Uranium: Critical to a Clean Energy Future

2015 ATSE Eminent Speaker Series

Vanessa Guthrie

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Why talk about uranium?

NUCLEAR FUEL CYCLE ROYAL COMMISSION

How safe is uranium and nuclear?

Can Fukushima happen again?

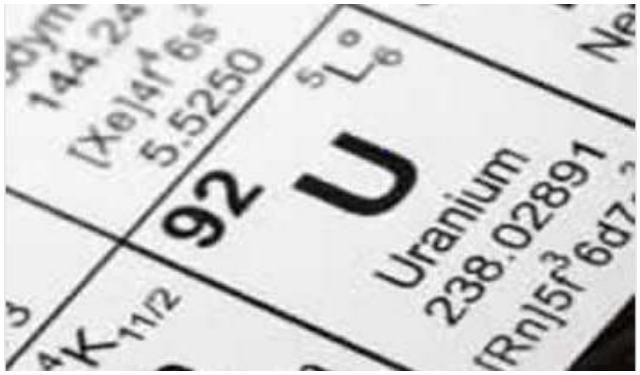
Can Australian uranium be diverted to weapons?

What is the answer to waste disposal?

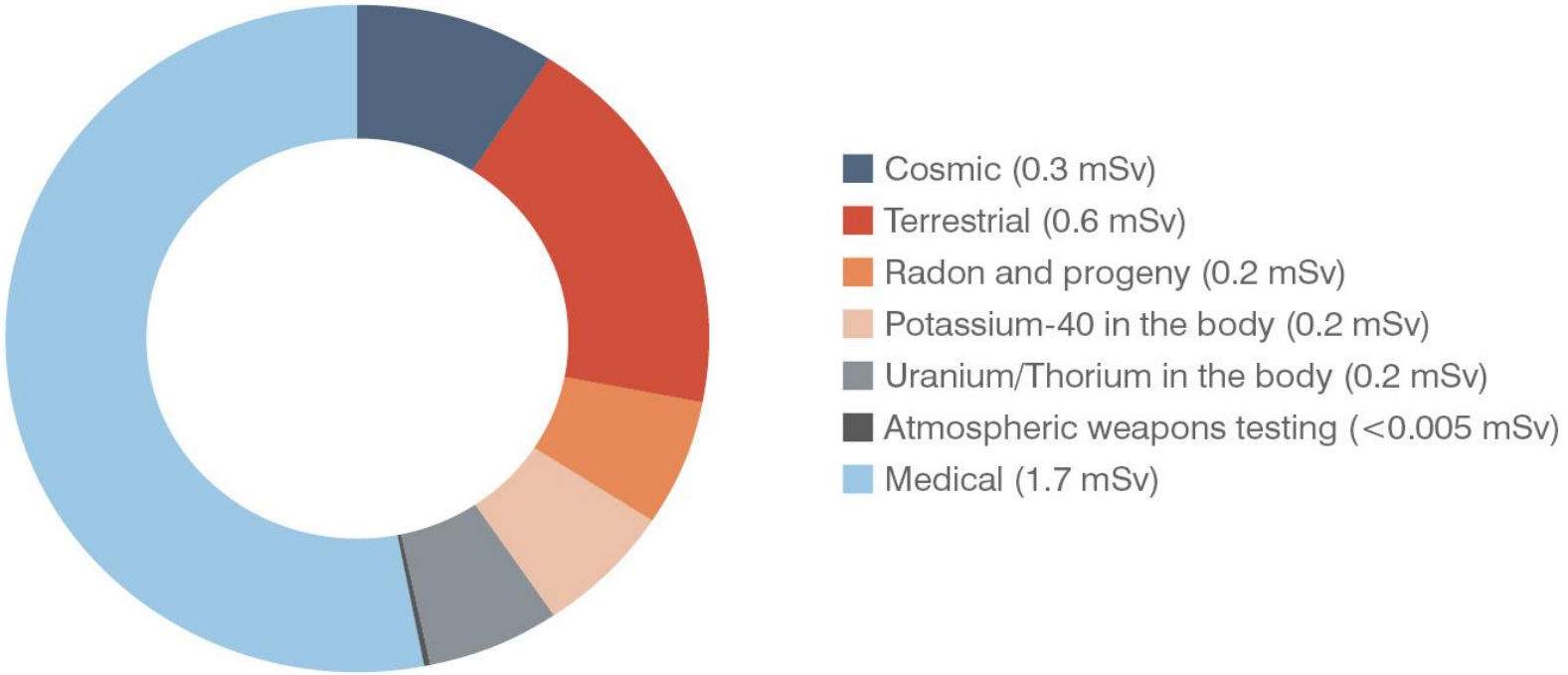
How is nuclear part of the world energy mix?

Uranium and Radiation

- Heaviest naturally occurring metal
- Mildly radioactive in natural form
- 3 isotopic forms – ^{238}U ^{235}U ^{234}U
- Uranium ore =
  - ^{238}U = 99.3%
  - ^{235}U = 0.7% (fissile)
- To convert U ore to nuclear fuel requires multiple processing steps
- 1 kg U_3O_8 = 20,000 t black coal
- Sufficient energy to power an average household for 25 years



Where does radiation come from?

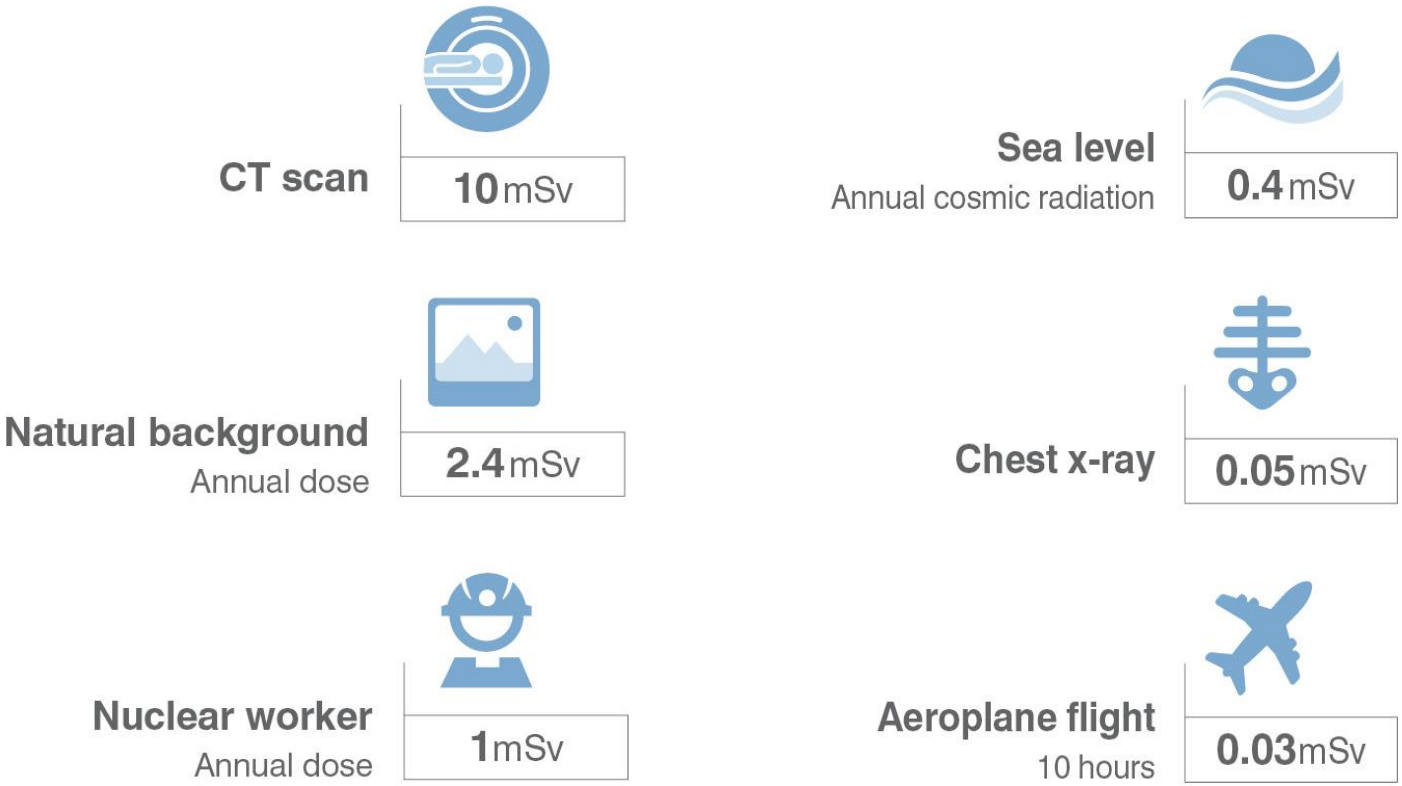


Total annual per capita dose = 3.2 mSv

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

Sources of Radiation Exposure

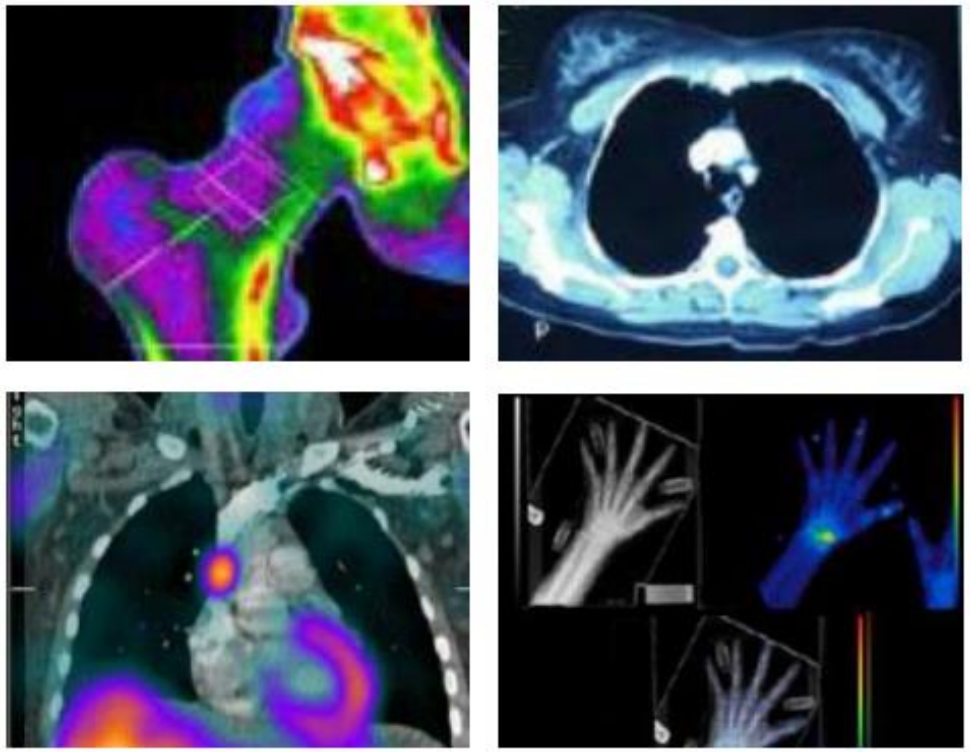
What most people don't know about radiation….



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

Ionising Radiation in Medicine

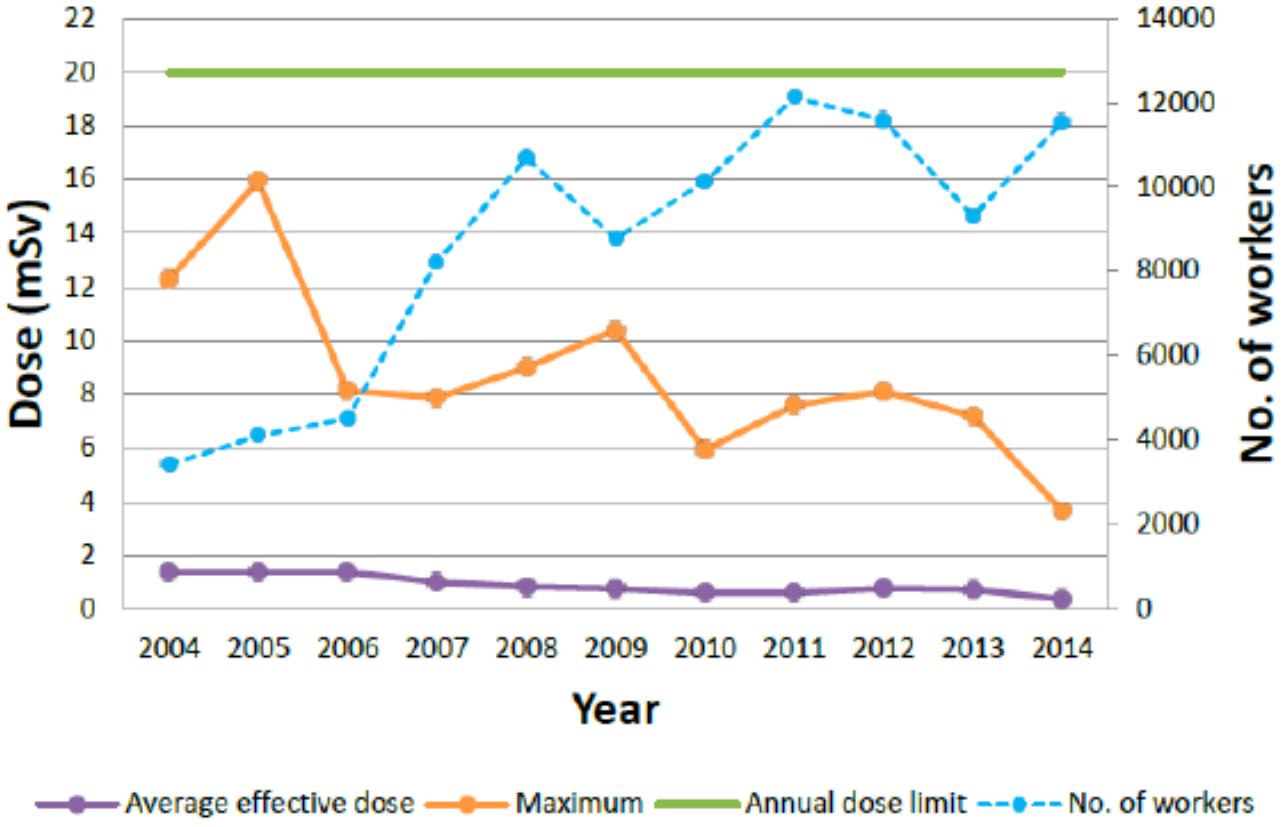
- 2 million doses made each year
- 1 in 2 Australians will have a nuclear medicine scan in their lifetime
- Diagnostic and therapeutic applications
  - Diagnosis and treatment of cancers
  - Scans for tumours, lymphoma, renal function etc
  - Organ imaging for functionality
- Tc-99m most commonly used
- Mo-99 only produced in Australia



Source: ANSTO 2015

Occupational Exposure in Australia

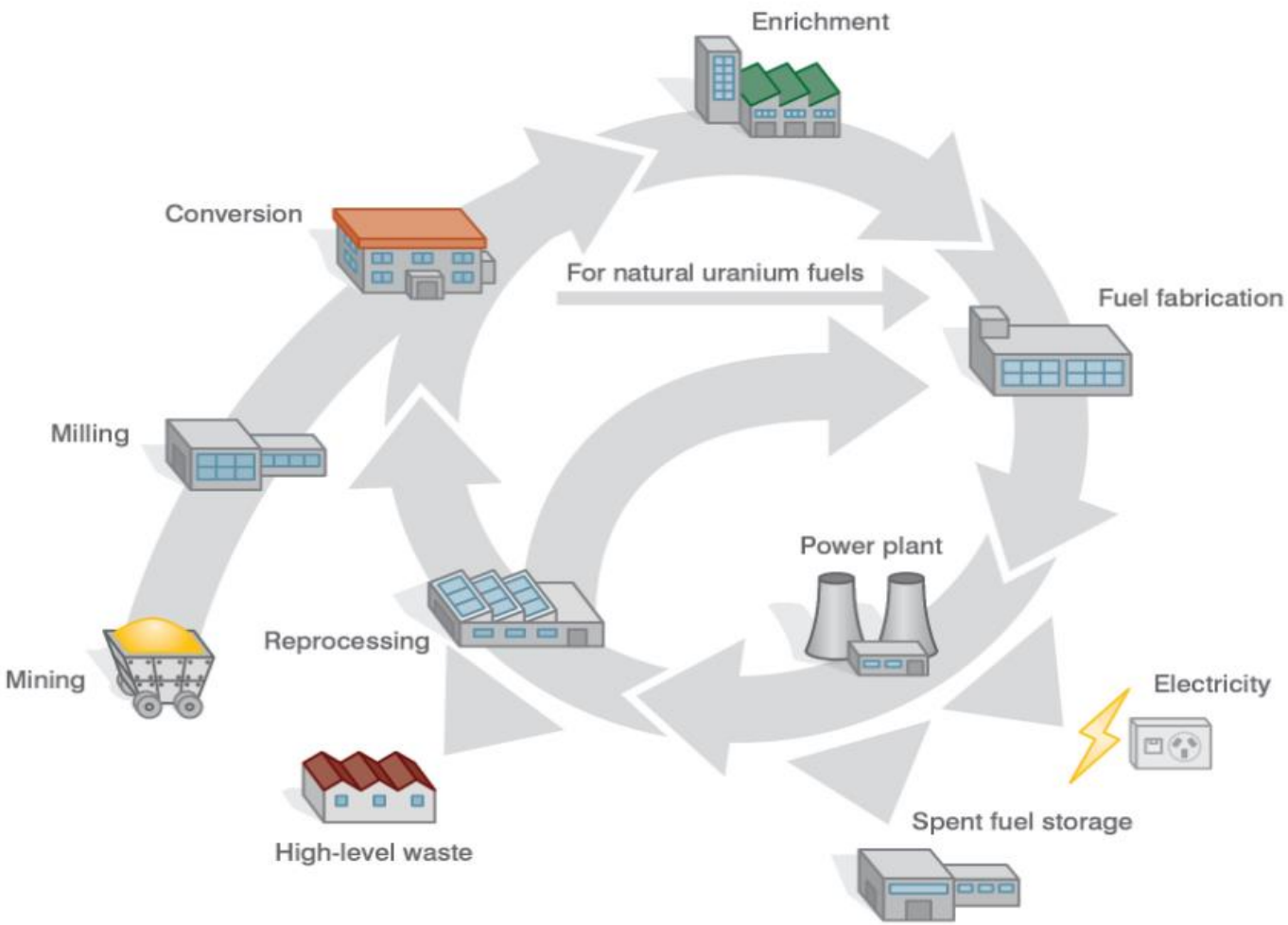
Average and maximum effective doses for uranium industry workers (2004 – 2014)



Source: Australian National Dose Register 2015

Nuclear Fuel Cycle

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



Lessons from Incidents

Three Mile Island

- Operator training
- “Human” factors

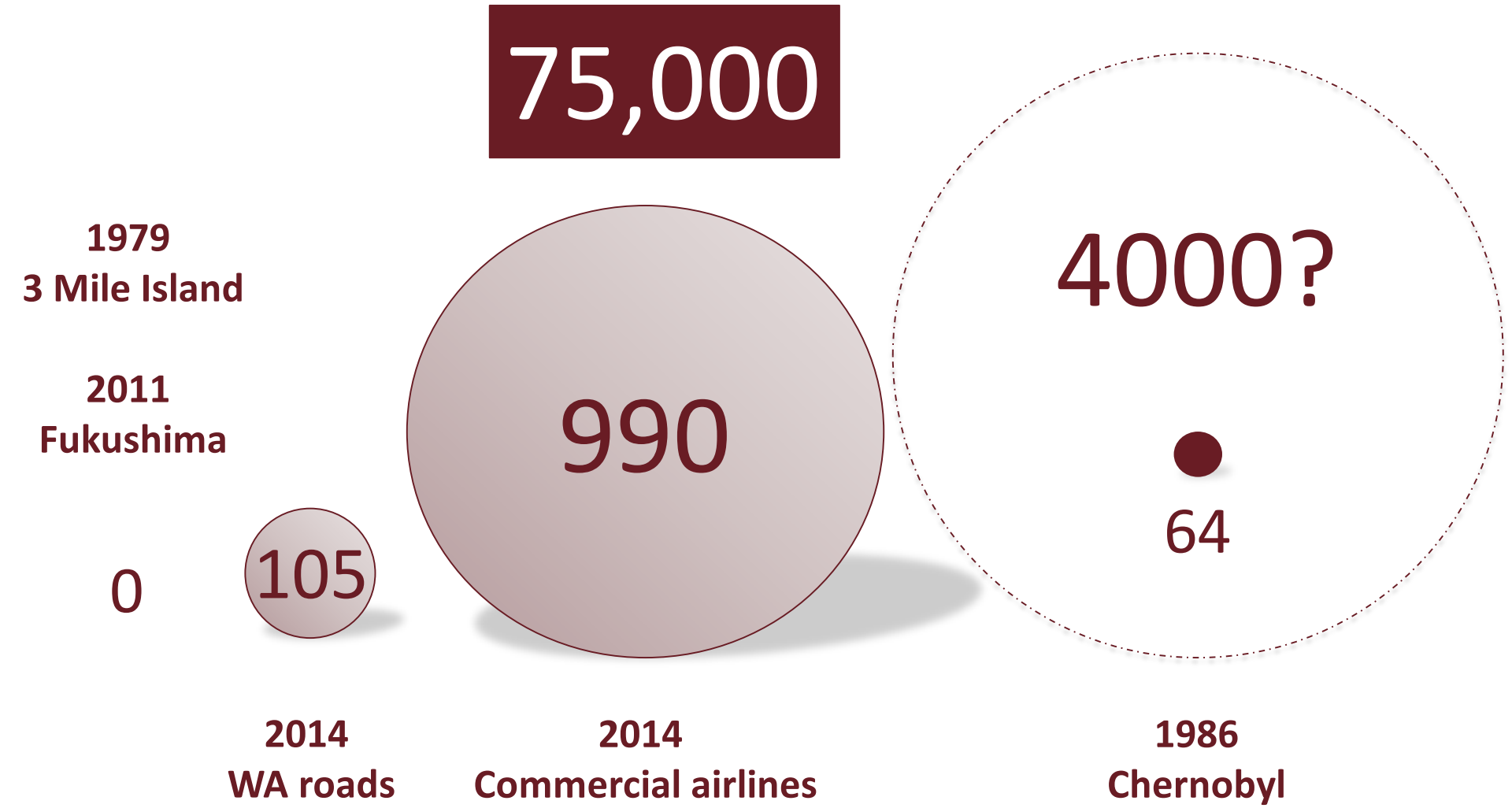
Chernobyl

- Plant design
- Planned maintenance
- “Human” factors

Fukushima

- Plant design
- Risk Protection
- Early warning systems
- Useful life

Deaths from nuclear related events



Source: WA Police, UNSCEAR, IAEA, CNN

Events since Fukushima

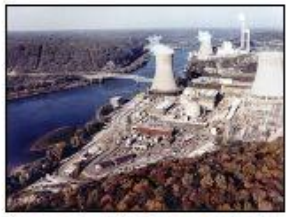
- Japan systematically closed reactor fleet over 2 year period
- Loss of 30% power generating capacity – replaced by oil, coal and gas
- Japan committed to 22% nuclear energy as part of future energy mix
- 2 reactors allowed to re-start – Ohi 1 and Ohi 2 then closed after one year operation
- 25 reactors re-start applications in place
- Sendai 1 reactor re-started 10 August, Sendai 2 reactor now ready
- Japanese nuclear operators investing ¥3 trillion in safety measures
- China suspended approvals for reactor new builds, now recommenced Gen IV design

New Reactor Design

Generation IV: Nuclear Energy Systems Deployable no later than 2030 and offering significant advances in sustainability, safety and reliability, and economics

Generation I

Early Prototype Reactors



- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors

- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

Near-Term Deployment

Generation III+ Evolutionary Designs Offering Improved Economics

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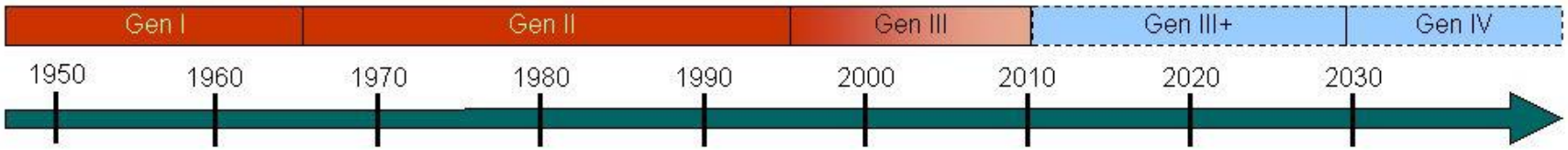
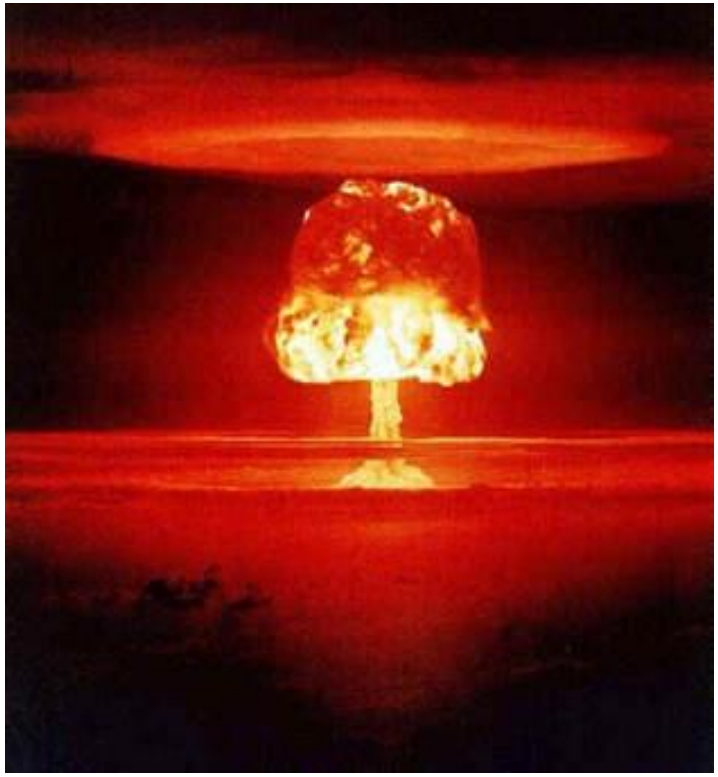
Generation IV

- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant



Uranium and Nuclear Weapons

- ^{235}U is required at 3-5% for nuclear power generation
- Fissile ^{235}U or ^{239}Pu is required at >95% for weapons
- ^{239}Pu only generated in first few months of reactor operation after which swamped by ^{240}Pu (non-fissile)
- IAEA safety checks every 13 months - including detection of weapons grade material or diversion
- International sanctions for non-compliance under NPT
- Australia contributes to IAEA inspectors, safeguards
- "Megatons to Megawatts" US-Russia program
  - 20 years, US$1.3 billion
  - 500 tonnes weapons grade HEU removed
  - 7 trillion KWH or 10% US electricity generation



Source: WNA

Nuclear Non-Proliferation Treaty

- NPT commenced in 1968, now 191 countries have signed
- 5 recognised nuclear states
  US, Russia, UK, France and China
- 5 other countries that are non-signatories
  India, Pakistan, South Sudan, Israel and North Korea
- Nuclear weapons declared in Pakistan, India, known in Israel, North Korea
- India = “no first use” policy, India Safeguards Agreement (IAEA)
- Australia-India Nuclear Civil Cooperation Agreement signed in 2014
  - Yet to be ratified by Australian Parliament
  - Will need to meet Australian Safeguards Act
  - Reflects IAEA requirements

Nuclear Fuel and Waste

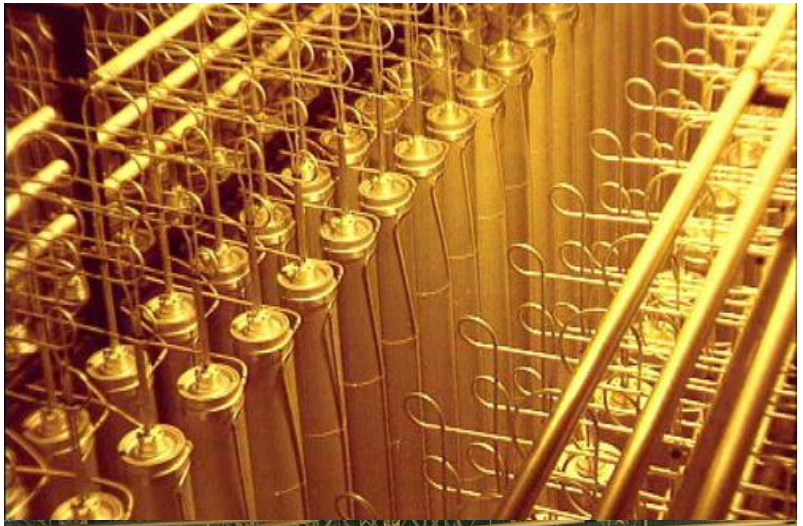
		Percent by radioactive content	Percent by volume
Low level waste	Hospitals/medical; Industrial, tailings	1	90
Intermediate level waste	Resins, cladding, industrial, construction	4	7
High level waste	Spent fuel, reprocessed waste	95	3

The hockey puck test:

High level spent fuel from one person's lifetime

The waste dilemma

- Technology solutions available today
  - Multiple barrier systems
  - Geological repositories
- Total waste over 60 years = 30,000m^3
- Equivalent to 10 Olympic swimming pools
- By 2040 = 60,000 m^3
- 1GWe reactor = 3m^3 (27t) per year of waste
- 1000 years to decay to original radioactivity levels
- 5% total cost of electricity production



Uranium – critical to a clean energy future

7.3 billion people….

47%

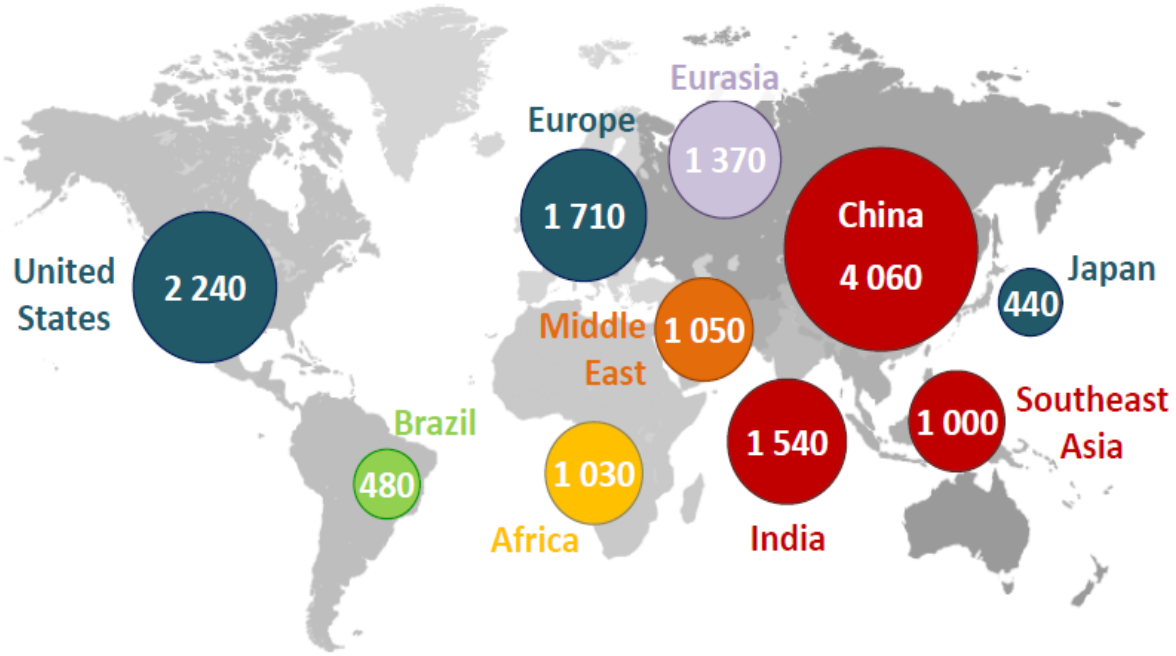
of world's population

6 out of 10

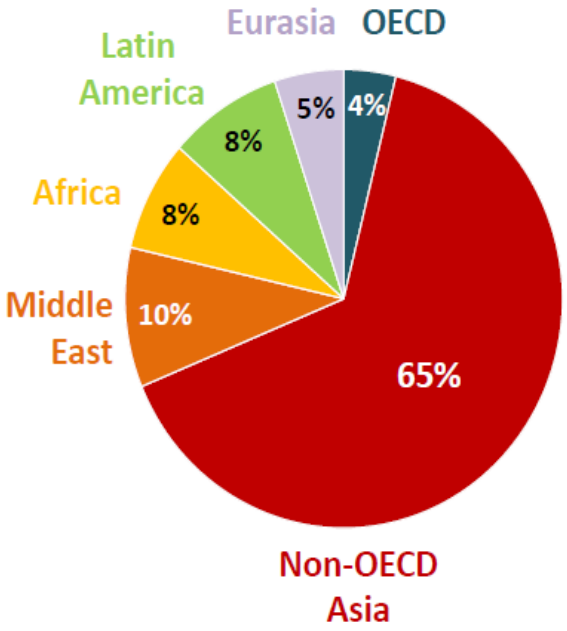
Have nuclear power

World Energy Outlook 2014

Primary energy demand, 2035 (Mtoe)[1]



Share of global growth 2012-2035



(1) Million tonnes oil equivalent (Mtoe)

Source: IEA 2014

Where will the energy come from?

		Increase by 2040	Percent % increase
Oil supplies	Non-OPEC supplies to 2025 Requires investments in Middle East	**14 mbd**	**15**
Coal	70% output from India, Indonesia, China, Australia by 2040	**6,350 Mtce**	**0.5%pa**
Gas	Includes unconventional gas 31% increase Requires $11 trillion infrastructure investment	**5,400 bcm**	**50**
Nuclear	Includes 380 GW added, 148 GW retired	**624 GW**	**60**
Renewables	Includes hydro, solar, wind, biofuels 33% global power generation by 2040 Requires subsidies of $205 billion in 2040	**16,500 TWh**	**300**
CO_2 emissions	40% of global emissions over the period	**15.4 Gt**	**16**

Source: IEA 2014

Uranium as a source of energy

=

1 kg uranium
Household for 25 years

The energy content of uranium oxide[6]

Nuclear Power today

437

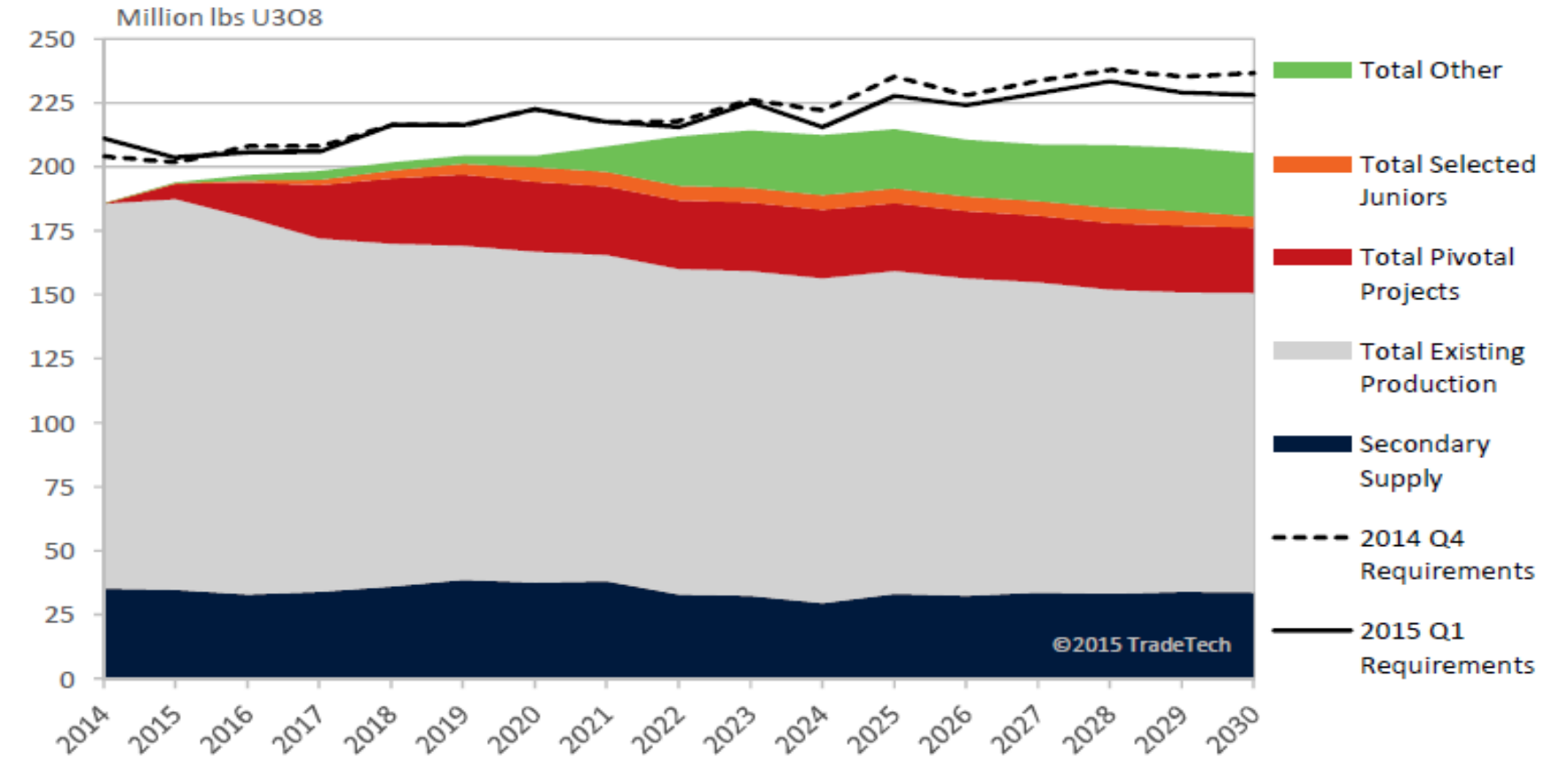
Operable reactors

69

Under construction

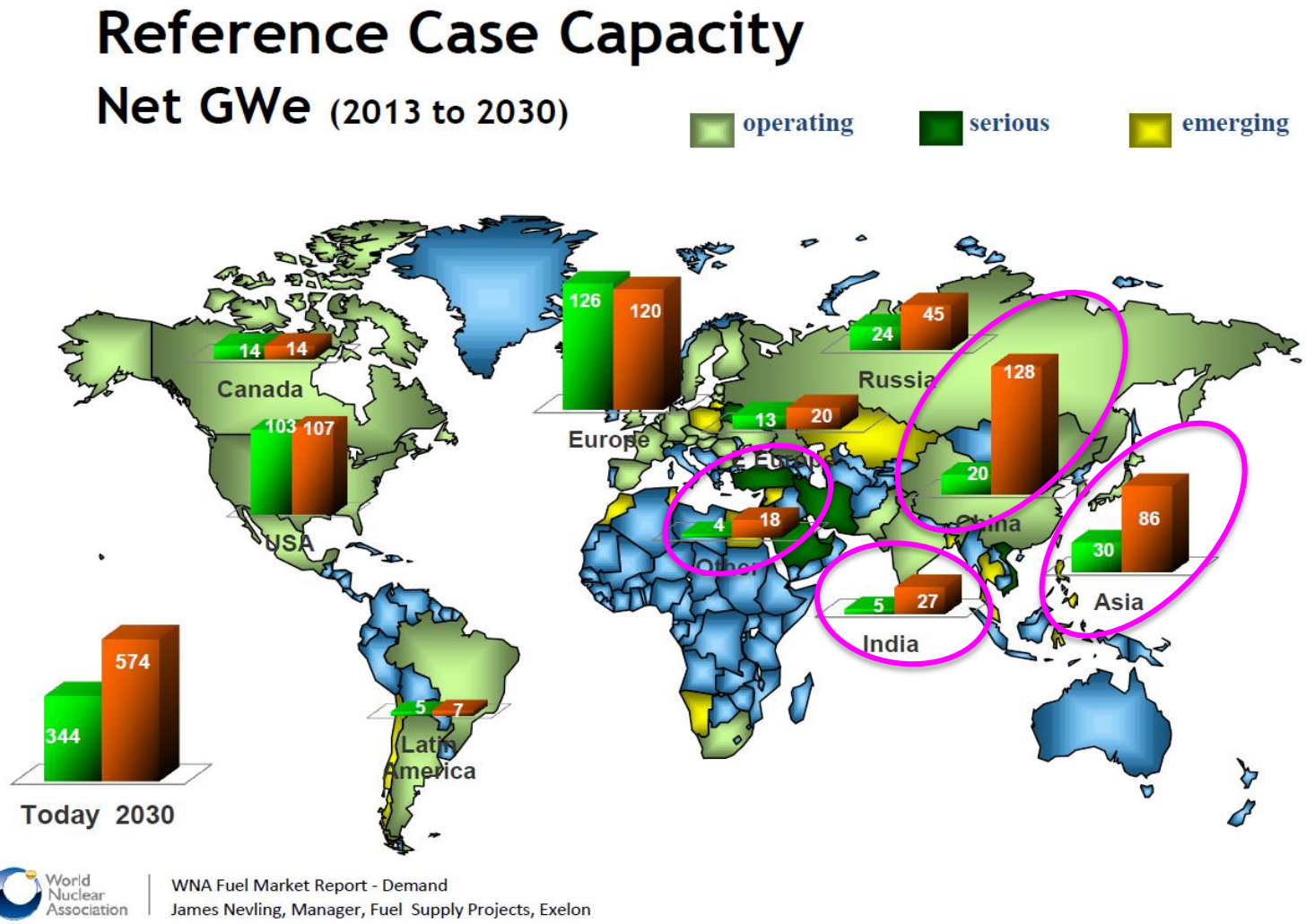
Global Uranium Market

Figure 59
FAM 2: Revised Supply and Demand Profile



Source: TradeTech 2015

Global Nuclear Power Growth



Nuclear Power in 2040

60% ↑

624GW

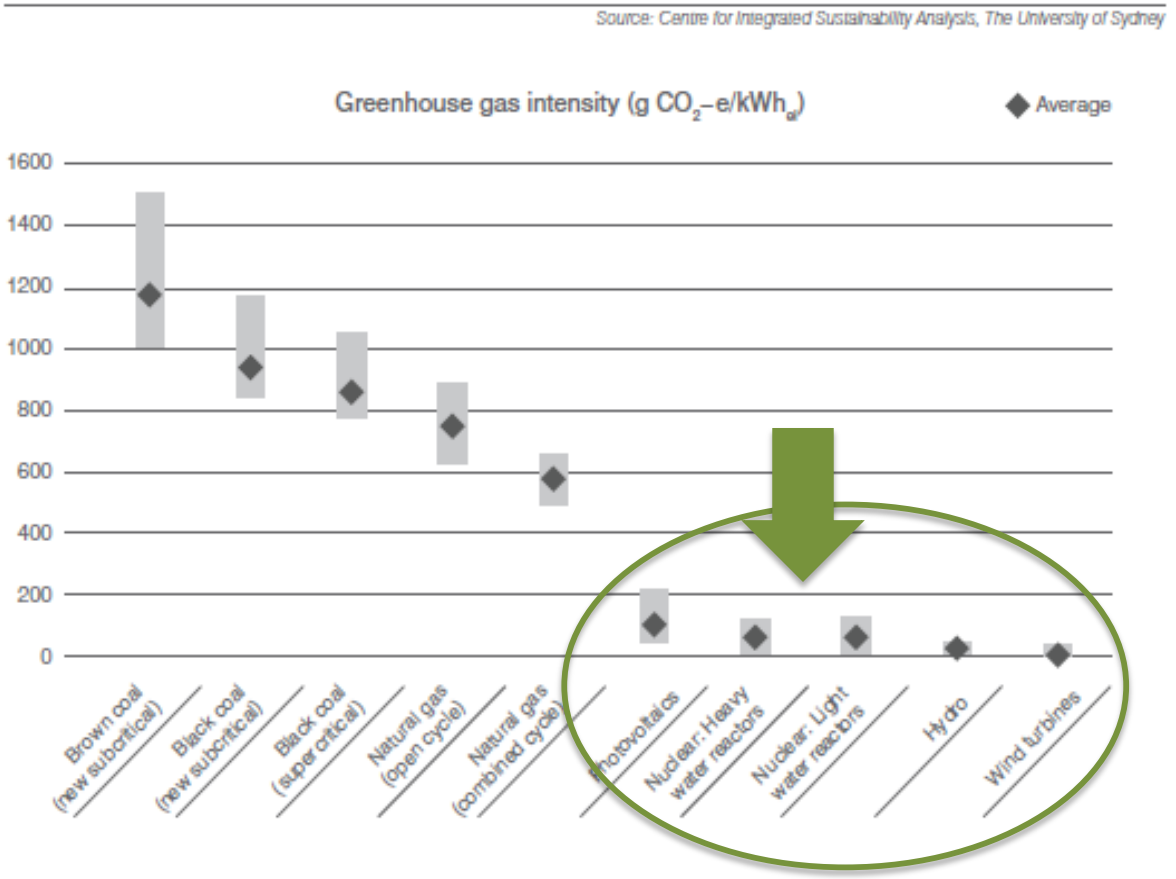
380 GW added
148 GW retired

112,000Mt

CO_2 emissions avoided

Nuclear Power & Climate Change

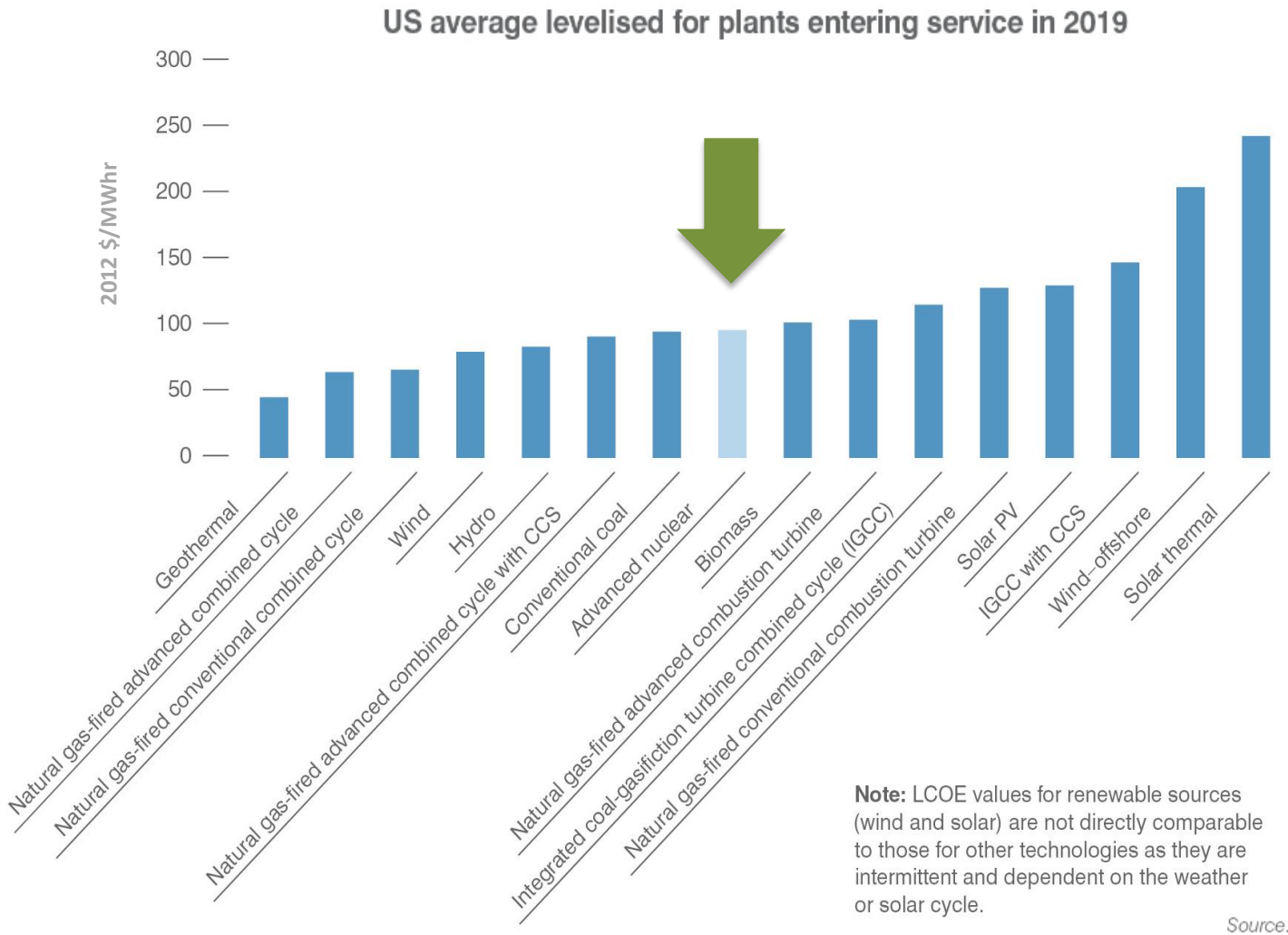
- Source of low emissions energy
- Life cycle emissions in the same range as renewables
- Competitive average levelised costs per unit power output ($/MWh)
- Recognition by US-China Joint Announcement on Climate Change
- Nuclear power generation projected to grow by 60% by 2040
- 1GWe nuclear reactor could meet Australia's emissions reductions commitments by displacement of fossil fuels



Life cycle emissions from power generation

Source: IEA, 2014; MCA 2015

Comparable cost of nuclear power



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.

Source: US Energy Information Administration

Australian Uranium Facts

1st in resources

- 32 per cent of global uranium resources

2nd largest primary energy source

- 22 per cent total primary energy production in 2012/13

3rd in global production

- 11 per cent of global supply in 2013.

4,200 jobs

- Uranium industry employment, much in remote areas

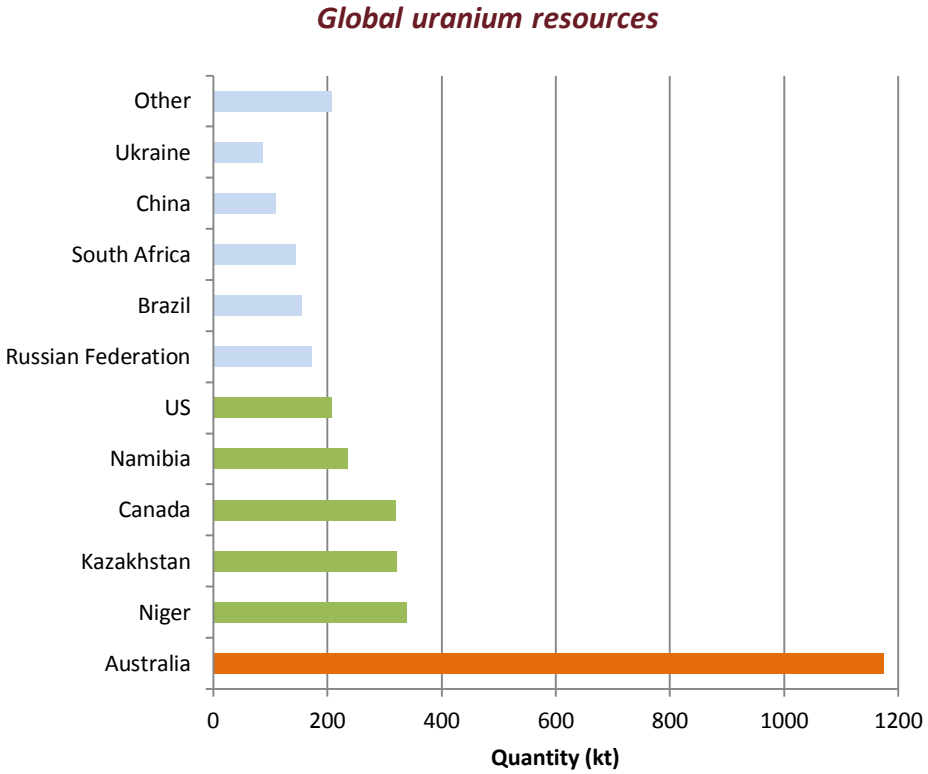
5,710 tonnes

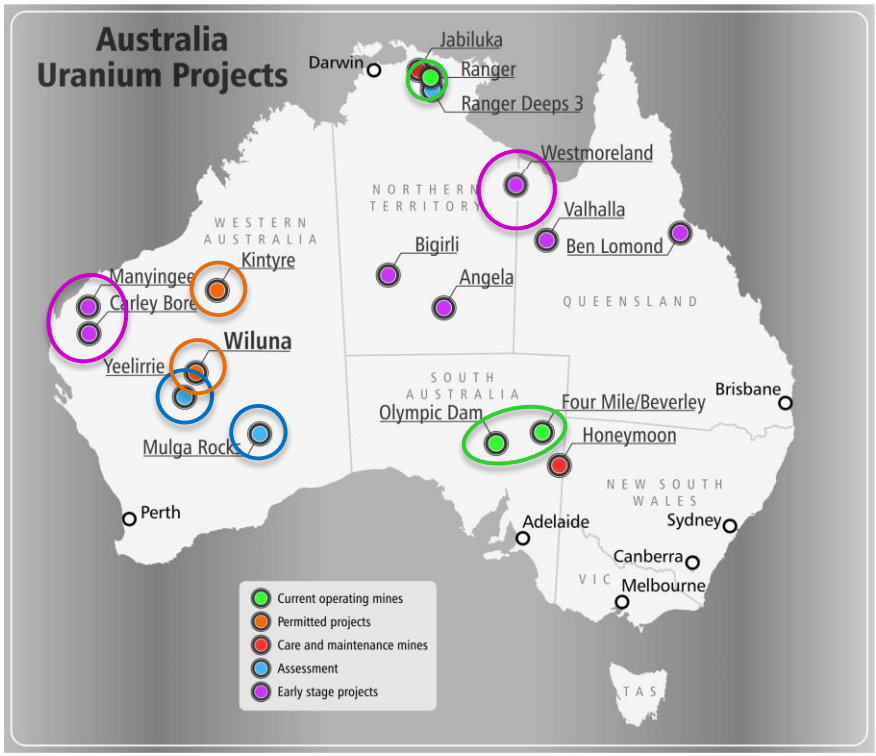
- production of uranium in 2013-14
- Equal to >90% of domestic energy consumption

$622 million

- Australian uranium export earnings in 2013/14
- $1.1billion forecast value of Australia's uranium exports in 2018/19

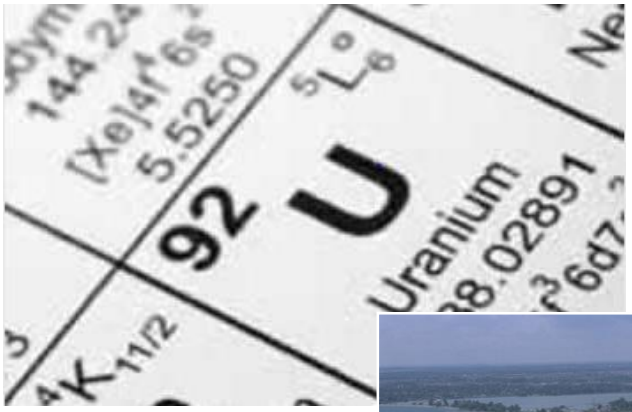
Australia's contribution…. and potential

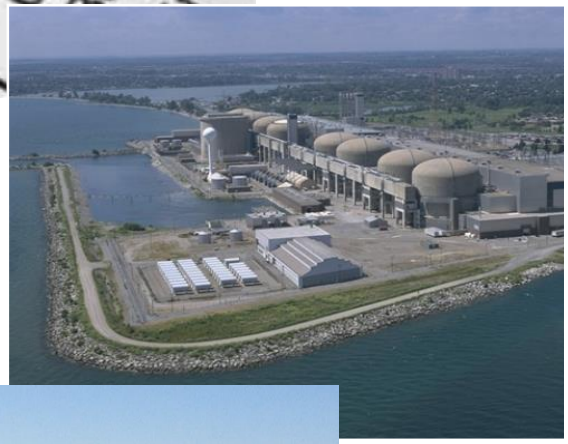




Uranium – critical to a clean energy future

- Uranium and nuclear industry has strong track record
- Strong regulatory environment controls safety
- International safeguards protect against proliferation
- Technical solutions for waste are available now
- Nuclear power is important in meeting global energy demand
- Nuclear is a natural partner for renewables
- Australia = significant U resources, but under-represented as a global supplier
- Wiluna Project = an opportunity for WA





Thank you

Dr Vanessa Guthrie
Managing Director
Toro Energy Limited
L3 33 Richardson street
WEST PERTH WA 6005
Telephone: +61 8 9214 2100
Email: info@toroenergy.com.au
Website: www.toroenergy.com.au