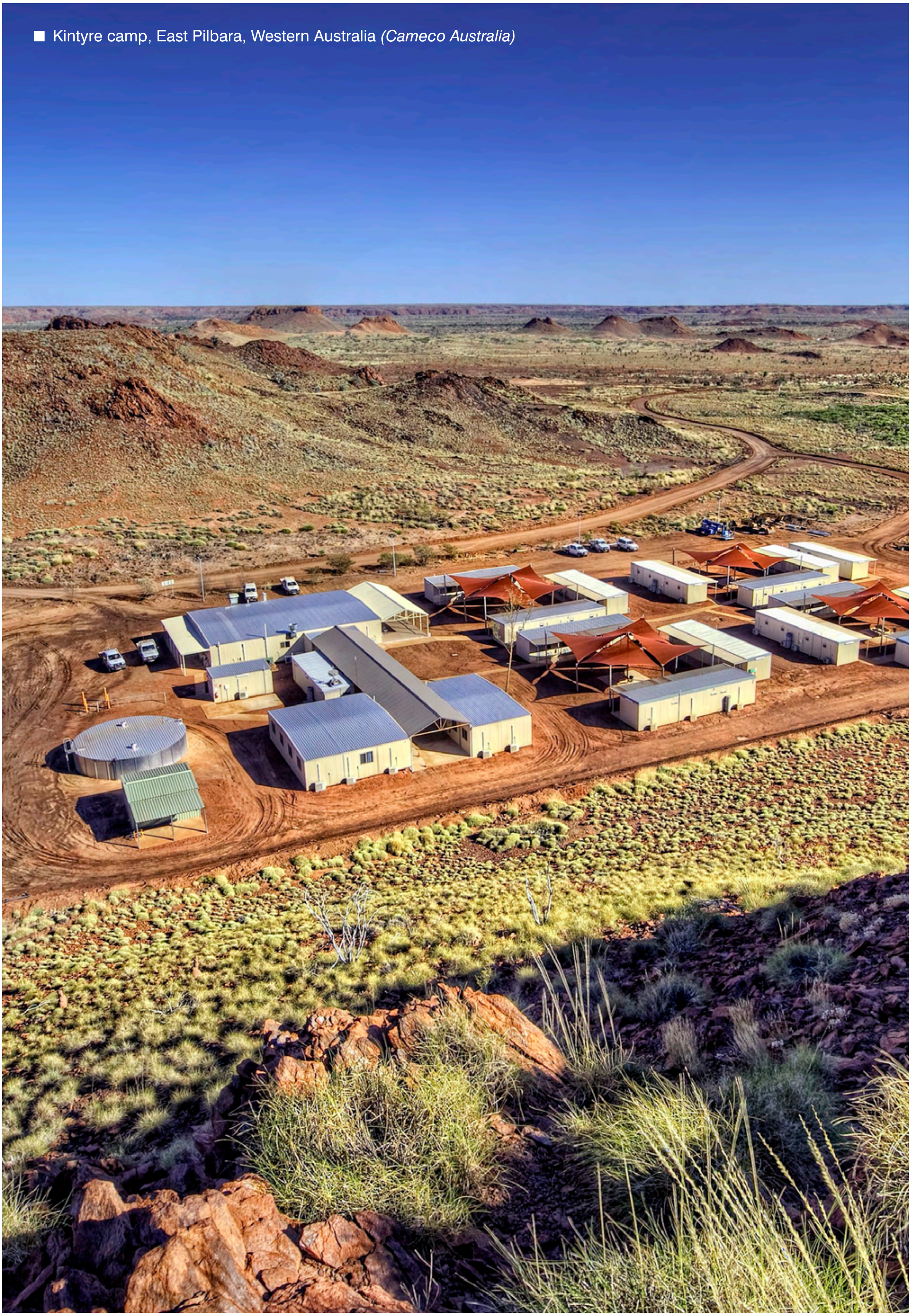

Belgium

The Australian Government also has civil Nuclear Cooperation Agreements with:


India (2014)


UAE (2012)


Russia (2010)



■ Kintyre camp, East Pilbara, Western Australia *(Cameco Australia)*

THE OPPORTUNITY FOR AUSTRALIA

AUSTRALIA IS A RELIABLE AND SECURE SUPPLIER OF URANIUM TO THE WORLD MARKET AND IS WELL PLACED TO MEET A SIGNIFICANT PROPORTION OF THE INCREASED DEMAND FOR URANIUM FOR USE AS AN ENERGY RESOURCE.

Australia's uranium industry generates approximately $620 million per annum in export revenue and approximately 4,000 jobs[21], based on capturing just 11 per cent share of the global uranium market. Yet, Australia possesses 32 per cent of the world's uranium resources. Based on today's demand, if Australia produced in line with its endowment, exports would be closer to $2 billion per annum generating potentially 10,000 jobs.

The factors that will affect realising the potential of expanding Australian uranium production and exports include:

- Political support for the generation of employment and export earnings
- Significant investment in exploring for new uranium discoveries
- The commercial feasibility of undeveloped deposits
- Creating improved access to port and shipping company options for exporting uranium
- Uranium mining prohibitions being lifted in New South Wales and Victoria.[24]

There are several major undeveloped deposits that may be developed if proven economically feasible and necessary approvals granted. Table 3 summarises the total ore reserves and mineral resources of the main undeveloped deposits as reported by resources companies.

TABLE 3 **Major undeveloped uranium deposits in Australia**

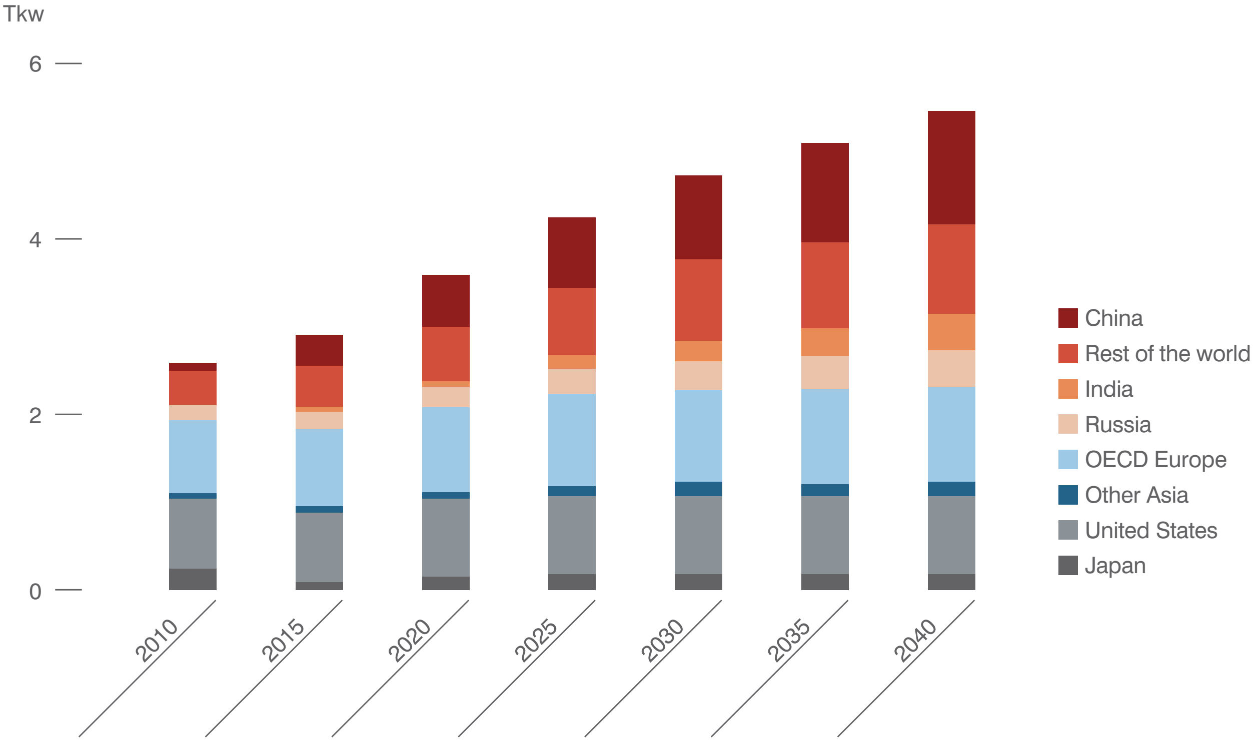
Source: Geoscience Australia, company reports, presentations and independent assessments

Deposits	Ore Reserves contained U_3O_8 (kt)	Minerals Resources contained U_3O_8 (kt)
Northern Territory		
Jabiluka 2	67.70	73.94
Koongarra		22.30
Bigrlyi		9.60
Angela		9.89
South Australia		
Four Mile West		18.70
Crocker Well and Mt. Victoria		6.74
Queensland		
Valhalla		34.6
Westmoreland (Redtree, Junnagunna, Huarabagoo, Sue & Outcamp)		25.12
Mt. Isa Region (Skal, Odin, Bikini, Andersons, Watta, Warwai, Mirrioola)		29.70
Western Australia		
Yeelirrie		52.50
Kintyre		29.39
Mulga Rock		28.30
Manyingee		10.90
Oobagooma		9.95
Wiluna (Centipede, Lake Way, Millipede, Dawson-Hinkler, Lake Maitland, Nowthanna)		34.65
Bennett Well		8.30
Total	**67.70**	**404.58**

Note: Ore reserves and mineral resources are company estimates.

CHART 6 **World net electricity generation from nuclear power by region, 2010-2040** (trillion kilowatt hours)

Source: Energy Information Agency



Growing demand for uranium

Between 1973 and 2012, nuclear power generation grew by an average over 6.5 per cent per year. In 2012, it generated 4.8 per cent of the world's primary energy consumption.[25]

Increasing demand for electricity, rising fossil fuel prices, energy security and concern around greenhouse gas emissions have stimulated new interest in nuclear power and consequently large increases in uranium demand are now projected.[26]

70 new reactors were under construction globally in December 2014:

- China has 26 plants under construction and a further 180 planned or proposed
- India has 21 reactors, is building six new ones and has 57 others planned or proposed
- In addition to the 437 operable reactors and 70 under construction worldwide, there are 179 planned reactors and a further 308 proposed reactors.[27]

The Energy Information Administration (EIA) projects electricity generation from nuclear power worldwide to more than double from 2,620 billion kilowatt hours in 2010 to 5,492 billion kilowatt hours in 2040.[28]

The OECD, Nuclear Energy Agency and International Atomic Energy Agency have together concluded:

> World reactor–related uranium requirements by the year 2035 (assuming a tails assay of 0.25 per cent) are projected to increase to a total of between 72,200 tonnes Uranium per annum in the low case and 121,100 tonnes Uranium per annum in the high case, representing increases of about 20 per cent and 105 per cent, respectively, compared with 2013 requirements.[29]

The International Energy Agency also projects strong uranium demand growth, especially in China:

> In the New Policies Scenario, demand for uranium for nuclear power plants increases from 56,000 tonnes in 2012 to 106,000 tonnes in 2040. The most significant increase comes from China, which becomes the world's largest uranium consumer around 2035, with its share of global demand rising from 4 per cent to 25 per cent.[30] ■

Box 1

Creating opportunities through partnerships

LOCAL PARTNERSHIPS ARE CREATING OPPORTUNITIES FOR STUDENTS THROUGH A SCHOOL-BASED APPRENTICESHIP PROGRAM.

An education partnership between Energy Resources of Australia (ERA), the Northern Territory Department of Education and the West Arnhem College is delivering opportunities for students to advance from apprenticeships to traineeships and employment in the uranium industry.

Under the education partnership, ERA actively engages in the schools-based apprentice program to identify and skill tradespeople from the local region.

Seven students from West Arnhem College joined the ERA workforce in 2014 as part of a successful school-based apprenticeships and traineeships education partnership.

For the first time, two Year 12 graduates from West Arnhem College's Gunbalanya campus, Jai Nabulwad and Kristy Garnarradj, commenced full-time traineeships at ERA. Both Jai and Kristy had previously completed work experience at ERA, and the quality education and training opportunities have led to real employment and career options. The other five students recently commenced school-based apprenticeships with ERA.

College Director Mark Monaghan said the annual intake offers part-time instruction for school-based apprentices, and full-time employment for trainees, at the Ranger mine.

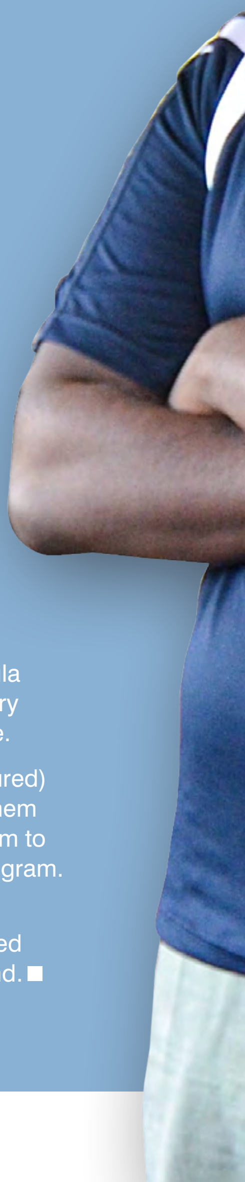
'The school-based apprentices are senior students who train at the mine for two days each week, and study at the West Arnhem College Jabiru campus. After they finish Year 12 the apprentices may go on to train with ERA full-time,' he said.

'West Arnhem College has trade training centres at Jabiru and Gunbalanya campuses and trainers to complement ERA's on the job instruction.'

In July 2014 two school-based apprentices from the Northern Territory's remote Cobourg Peninsula were given a unique opportunity to explore tertiary education opportunities and life away from home.

Siblings Tristan and Shierese Cunningham (pictured) flew to Trinity College, Melbourne with West Arnhem College Child and Family Leader Michelle McColm to participate in a Young Leaders Social Justice Program.

The visit was an extension of Trinity College's established Indigenous programs and has allowed the students to experience university life first-hand. ■



Seven students from West Arnhem College joined the ERA workforce in 2014 as part of a successful school-based apprenticeships and traineeships education partnership.

■ **ERA school-based apprentices** Tristan Cunningham and Shierese Cunningham travel to Trinity College with West Arnhem College Child and Family Leader Michelle McColm

RELEASING URANIUM'S ENERGY

'Our future prosperity depends on cheap abundant reliable supplies of electricity... Nuclear's power-density advantages simply cannot be ignored.'

Robert Bryce
Senior Fellow, Center for Energy Policy and the Environment, Manhattan Institute[31]

99.3 per cent of uranium is U-238. Most of the balance is U-235. Both are mildly radioactive. Naturally occurring uranium is typically milled at the mine site to produce uranium oxide. This is the form in which Australia exports uranium.

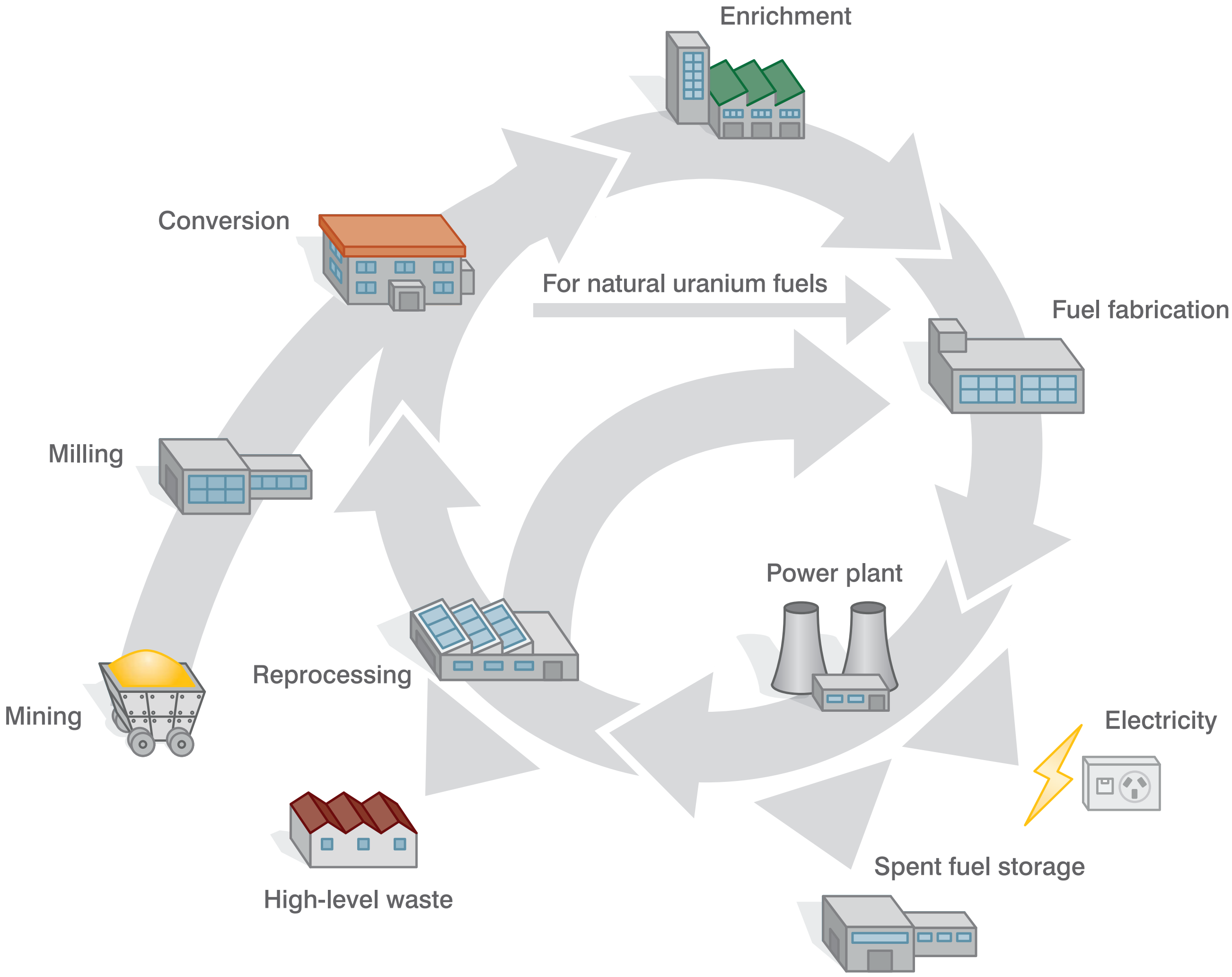
The nuclear energy cycle begins with the conversion of uranium oxide into uranium hexafluoride gas (UF_6). The UF_6 gas is drained into 14-tonne metal cylinders and then delivered to the enrichment plant. Although some reactors do not require uranium to be enriched, for most reactors the concentration of the U-235 isotope needs to be enriched from 0.7 per cent to between 3.5 and 5 per cent U-235.

At the enrichment plant, the difference in physical properties of U-238 and U-235 is used to separate the UF_6 gas into two streams: U-235 is enriched to the required level with the end product known as low-enriched uranium. The other product stream from the enrichment process is depleted in U-235 and is called 'tails', or simply depleted uranium. The enriched uranium is taken to a fuel fabrication facility where it is pressed and 'baked' at 1,400°C. (UO_2's melting point is 2,865°C.) The pellets are then encased in metal tubes to form fuel rods and arranged into a fuel assembly ready for introduction into a reactor.

Inside the nuclear reactor, the uranium fuel is assembled in such a way that a controlled fission chain reaction can be achieved. The heat created by splitting the U-235 atoms is then used to make steam which spins a turbine to drive a generator, producing electricity.[32]

CHART 7 **Schematic of the nuclear fuel cycle**

Source: Australian Government, Department of the Prime Minister and Cabinet



Most countries currently using nuclear power use an 'open fuel cycle' also known as 'once through' cycle. Fuel is used in the reactor to generate power, then removed from the reactor during periodic refuelling. As spent fuel is initially highly radioactive and self-heating, it is stored in dedicated water ponds for some years to allow the radioactivity to decline and the material to cool sufficiently for long-term storage. After a period of three years or more, the spent fuel assemblies may be moved to 'dry storage' to await final deep geological disposal. In some countries, such as France, the spent fuel is reprocessed, with the uranium and plutonium being removed for reuse in fresh fuel and the remaining waste products being solidified for final deep geological disposal.[33]

Climate change and the role of nuclear energy

The potential for nuclear energy to grow lies in its contribution to low emission energy generation.

A major study was undertaken for the Department of the Prime Minister and Cabinet of the Australian Government by the Centre for Integrated Sustainability Analysis, The University of Sydney, Australia. It concluded that the greenhouse gas intensity of nuclear power is around 60-65 g CO_2-e/$kWh_{el.}$

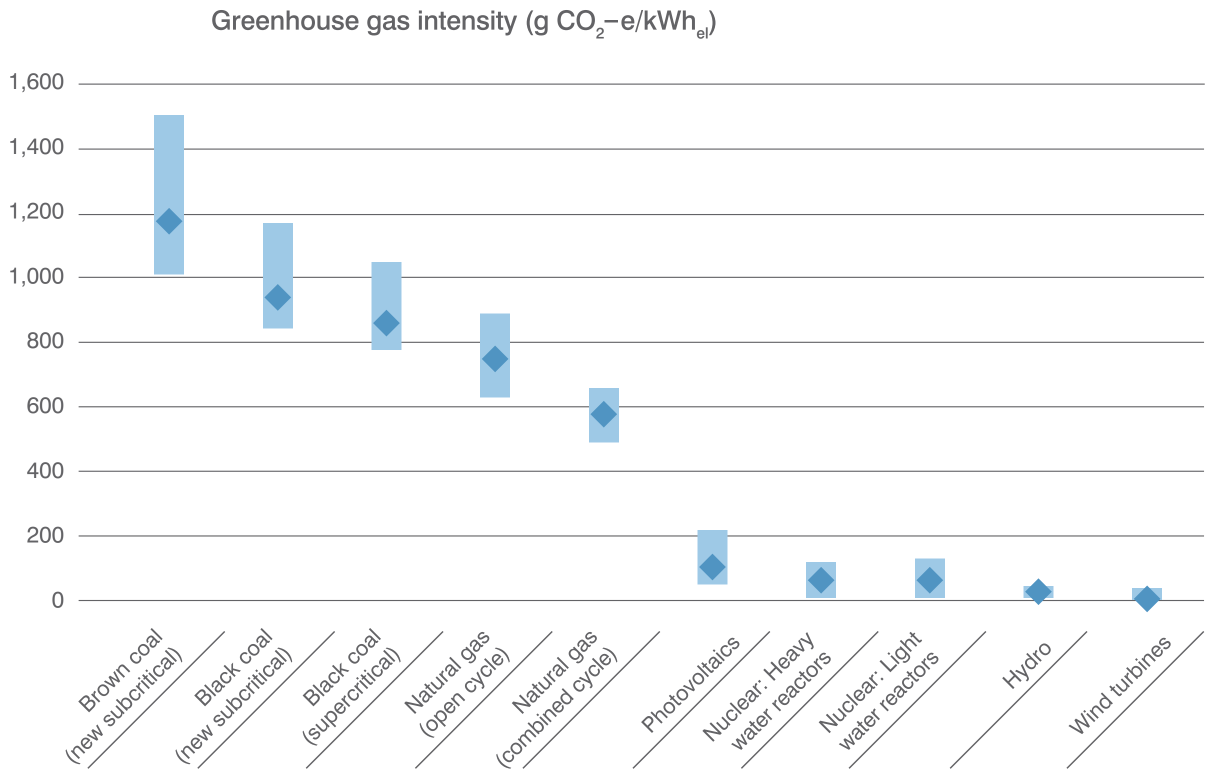
A comparable analysis was undertaken for a number of other electricity technologies. As with the methodology for the nuclear case, a range of literature values and estimates were used to examine the performance of technologies in an Australian context, assuming new capacity were to be installed at close to world's best practice. These results are in Chart 8.

Nuclear energy's low lifecycle emissions profile is widely recognised. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Synthesis Report states that modelled scenarios *likely* to limit warming include:

> …more rapid improvements in energy efficiency and a tripling to nearly a quadrupling of the share of zero- and low-carbon energy supply from renewable energy, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by the year 2050[35]

CHART 8 **Lifecycle emissions of different electricity generating technologies[34]**

Source: Centre for Integrated Sustainability Analysis, The University of Sydney



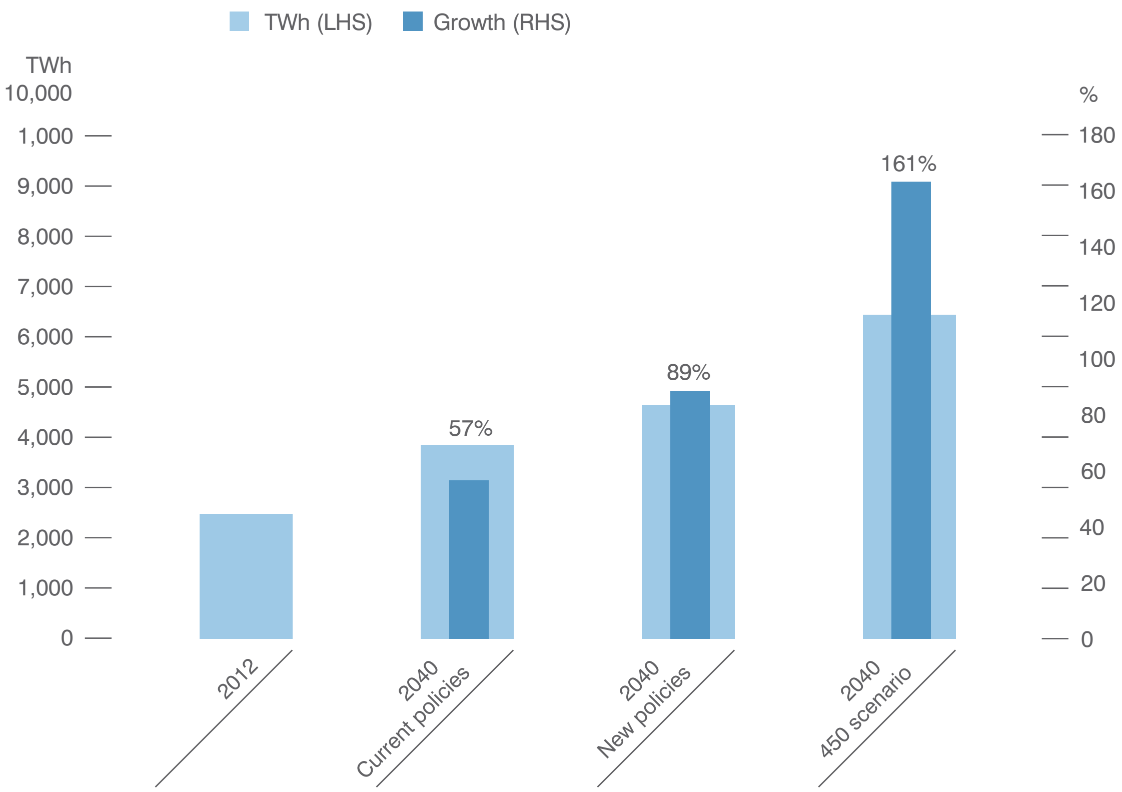
The most recent World Energy Outlook (WEO) by the OECD's International Energy Agency (IEA) presents energy projections to 2040. It covers the prospects for all energy sources, regions and sectors and an assessment of energy use on climate. Three scenarios are presented: the Current Policies Scenario; the New Policies Scenario (the central case) and the 450 Scenario which seeks to limit the long-term increase in the global average temperature to two degrees Celsius. In all three scenarios, nuclear power generation is projected to grow substantially: 57 per cent in the Current Policies Scenario; 89 per cent in the New Policies case; and 161 per cent in the 450 Scenario.[36]

In November 2014, the US-China Joint Announcement on Climate Change specifically noted nuclear energy's potential as a critical component of the energy mix in a climate constrained world:

> The two sides intend to continue strengthening their policy dialogue and practical cooperation, including cooperation on advanced coal technologies, nuclear energy, shale gas and renewable energy, which will help optimize the energy mix and reduce emissions, including from coal, in both countries.[37]

CHART 9 **International Energy Agency nuclear energy projections 2012-2040**

Source: International Energy Agency

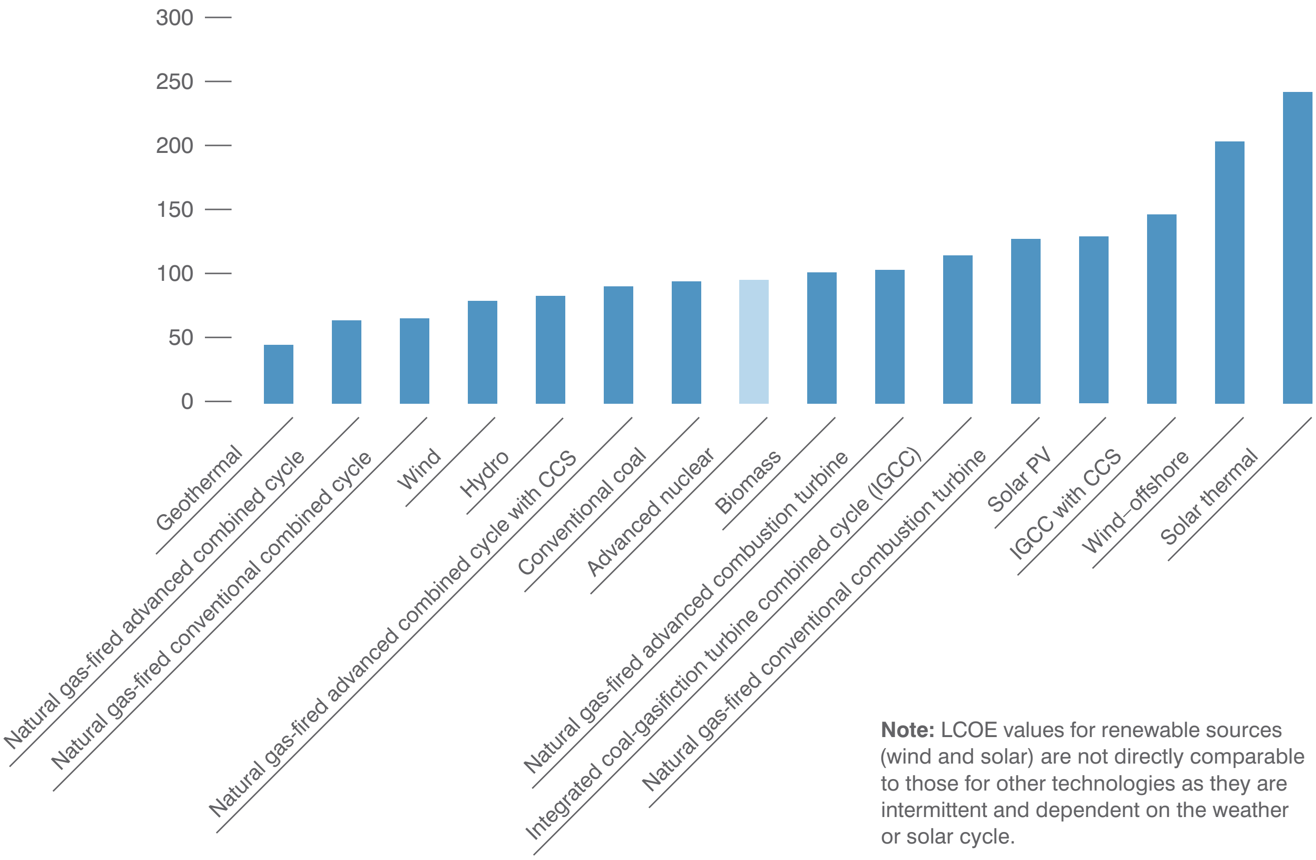


> "I really believe nuclear power has a place in the mix for Australia for all sorts of reasons: we are a geologically benign environment, we've got a large part of the world's uranium, we are technically smart and we are committed to moving to a cleaner energy mix."

Ziggy Switkowski,
RMIT Chancellor[39]

CHART 10 **US average levelised for plants entering service in 2019** (2012 $/MWhr)

Source: US Energy Information Administration



Note: LCOE values for renewable sources (wind and solar) are not directly comparable to those for other technologies as they are intermittent and dependent on the weather or solar cycle.

A clean and cost effective option

The US Energy Information Administration (EIA) has calculated the average levelised costs per unit of output for generating technologies for projects modelled to be brought on line in 2019. Nuclear featured competitively.[38]

Levelised cost of electricity (LCOE) represents the per-kilowatt hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs include capital costs, fuel costs, fixed and variable operations and maintenance costs, financing costs, and an assumed utilisation rate for each plant type. ■

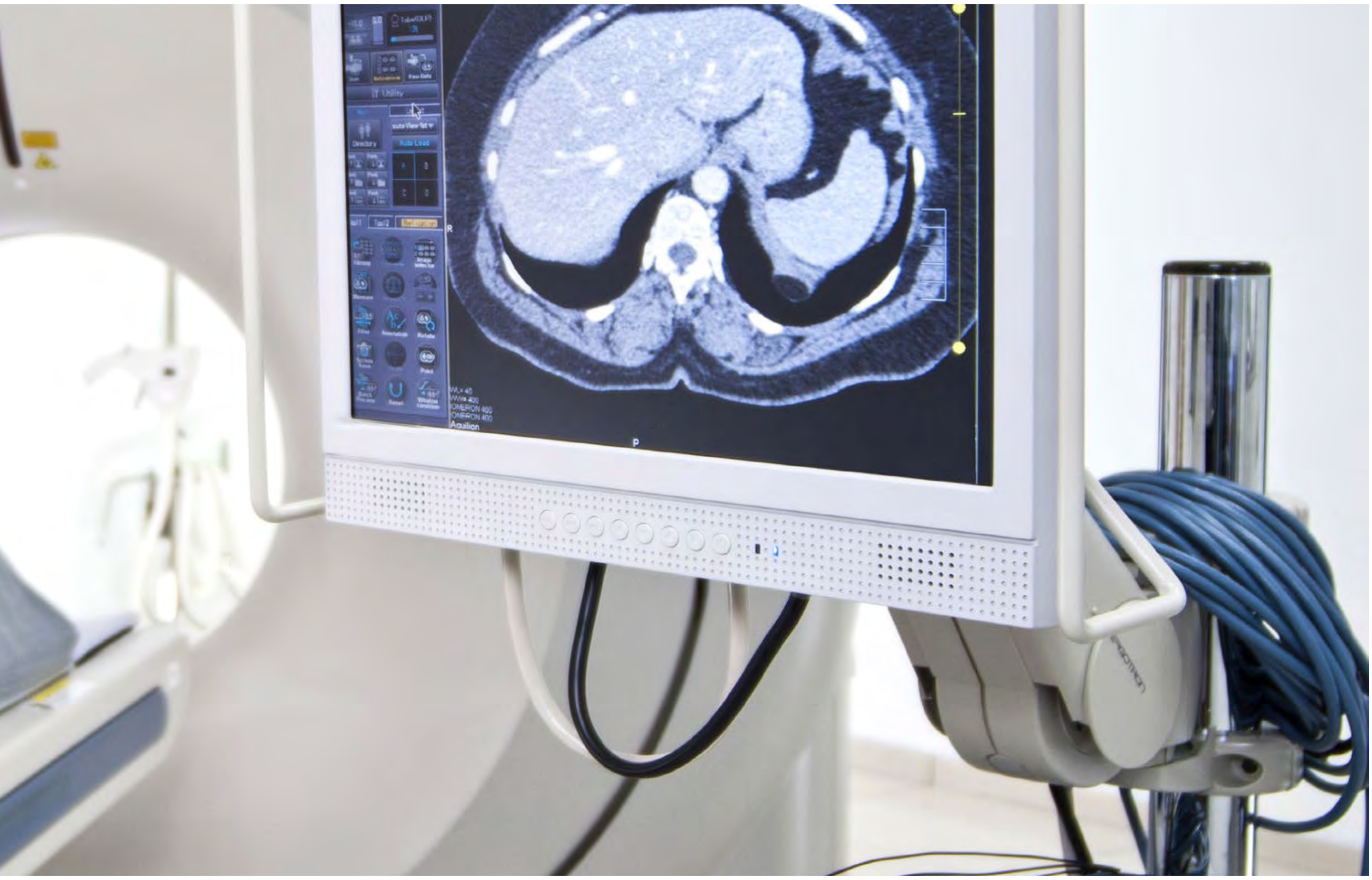
■ AREVA's Belleville nuclear power plant, France *(Philippe Bauduin)*

URANIUM'S PLACE IN NUCLEAR MEDICINE

NUCLEAR MEDICINE IS A VITAL PART OF MODERN HEALTHCARE.

About one-third of all hospital procedures involve radiation or radioactivity to diagnose, treat and prevent disease. These procedures are safe, effective and do not require anaesthetic. They are employed in a range of medical specialties, from paediatrics to cardiology and psychiatry.

Nuclear medicine uses safe levels of radiation from radioactive tracers produced from uranium. The tracers, or 'radiopharmaceuticals', are injected, inhaled or digested. They emit gamma rays which are digitally



On average, one in two Australians will need a nuclear medicine scan during his or her lifetime.

recorded as images by which doctors can determine if the body is functioning normally. The tracers rapidly lose their radioactivity and are quickly and naturally eliminated from the body.

On average, one in two Australians will need a nuclear medicine scan during his or her lifetime. Scans using radiopharmaceuticals commonly diagnose heart, thyroid, lung and kidney conditions and diagnose infection, tumours, fractures and sports injuries.[40]

Technetium-99, which is sourced from uranium, is the most common radioisotope used in diagnosis. It is used in some 40 million procedures per year which is 80 per cent of all nuclear medicine procedures worldwide. In Australia there are about 560,000 nuclear medicine procedures per year – 470,000 of these use reactor isotopes.[41]

In addition to its diagnostic applications, nuclear medicine also plays an important therapeutic role. It is commonly used to treat overactive thyroids and thyroid cancer. Radiopharmaceuticals are also injected into joints, to treat certain types of arthritis and are providing pain relief for sufferers of bone cancer.

Australia is one of the few nations that produce significant quantities of radioisotopes used in medical procedures. The radiopharmaceuticals are manufactured from uranium at Lucas Heights in Sydney's southern suburbs by the Australian Nuclear Science and Technology Organisation (ANSTO) using its OPAL reactor. The reactor operates on the same principle as power reactors, with fuel enriched in U-235 undergoing a fission reaction. However, research reactors are engineered to produce excess neutrons, rather than heat.

ANSTO's radiopharmaceuticals are supplied to nuclear medicine centres across Australia and are exported to the US, China, Japan and South Korea.[42] These exports currently generate $10 million in export revenue. This is forecast to triple after 2016 with the opening of ANSTO's new nuclear medicine processing facility.[43] ■

THE SAFE PRODUCTION OF URANIUM

Health and safety

Uranium emits low levels of radiation which need to be managed in order to protect uranium workers and the public from potentially harmful effects. The principles, regulation and practice of radiation protection in Australia draw on internationally-developed and recognised scientific research and application over a long period. The uranium industry has thoroughly developed best-practice systems and processes for minimising the radiation hazard.

Natural radiation

Radiation exists naturally in the environment from both cosmic and terrestrial sources. Most living things also have internal radioactive isotopes.

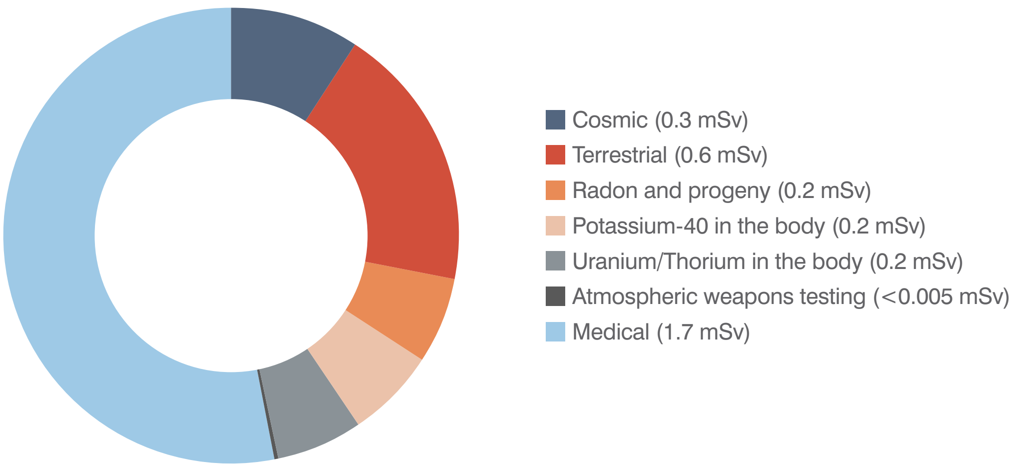
A measure of total radiation dose received is expressed in the unit Sievert(Sv) or fractions according to the metric system: a millisievert (mSv) is one-thousandth of a Sievert; a microsievert (μSv) is one-millionth of a Sievert.

There is considerable variation in the background radiation levels throughout the world. The world average is 2.4 mSv per year and the average Australian background radiation dose is around 2 mSv per year.[44]

Due to the presence of local igneous granite, which naturally contains more uranium than other rocks, general background radiation in Cornwall in the United Kingdom is 7.8 mSv per year.[45]

CHART 11 **Relative annual per capita dose to the Australian population from the various radiation sources**

Source: Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)



Radiation exists naturally in the environment from both cosmic and terrestrial sources. Most living things also have internal radioactive isotopes.

Radiation protection

The risks associated with radiation depend on a number of factors including the amount of exposure. The most hazardous kind of exposure is an acute dose, a high dose of radiation delivered over a short period, from a few hours to a few days.

The principles, regulation and practice of radiation protection in Australia draw on internationally-developed and recognised scientific research and the work of the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Radiation protection regulations are based on a model of how radiation affects human health. A model is needed because the risk is small at low doses of radiation and there are not enough observed cases of harm to confirm the risk, or rule it out. The model presumes there is always some risk, even at very low doses, with the risk being proportional to the dose. As a precaution, unnecessary exposures to radiation should be avoided. This is known as the principle of optimisation of protection.[46]

In Australia, standards for radiation protection of the public and workers are set by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The annual dose limit for members of the public is 1 mSv over and above background radiation doses or doses from medical procedures. Where it is expected that a worker will be exposed to radiation as a result of their employment, the prescribed limit is 20 mSv per year averaged over five years, and not more than 50 mSv received in any one year. On average, the typical exposure to workers in industries currently registered in the Australian National Radiation Dose Register (ANRDR) is significantly less than the prescribed dose limits.

TABLE 4

Sources of radiation exposure
(typical dose)

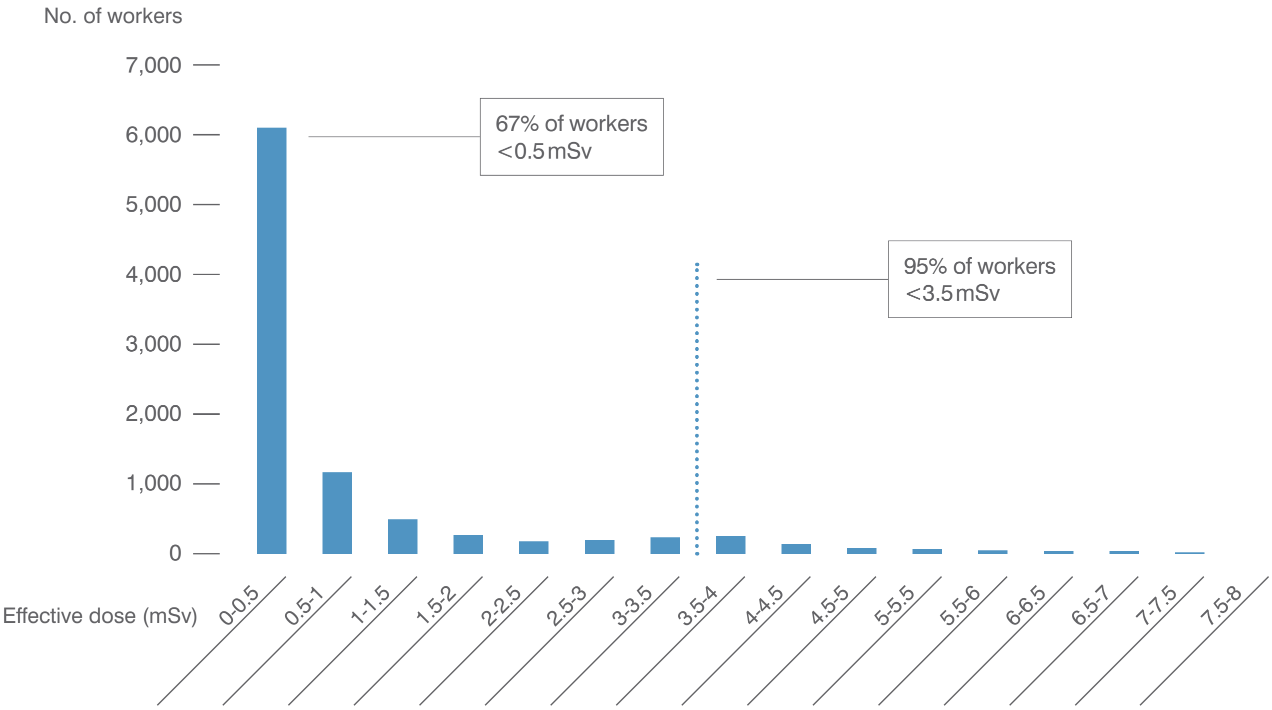
Source: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

CT scan	**10** mSv
Natural background Annual dose	**2.4** mSv
Nuclear worker Annual dose	**1** mSv
Mexico City (2,300m) Annual cosmic radiation	**0.8** mSv
Sea level Annual cosmic radiation	**0.4** mSv
Chest x-ray	**0.05** mSv
Aeroplane flight 10 hours	**0.03** mSv

In 2013, approximately 95 per cent of workers received a dose less than 3.5 mSv per year. 67 per cent of workers received a dose below 0.5 mSv per year.

CHART 12 **Annual dose distribution for all Australian uranium mine workers, 2013**

Source: ARPANSA



Recording workers' radiation dose histories

The radiation dose histories of all uranium mine workers are recorded on the Australian National Radiation Dose Register (ANRDR). More than 31,700 individual workers from the uranium mining industry are recorded on the database which is maintained and managed by ARPANSA.

The register tracks a worker's cumulative dose based on data provided by the employer. It assists in minimising the possibility of a worker receiving a dose greater than the Australian dose limit when moving from one employer to another. The data is available to workers and is also used to generate annual statistics relating to exposure trends to assist in the optimisation of radiation protection.[47]

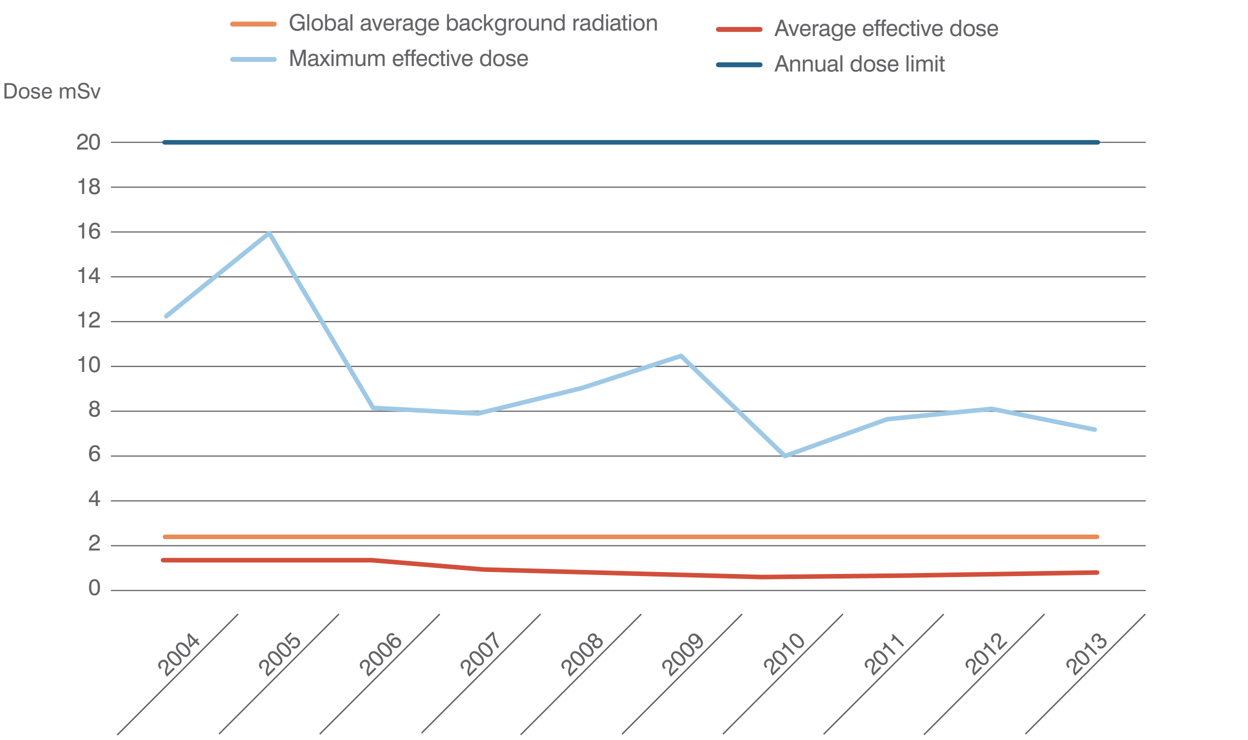
Analysis of ANRDR data in July 2014 found the average and maximum annual effective doses trended downwards over the period 2004 to 2013 and the average dose was less than a tenth of the annual dose limit.

Doses received by workers are well below the prescribed limit of 50 mSv in any one year and 20 mSv per year averaged over 5 years. ■

Doses received by workers are well below the prescribed limit of 50 mSv in any one year and 20 mSv per year averaged over 5 years.

CHART 13 **Average and maximum effective dose trends for Australian uranium mine workers, 2004-13**

Source: ARPANSA



Box 2

Connecting cultures: Kintyre Project Indigenous Land Use Agreement

CAMECO IS ONE OF THE WORLD'S LARGEST URANIUM PRODUCERS WITH OPERATIONS IN CANADA, AMERICA, CENTRAL ASIA AND AUSTRALIA.

■ Hiring and training local Martu people from nearby communities remains a priority, East Pilbara, Western Australia *(Cameco Australia)*

Cameco has been actively exploring for uranium in Australia since 1996 and is involved in a number of projects, including two of Australia's largest undeveloped uranium deposits, Kintyre and Yeelirrie.

As Canada's largest industrial employer of Aboriginal people, the company respects Indigenous culture, heritage, values and beliefs and is committed to making a positive difference in the communities in which it operates.

Cameco understands the importance of a long term approach to community engagement. For more than 25 years, the company's focus has been on building relationships and trust with local people, through open communication and active engagement.

When Cameco acquired the Kintyre project in the East Pilbara region of Western Australia in 2008, it began working with the Western Desert Lands Aboriginal Corporation (WDLAC), the prescribed body corporate for the Martu people, and Murdoch University to develop educational material about uranium mining. The goal was to make highly technical terms and concepts straight forward and easy to understand, so the Martu could learn about the uranium industry in their own language.

■ From Australia's Western Desert to Canada's Northern Saskatchewan *(Cameco Australia)*

Cameco met regularly with local Martu communities and learned, especially from the elders, the significance of Martu culture and heritage, and the importance of the land.

In addition, Cameco met regularly with local Martu communities and learned, especially from the elders, the significance of Martu culture and heritage, and the importance of the land. Cameco and WDLAC completed a social impact study and began training and building local business capacity.

However, the Martu remained skeptical about uranium mining so Cameco invited 11 Martu leaders to Canada to see Cameco's operations and speak directly with Indigenous peoples, some who had families that had worked for Cameco for two generations.

Noeletta Lee was a member of the delegation who made the trip from Western Desert to northern Saskatchewan. She says her perception and understanding of uranium mining were completely changed.

'It was not what I was expecting at all. We saw firsthand how Cameco rehabilitated the land after mining. It was so green, with so many trees and new growth.

'In the desert, the main thing we worry about is water. We know water is used to process uranium and we were worried this could affect our water supply. We were able to see how the water is recycled and safely put back into the river system.

'It was the trip of a lifetime. We got to see every stage of the mining operations, from mining to processing and rehabilitation. We sat down and talked to the First Nation elders and asked them questions about mining and how it affected their country. They live like us. There is a mine, yet people still hunt and gather and live their traditional lives. We were able to learn a lot from them.'

Cameco and the Martu signed an Indigenous Land Use Agreement (ILUA) in October 2012. It was the culmination of more than three years of relationship building with the Martu and provides for a range of business, employment and cultural and community development initiatives which ensure the Martu have a shared stake in the future of the mine. ■

■ Arid Recovery, Olympic Dam, South Australia *(BHP Billiton)*

ENVIRONMENTAL PROTECTION

ALL MINING HAS AN ENVIRONMENTAL IMPACT. AUSTRALIA'S REGULATORY FRAMEWORK MANAGES THIS RISK AND MODERATES THE IMPACTS.

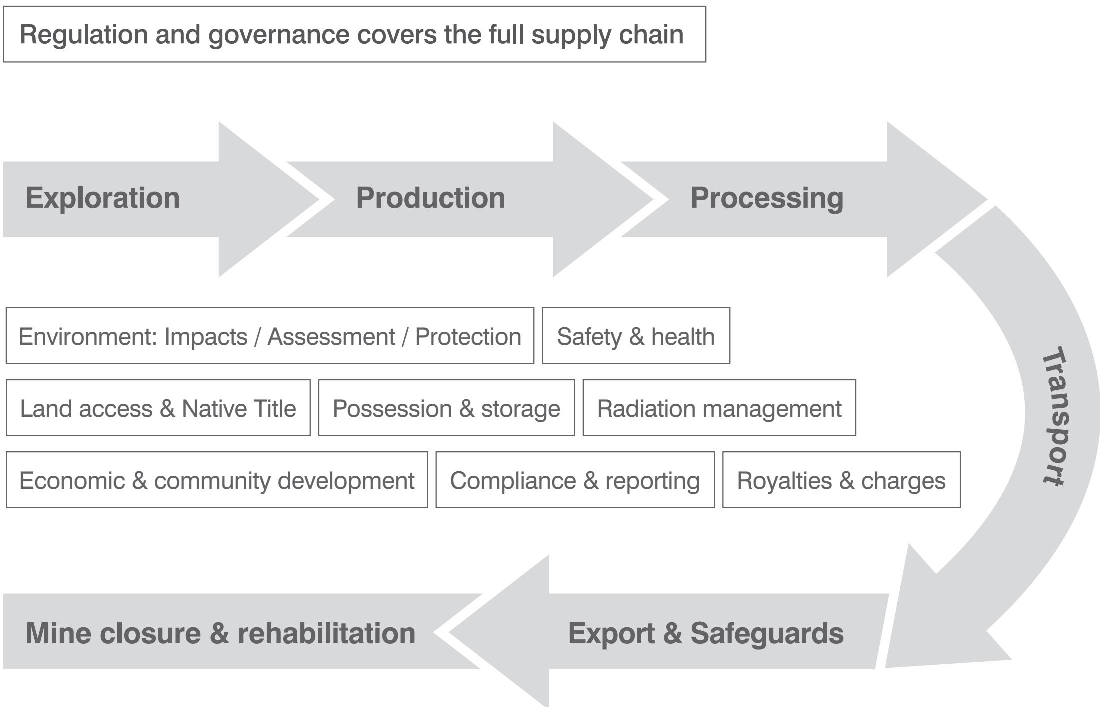
Australia's regulatory framework attempts to moderate the impact by assessing potential effects as part of the approval process, then subjecting mining to conditions by monitoring operations and by requiring projects to report environmental performance and impact.

The uranium mining industry is subject to additional scrutiny. For example, all uranium projects undergo mandatory assessment under the *Environment Protection and Biodiversity Conservation (EPBC) Act*. The Northern Territory's Ranger mine is additionally overseen by the Supervising Scientist – a statutory position specifically established for the mine under the Commonwealth *Environment Protection (Alligator Rivers Region) Act 1978*.

Uranium mining's regulatory framework is a complex system of federal, state and territory legislation, guidelines and policies administered by a variety of agencies and organisations, covering the full supply chain, from exploration to export and mine closure and rehabilitation. A typical assessment and approval process for a uranium mine in Australia can take more than three years from referral to ministerial approvals.

CHART 15 **Uranium mining in Australia**

Source: Queensland Government Department of the Premier and Cabinet



> 'Societal expectations related to environmental protection and the safety of workers and the public evolved considerably as the outcomes of the early era of mining became apparent, driving changes in regulatory oversight and mining practices.
>
> Uranium mining is now conducted under significantly different circumstances, with leading practice mining the most regulated and one of the safest and environmentally responsible forms of mining in the world.'[48]

Organisation for Economic Co-Operation and Development
Nuclear Energy Agency

Tailings management

Tailings are the fine materials and ground rock remaining after the extraction of the valuable mineral from the mined ore. Tailings management broadly encompasses the chemical and physical processes involved in the production and placement of tailings, and the design, approval, development, operation and closure of the facility into which the tailings are impounded.[49]

Tailings still contain some uranium. While these tailings are less radioactive than the original ore, the acidic or alkali leaching process used to extract the uranium also liberates other potentially hazardous naturally occurring constituents such as heavy metals, similar to other mine processing. Consequently tailings, and the water discharged with the tailings solids, must be isolated, stored, treated and ultimately rehabilitated at mine closure.

Past examples of poor practice in uranium and other mining during periods of less developed regulatory requirements have rightfully been criticised. Those outcomes and their inconsistency with modern expectations of good environmental management have led to greater scrutiny of contemporary mining, and consequently better performance.

Mine rehabilitation

Planning the closure of a uranium mine, as with all mines, begins with the first planning for development and operation of the mine. Rehabilitation works commence during operation and continue well after the mine is closed. Environmental monitoring requirements for uranium mines in Australia can be up to 99 years post closure.

While there are leading practice principles and guidelines for closure planning, each project and each operating mine is unique. The geological, climatic, metallurgical, hydrological, economic and cultural aspects of each mine are unique in themselves and unique in combination.

Rehabilitation and closure plans are regularly reviewed and updated in light of changing technology and practice and to reflect cultural change and changes in expectations of traditional owners and other stakeholders.

A vital principle is for mine operators always to estimate and re-estimate the costs of rehabilitation and mine closure and to make prudent provisions for these estimated costs in company accounts; companies plan for this upfront. In order to secure their licences, companies are required to demonstrate to government that such funds are available, and governments may require them to be held in a government operated trust.

Uranium packaging and transportation

Uranium oxide is transported by road and/or rail from mine sites to existing authorised container port facilities in South Australia or the Northern Territory for shipment by sea to international customers.

Uranium oxide is transported in 200 litre steel drums in accordance with IAEA requirements. The drums contain between 370 kilograms and 400 kilograms of uranium oxide depending on product density and delivery location.

Each drum has a tight fitting lid that is secured to the drum by means of a steel locking ring and then clamped by a locking ring bolt. The drums are stowed into 20 foot International Organisation for Standardisation (ISO) shipping containers for road, rail and sea transportation.

Uranium oxide that is stored before or during shipment must be placed in a secure area with restricted access. Specialised drum lifting equipment must be used when loading shipping containers.

Drums are secured inside the shipping containers to international standards using a webbed Kevlar-based strapping system. The method for securing drums is approved and audited annually by the Australian Maritime Safety Authority (AMSA) for sea transport.

Uranium oxide is classified by the IAEA as a 'Low Specific Activity' LSA-1 material because of the low level of radiation per unit mass. Even in a severe accident, uranium oxide does not pose a fire or explosion hazard.[50]

Australia has been shipping uranium oxide for more than 30 years. During this period, there have been no incidents that posed risk to public health or to the environment reported in more than 11,000 container movements. ■

Box 3

Arid Recovery leads the way on conservation

ARID RECOVERY IS AUSTRALIA'S PREMIER ARID ZONE CONSERVATION PROGRAM.

Arid Recovery is an independent, not-for-profit conservation initiative that has been restoring Australia's arid lands since 1997.

Based at Roxby Downs, the program has become a world leader in ecosystem restoration through the use of exclusion fencing, threatened species re-introductions and feral animal and weed control.

The program is supported by local community volunteers, the South Australian Department for Environment, Water & Natural Resources, the University of Adelaide and BHP Billiton. It is centred on a 123km^2 fenced reserve substantially funded by BHP Billiton's mine on the giant Olympic Dam copper-uranium deposit. To date, the project has been centred on a 123 km^2 fenced reserve which is situated partly on the Olympic Dam Mine Lease (7 km^2) and partly on adjoining pastoral properties including areas of privately-owned Billa Kalina station and BHP Billiton pastoral lease properties; Roxby Downs Station (49 km^2), Mulgaria Station (1 km^2), and Stuart Creek Station (66 km^2).

Four locally extinct mammal species have been successfully reintroduced to the reserve to date: the Greater Stick Nest Rat, Burrowing Bettong, Greater Bilby and the Western Barred Bandicoot. All four species are now thriving within the reserve. Future re-introductions will be trialled to encourage a variety of sustainable trophic levels (i.e. both predator and prey species) within the reserve.

The careful management of herbivory through fencing and pest control over a decade has allowed the recovery of long-lived plants (such as mulga); an overall increase in vegetation cover within the reserve; and a major increase in seed reserves including for some species that had never been recorded. There has also been a marked increase in the suite of mammals within the reserve and a higher abundance of bird species than outside the reserve.

Arid Recovery is a world class laboratory and reference site for arid zone recovery because of the establishment of permanent monitoring sites and standard monitoring protocols at its inception, and the deliberate experimental design of its layout. Research visits, guided tours and VIP visits are undertaken within the Arid Recovery fenced habitat.

Arid Recovery is the benchmark for what can be achieved in the restoration of biodiversity in arid areas. It is an acclaimed example of a highly successful partnership between industry, government, the university sector and the community. It showcases modern mining's ability to co-exist with a sustainable natural habitat, its commitment to responsible environmental management and its active support for world-leading habitat restoration. Arid Recovery is one of the dividends of Australia's uranium industry. ■

■ Arid Recovery, Olympic Dam, South Australia *(BHP Billiton)*

Arid Recovery is the benchmark for what can be achieved in the restoration of biodiversity in arid areas.

It is an acclaimed example of a highly successful partnership between industry, government, the university sector and the community.

DISPELLING URANIUM MYTHS

Is uranium mining and transportation safe?

Australian miners working with radioactive ores receive an average of 2 to 5 mSv per year. This is lower than the natural background radiation levels in many well populated parts of the earth. It is well within the acceptable maximum annual dose of 20 mSv per year recommended by the ARPANSA, the ICRP and the IAEA, whose guidelines form the basis of Australian legislation covering mine worker radiation safety.[51]

Mining operations in Australia are undertaken under the *Code of Practice and Safety Guide for Radiation Protection* and *Radioactive Waste Management in Mining and Mineral Processing*, administered by state and territory governments.[52]

Uranium oxide is classified as a 'Low Specific Activity' LSA-1 material by the IAEA because of its low level of radiation per unit mass and strict packaging requirements minimise the risk of radiation exposure from its transport and handling. Uranium oxide remains stable under all conditions of storage, handling and transport.[53]

There have been no uranium transport incidents that have posed any risk to public health or to the environment in more than 11,000 container movements. Uranium has been transported in Australia from mines to ports for export for more than 30 years.

Is Australian uranium used in nuclear weapons?

Since 1977, Australia's uranium export policy has been 'to establish a framework of control within which the benefits which many countries see in the peaceful use of nuclear energy can be safely realised.'[54]

In addition to the International Atomic Energy Agency (IAEA) safeguards, Australia imposes requirements through a network of bilateral safeguards agreements.

The Australian Safeguards and Non-Proliferation Office (ASNO) annual reports affirm that no Australian uranium has been diverted from peaceful purposes.

In 2014, the Nuclear Threat Initiative ranked Australia first in its NTI Nuclear Materials Security Index.[55]

Contrary to fears that the civilian nuclear power industry would be a pathway to further nuclear weapons production, the past two decades have seen the blending-down of Russian warheads into nuclear fuel for consumption in nuclear power plants in the US. The 'Megatons to Megawatts' program saw 500 metric tons of bomb-grade uranium recycled into more than 14,000 metric tons of uranium fuel. This equates to the elimination of 20,000 nuclear warheads.

ISR well-fields, Beverley Mine, South Australia *(Heathgate Resources)*

> ‘Fast reactors can be used to burn all existing reserves of plutonium and the nuclear waste from the past and present generation of thermal reactors. With additional uranium mining, there is enough energy in proven deposits to supply the entire world for many thousands of years.’[58]

Professor Barry Brook
Professor of Environmental Sustainability at University of Tasmania.
Formerly, Sir Hubert Wilkins Chair of Climate Change and Director of Climate Science, The Environment Institute at University of Adelaide.

Can radioactive waste be safely handled and managed?

Radioactive waste encompasses a range of materials. The most significant high-level waste from a nuclear power reactor is the spent nuclear fuel. It makes up the smallest proportion of the total volume of waste but generates most of the radioactive content.

Low-level waste is made up of lightly-contaminated items like tools and work clothing from power plant operation, medical waste and diodes from watches and makes up the bulk of radioactive wastes.

Intermediate-level wastes include wastes arising from the reprocessing of research reactor fuel, used filters, steel components from within the reactor, effluents from reprocessing and components of decommissioned reactors.

Although spent nuclear fuel is hot and radioactive, it can be handled and stored safely when cooled and shielded by a dense material such as concrete or steel. Water can provide both cooling and shielding, so a typical power reactor will remove the fuel underwater and transfer it to a storage pool. After about five years, spent fuel is typically transferred into dry ventilated concrete casks.[56]

Spent nuclear fuel can be disposed of in deep geological repositories or reprocessed which reduces the volume of the waste to approximately just 3 per cent of the original volume. Without reprocessing, a 1 GWe nuclear plant typically generates only around 27 tonnes of waste per annum.

Radioactivity dissipates over time. After 40 to 50 years the heat and radioactivity of spent fuel falls to 1/1000th of the level at removal from the reactor. After 1,000 years most radioactivity will have decayed to a level comparable to that of naturally-occurring uranium ore.[57]

Current global hazardous waste production is approximately 400 million metric tonnes per annum. Radioactive waste from nuclear power plants and the fuel cycle support facilities comprises approximately 0.1 per cent of all global hazardous waste.

The vast majority of spent nuclear fuel is U-238, which is effectively unchanged from when it was drummed at the mine. It is expected that Generation IV fast or breeder reactors will consume U-238 as a fuel source.

TABLE 5 **Managing nuclear waste**

Source: World Nuclear Association

Type of waste	By radioactive content	By volume
High level	95 per cent	3 per cent
Intermediate level	4 per cent	7 per cent
Low level	1 per cent	90 per cent

Dispelling uranium myths

Is the risk of another Fukushima event too great?

The incident at Fukushima rekindled fears about nuclear energy yet no fatalities occurred due to the nuclear incident or consequent radiation leak.

UNSCEAR's report released in April 2014 concluded its Scientific Findings on the expected long term health implications stating:

> No radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident…. The doses to the general public, both those incurred during the first year and estimated for their lifetimes, are generally low or very low. No discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants. The most important health effect is on mental and social well-being, related to the enormous impact of the earthquake, tsunami and nuclear accident, and the fear and stigma related to the perceived risk of exposure to ionizing radiation.[59]

Nuclear energy has the best safety record of all energy sources when measured as fatalities per unit of energy produced.[60] This is a function not only of the industry's strong safety practices and record, but of uranium's energy density which allows the production of substantial amounts of electricity for relatively little industrial activity.

A commercial-type power reactor cannot under any circumstances explode like a nuclear bomb – the fuel is not enriched beyond about 5 per cent[61], compared with bomb grade uranium at 90 per cent. ■

> 'I can assure you that none of us are in the pay of the nuclear industry. 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.'[62]

Professor Geraldine Thomas
London's Imperial College.
Member of the UNSCEAR committee on the health effects of the Chernobyl accident.

■ Benita Alangale at work at Ranger, Northern Territory *(Energy Resources of Australia)*

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