Sydney Probus Club

Nuclear Energy – Australia's Opportunity?

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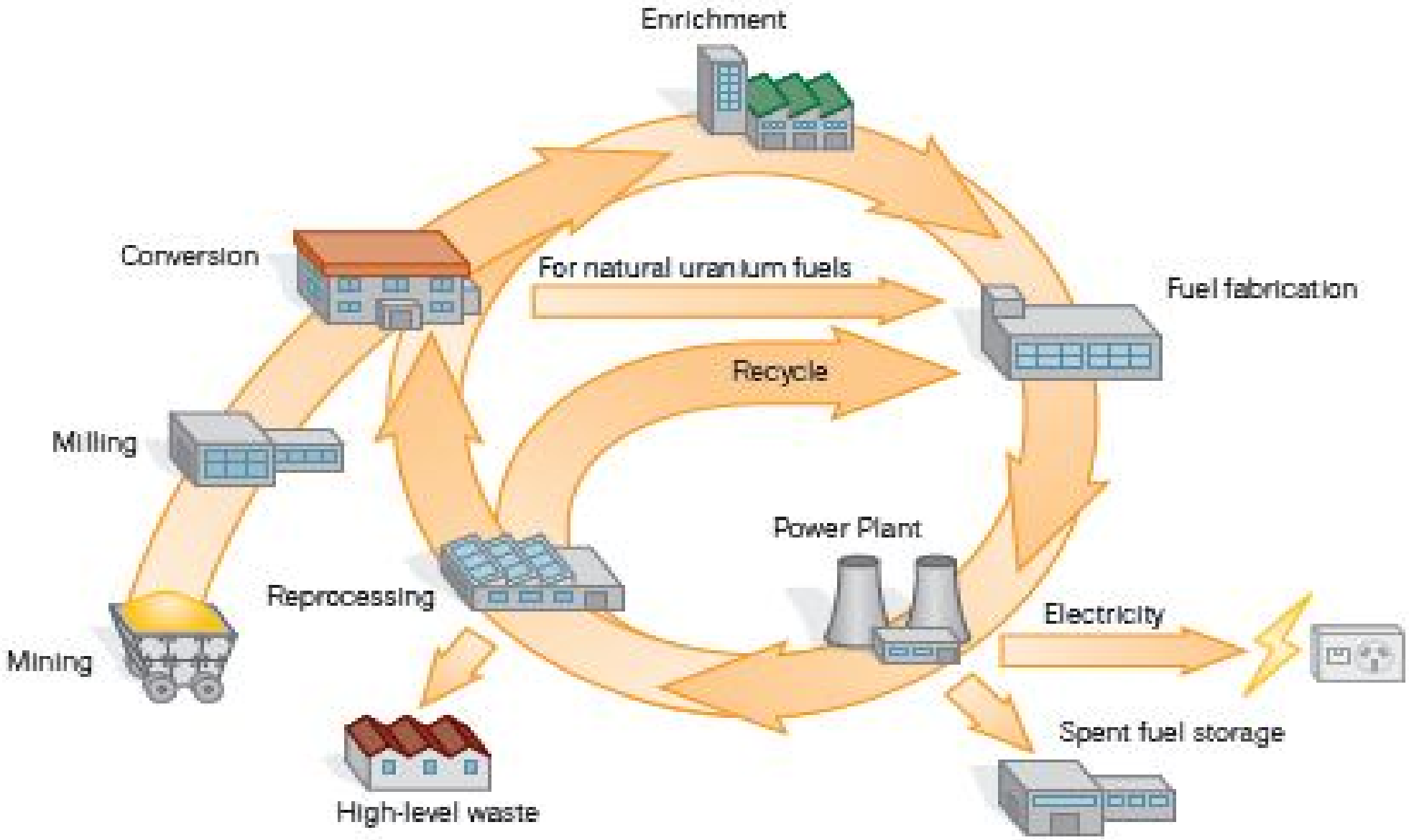
Presentation Structure

- The nuclear fuel cycle
- The UMPNER report process
- The UMPNER report findings
  - Uranium mining and exports
  - Conversion, enrichment and fuel fabrication
  - Electricity generation
  - Radioactive wast and spent fuel management
  - Health and safety
  - Environmental impacts
  - Non-proliferation and security
  - Regulation
  - Research, development, education and training
- Conclusions – the challenges for Australia

The Nuclear Fuel Cycle

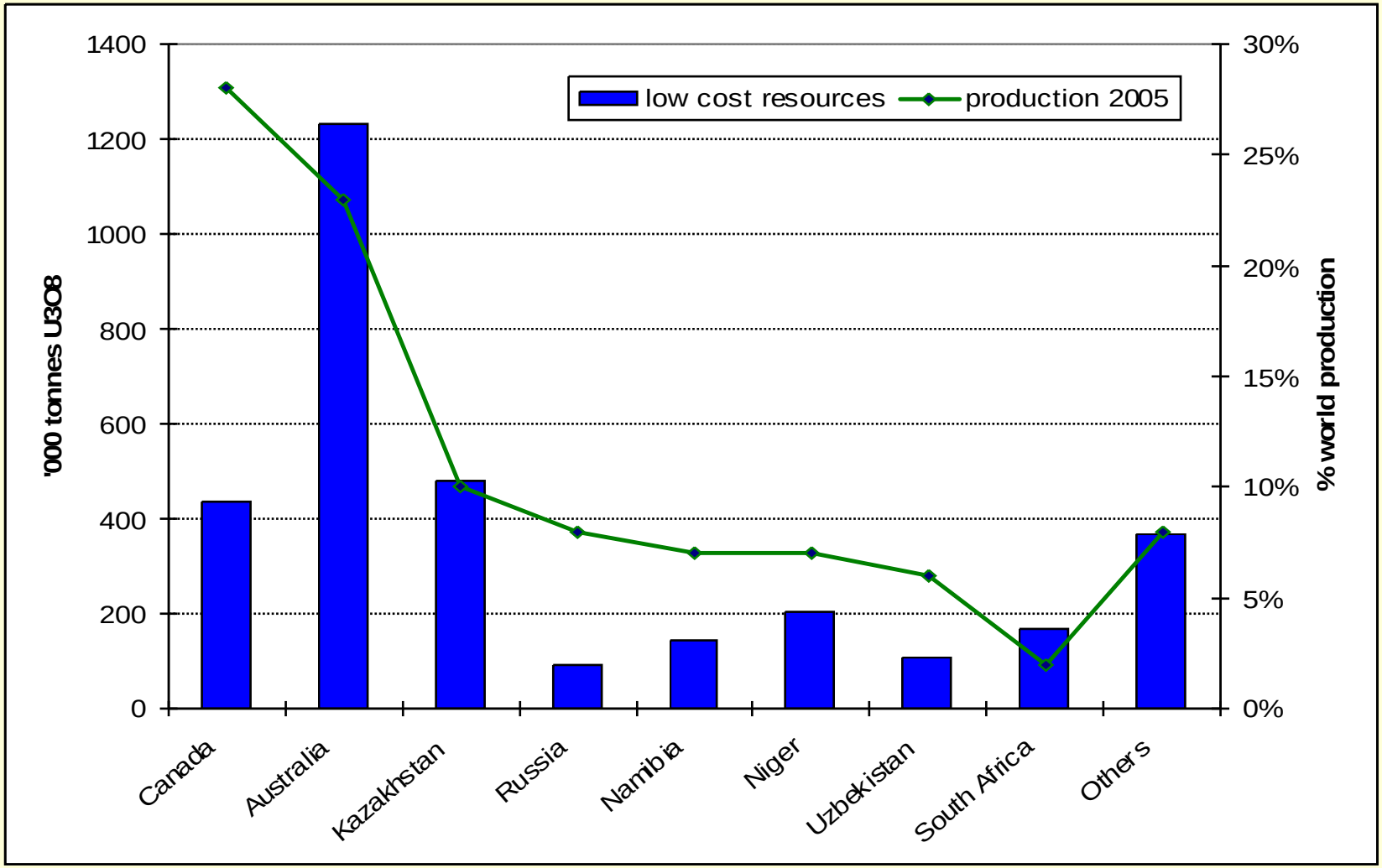
Figure 1.1 Schematic of the nuclear fuel cycle



The UMPNER process

- Terms of reference - June 06 – to be factual, objective, informative, balanced – without advocacy
- Encourage public contributions
- Hold face to face interviews - all persuasions
- Visit Australian uranium mining operations
- Consult overseas with facility visits - Finland, UK (Sellafields), Ukraine (Chernobyl), France, Canada, USA (Three Mile Island, Yucca Mountain), Japan, Korea
- Deliver draft report by November 06 – public launching – further public comment invited
- Final report to Prime Minister - December 06

Australia has the world's largest U resources (38%) but only 2nd largest producer (23%)



World uranium market outlook

- **World uranium demand increasing …**
- **And price increased dramatically for some time …**
  - **US$10/lb to US$110/lb in 3 years (was US$60/lb when we wrote UMPNER report and has been as high as US$133/lb!) Website quote of 11 April 07 read:**

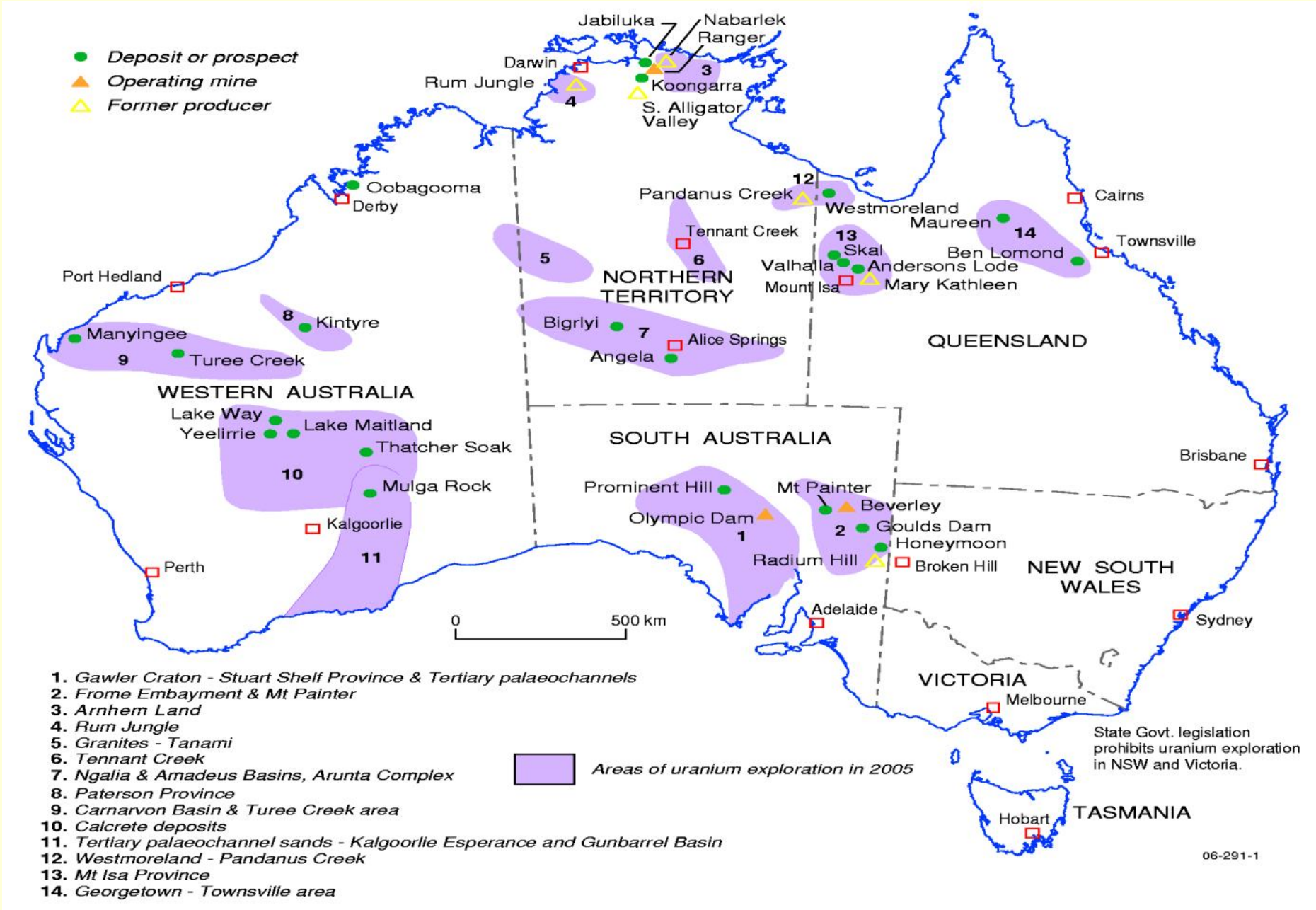
"Record uranium prices set off chain reaction of heated market activity … companies and investors engage in global race to profit from jump in element's spot price"

"Junior exploration companies boosted by hike in uranium prices to US$113 a pound, highest since 1970s"

  – **But in Jan 08 back to US$78.00/lb**

- **Uranium resources are plentiful**
  - **high potential for future discoveries in Australia – limited exploration over last 20 years**
  - **supply will not constrain nuclear power development**

Uranium deposits are widespread



Ranger uranium mine

Figure 7.10 Ranger uranium mine, Northern Territory

Source: Skycans/Energy Resources of Australia Ltd

U_3O_8 (Yellowcake) export

Figure 2.8 Drums of U_3O_8 being loaded into a shipping container for transport

Source: Heathgate Resources

Downstream value-add opportunities and challenges

- **Uranium exports (presently $A 0.6bn/a) could be transformed into a further $A 1.8bn/a (but note coal exports are $A 25bn/a!)**
- **Value add through:**
  - **conversion, enrichment (especially) and fuel fabrication**
- **Challenges are significant – international industry well established and controlled**
- **Did Australia miss the opportunity in the 1980's? Yes – we probably did!**

Conversion plant

Figure 3.3 The Cameco conversion plant at Port Hope, Canada

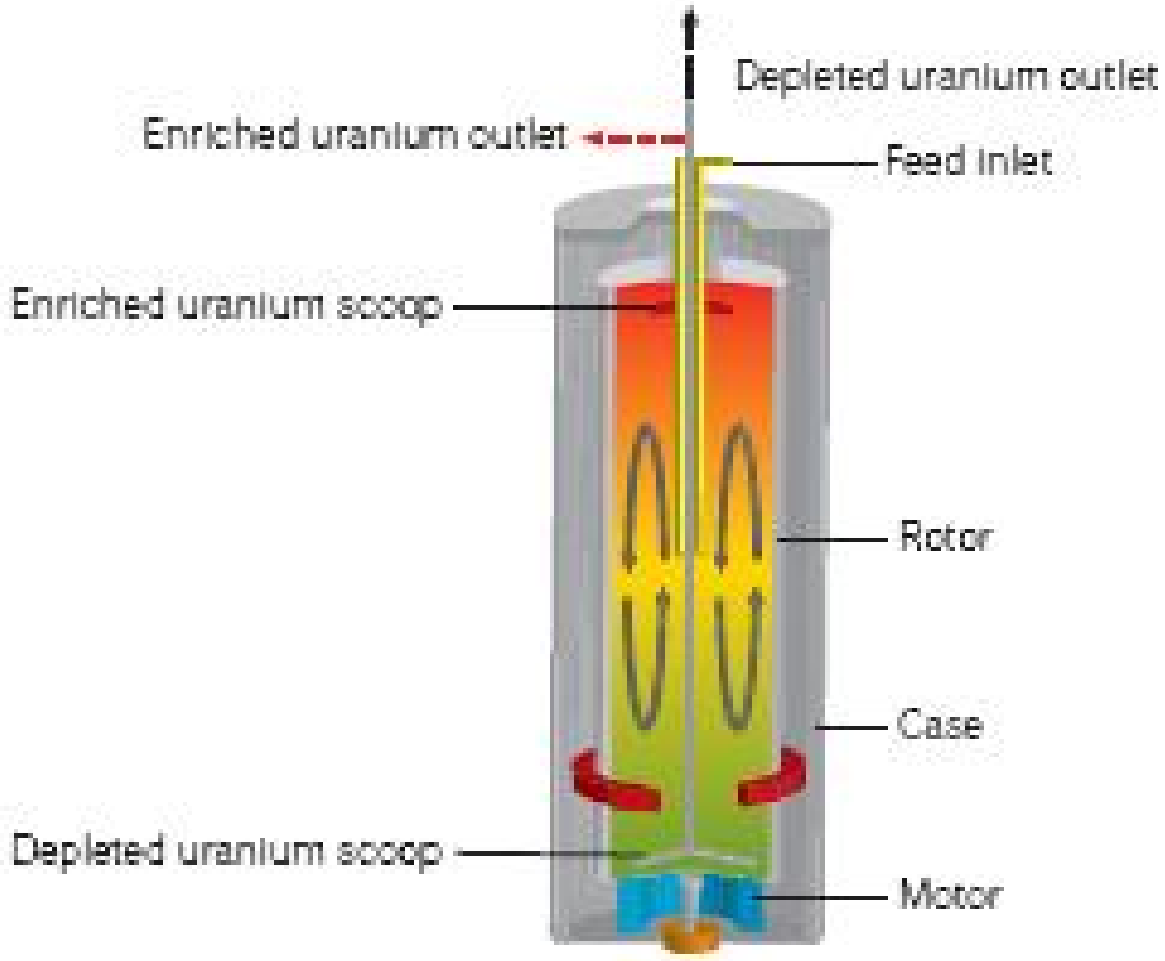
Source: Cameco

The enrichment market

- **Enrichment market highly concentrated – small number of suppliers worldwide**
- **Barriers to entry high – technology capital intensive and tightly held with trade restrictions and limited access to skills base**
- **Enrichment technology proliferation sensitive**
  - **Low enrichment (3.5-5% U^{235}) - power generation**
  - **High enrichment (85-90% U^{235}) - weapons grade material**

Uranium enrichment

Figure 3.5 Gas centrifuges



Source: Westinghouse presentation to the Review, United Kingdom, 5 September 2006.

The fuel fabrication market

- **Products highly customised (see samples)**
- **Specifications depend on reactor design and a utility's fuel management strategy**
- **Forecasts indicate capacity significantly exceeds demand**
- **So perhaps unlikely industry for Australia**

Fuel pellet

Figure 3.7 Fuel pellet

Source: Cameco

Fuel assembly

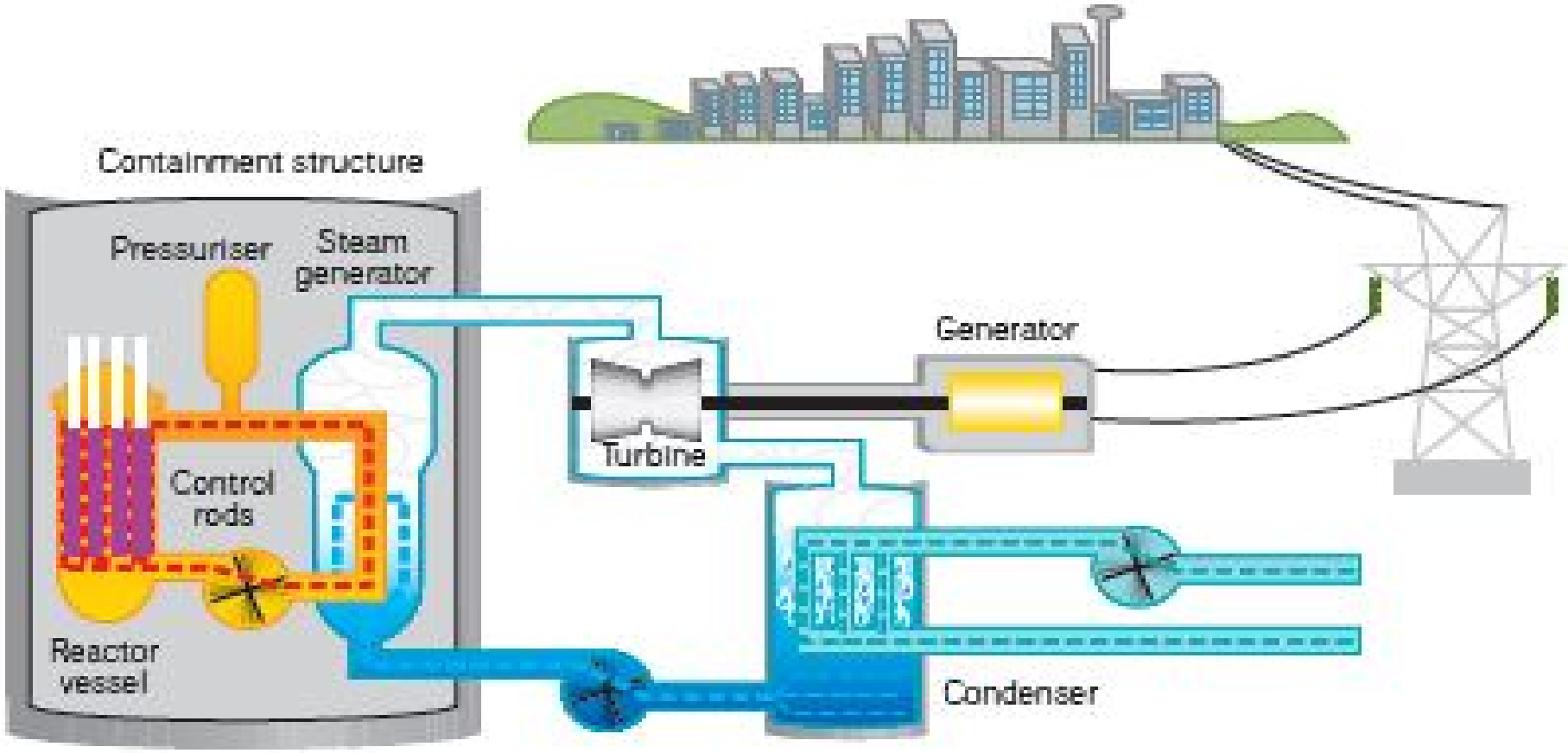
Figure 3.8 Boiling water reactor fuel assembly[3-1]

Electricity generation

- **Electricity demand to double before 2050**
  - **Around 100 GW new generating capacity needed in Australia by 2050 (currently 45 GW installed)**
  - **Spread of technologies needed in generation mix (clean coal, renewables, nuclear)**
- **Nuclear power the internationally proven least cost option for many countries**
  - **Includes lifetime waste disposal and decommissioning**
- **Cost estimates vary - but nuclear not yet competitive with Australia's low cost coal**
  - **Still 20-50% more expensive than current coal – but situation changing with carbon trading imminent**

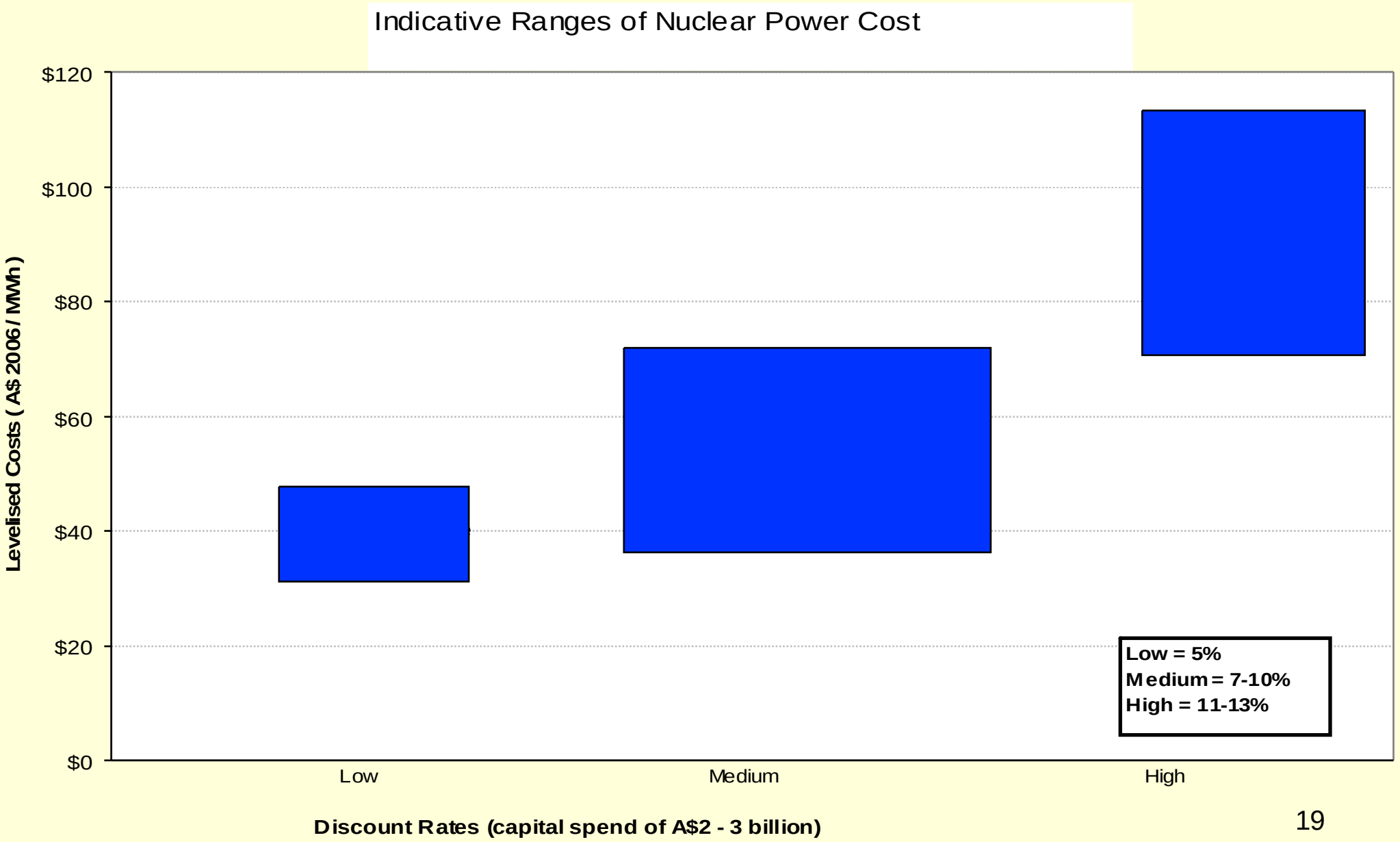
Typical nuclear power station

Figure 1.2 Schematic of a pressurised water reactor

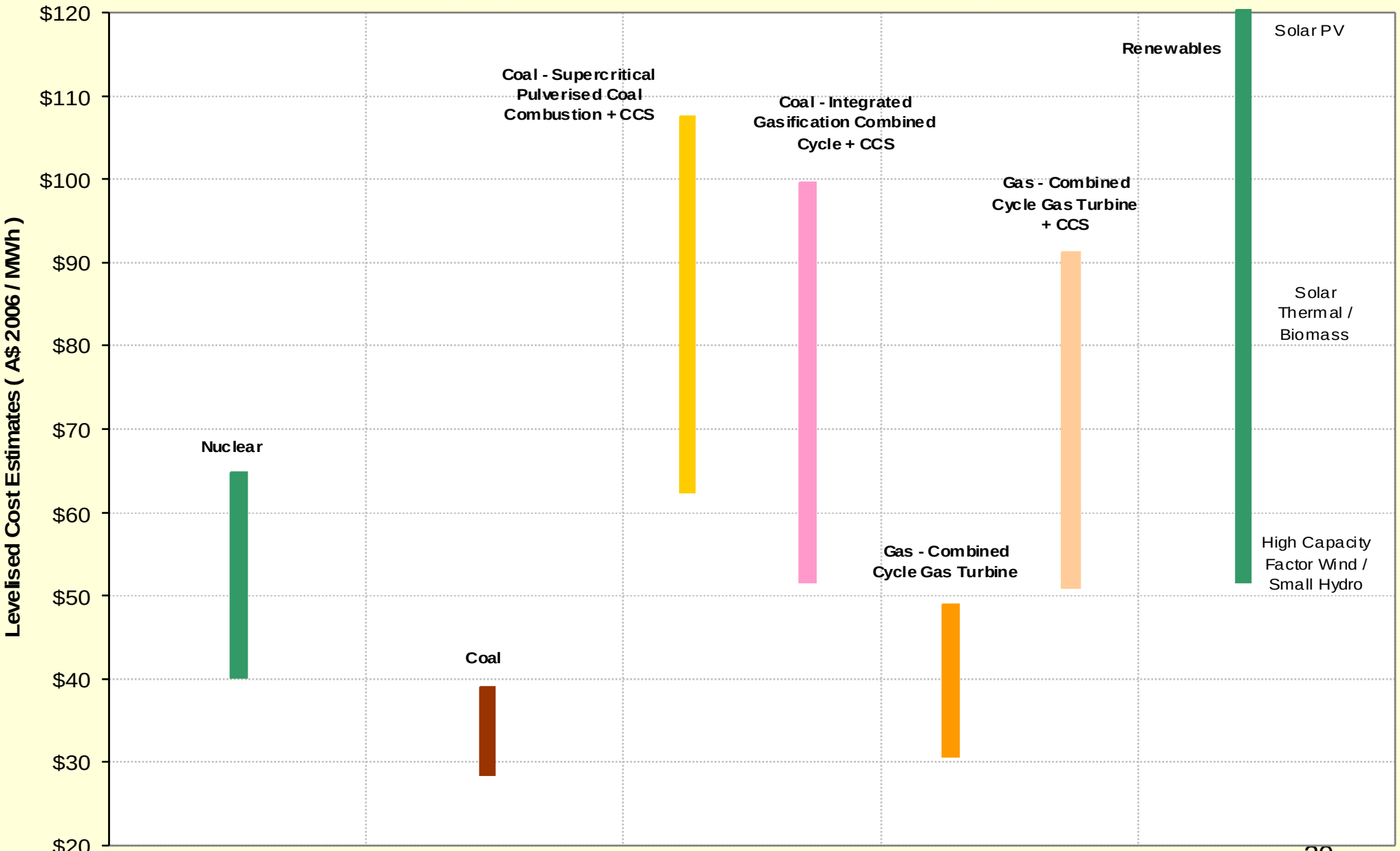


Source: United States Nuclear Regulatory Commission (NRC)[1]

Nuclear power cost ranges



Generation cost comparisons

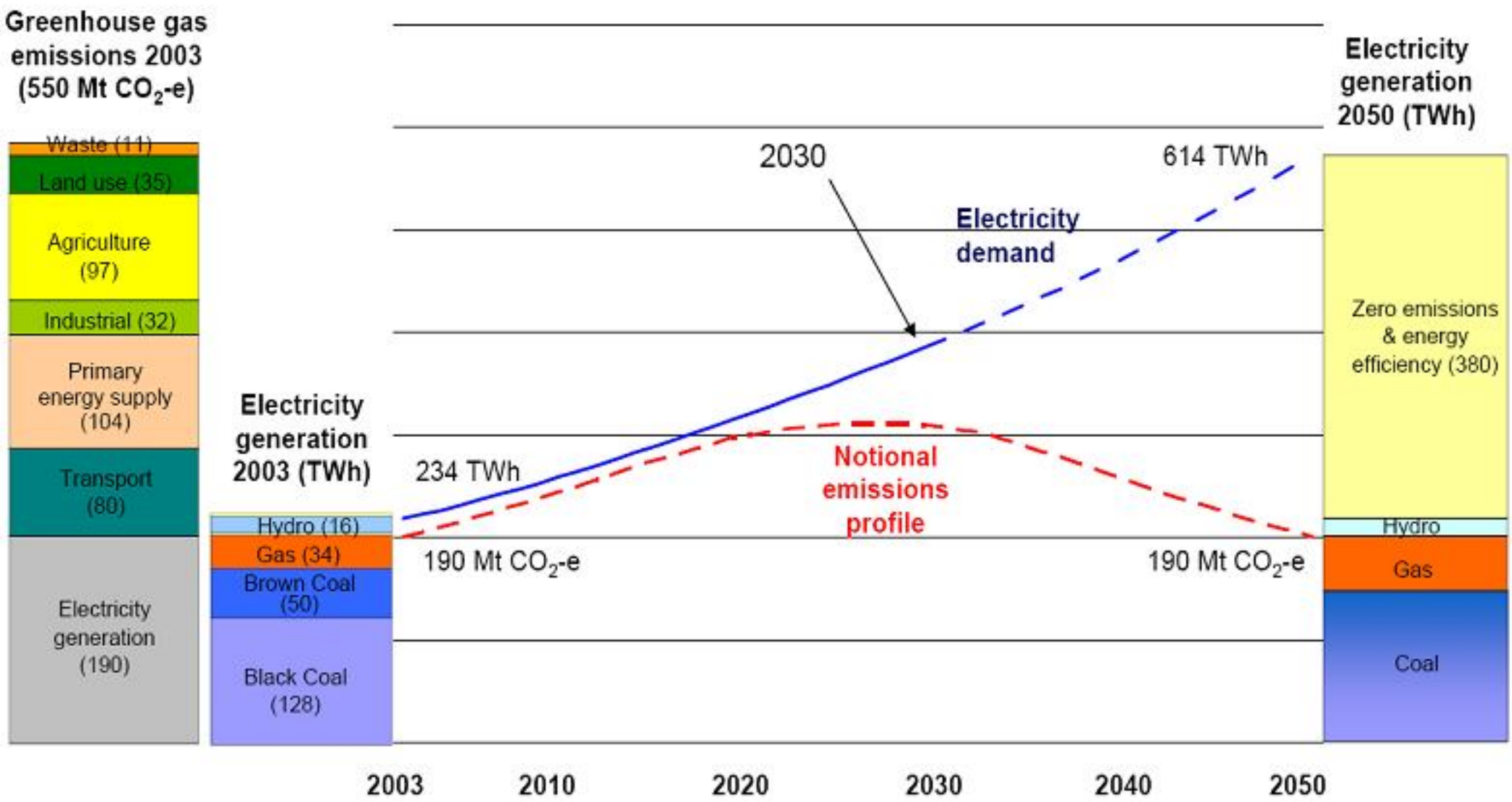


Nuclear costs are for an established industry
CCS estimates are indicative only
Renewables have large ranges and substantial overlaps

Generation cost comparisons

- **Nuclear the least-cost low emission technology (LET)**
  - ***renewables, CCS generally more expensive (ESAA concur)***
  - ***but will have substantial niche roles***
- **Without carbon constraint (ie carbon pricing) all LETs uncompetitive in Australia - compared to coal without carbon capture and sequestration (CCS)**
- **With moderate carbon price nuclear power is competitive**
  - ***Say $15 to $40 /tonne CO_2 - e***
  - ***Competitiveness of other LETs (ie renewables) will also improve***

Electricity generation and emissions scenario to 2050



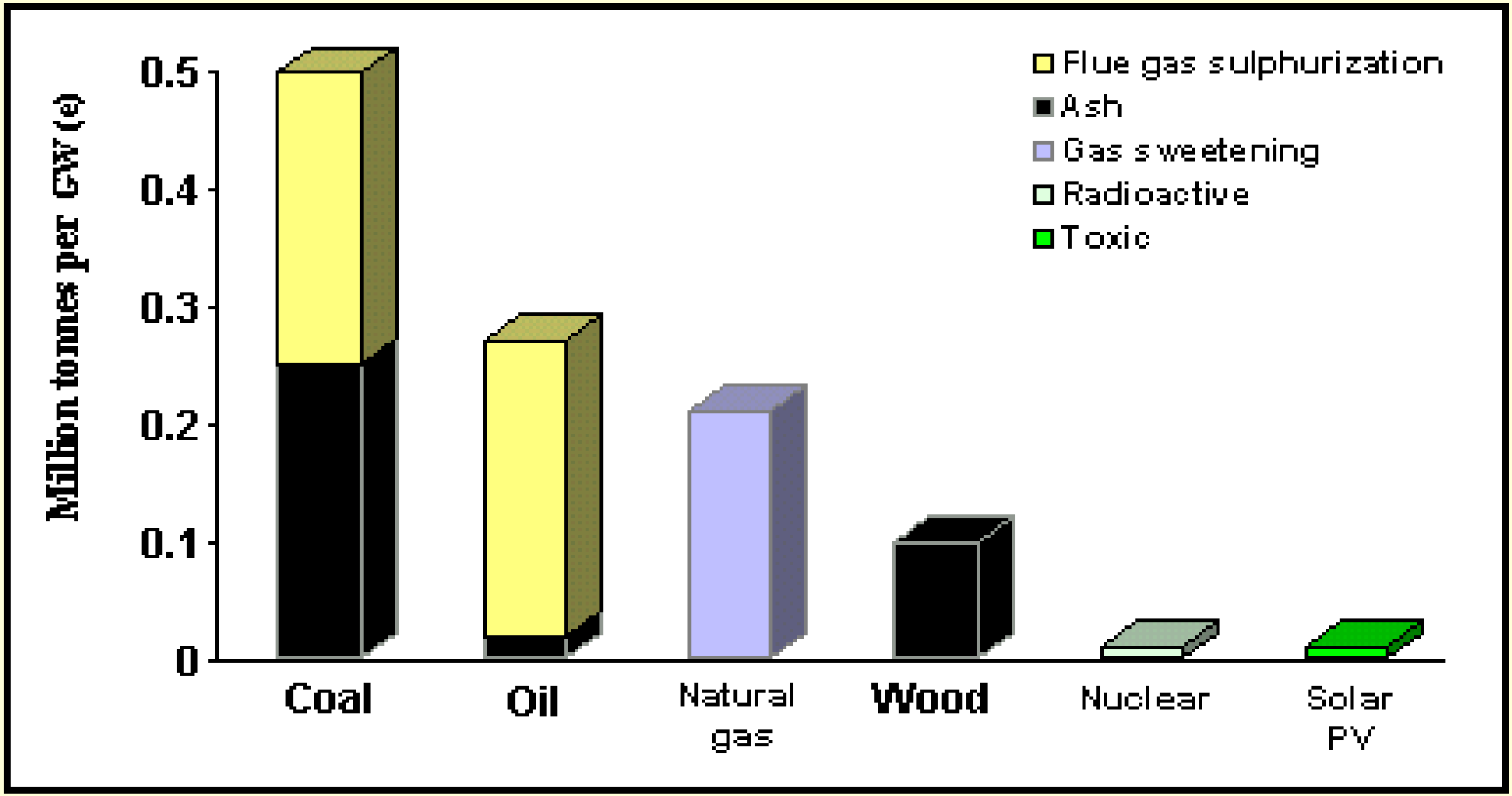
Investment in nuclear power

- **Investors in nuclear power in Australia require:**
  - **Stable long term policy environment, and**
  - **Predictable, robust, consistent licensing and regulatory regime**
- **Investment will establish funds to meet:**
  - **Whole of life spent fuel management costs, and**
  - **Final decommissioning costs**
- **No other technology offers this holistic approach**

Power plant siting criteria

- Land – comparable to coal for PS with no chimneys, mine, conveyors or ash dam
- Water – 20% more CW due lower efficiency – can be once-through sea or estuary water, evaporative cooling towers or dry cooling
- Air pollution – much less than coal – no CO_2
- Access – same as coal for plant items
- Safety and noise – better than coal
- Location – anywhere near grid – unlike coal

Radioactive waste and spent fuel management



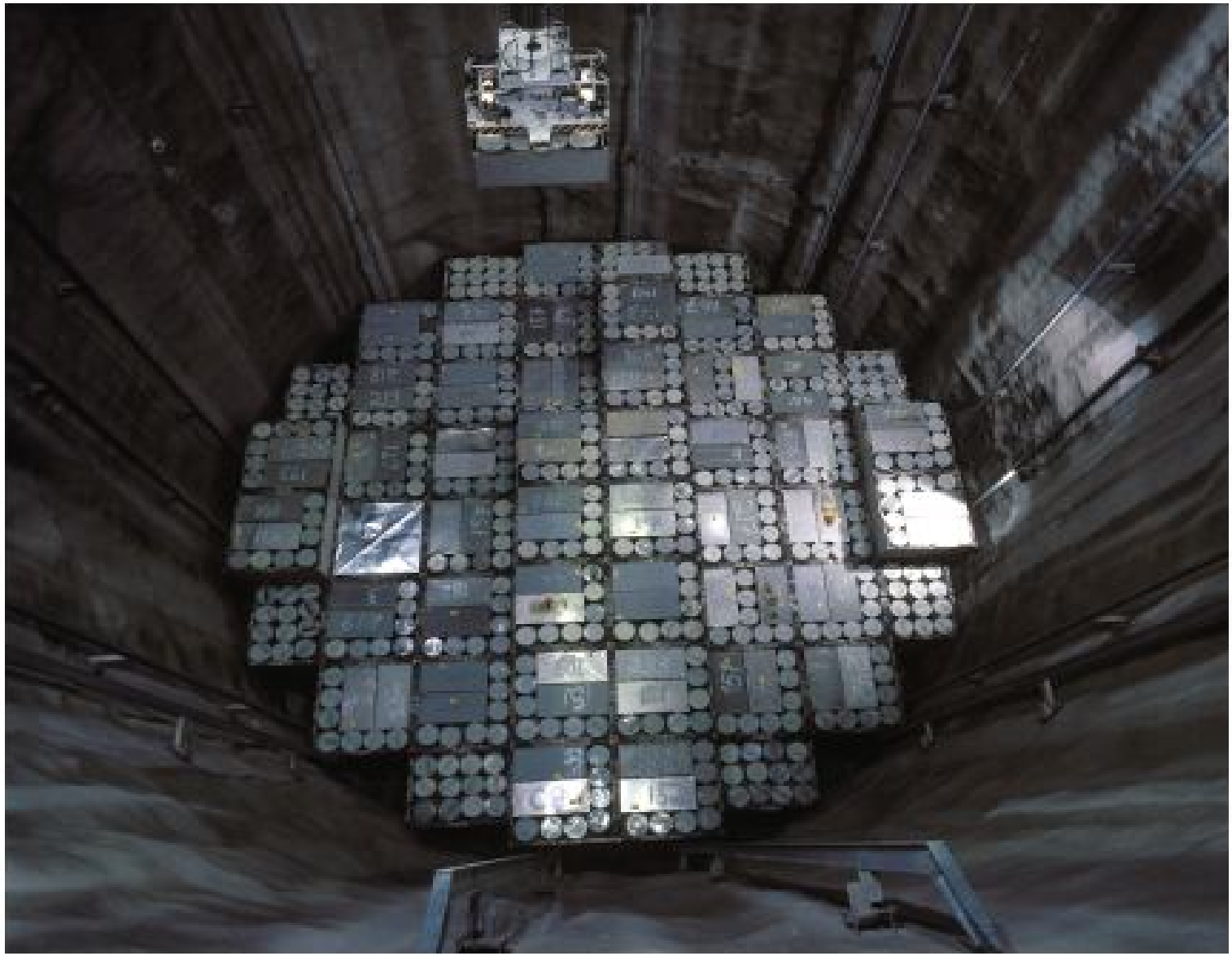
- Note very small waste volume for nuclear energy. For countries with nuclear power radioactive wastes are >1% of total industrial toxic wastes

Low and intermediate level wastes

- **LLW – paper, glassware, tools, clothing – very lightly contaminated – no special shielding**
- **ILW – reactor components, chemical residues, spent medical radioisotopes – needs special handling and shielding, but not cooling**
- **Safe LLW and ILW disposal already well demonstrated at sites worldwide including Australia**
- **Australian uranium mine waste management standards very high**

Intermediate level waste (ILW) repository

Figure 5.2 Intermediate waste repository, Olkiluoto, Finland (Markku Korpi-Hallila TVO)



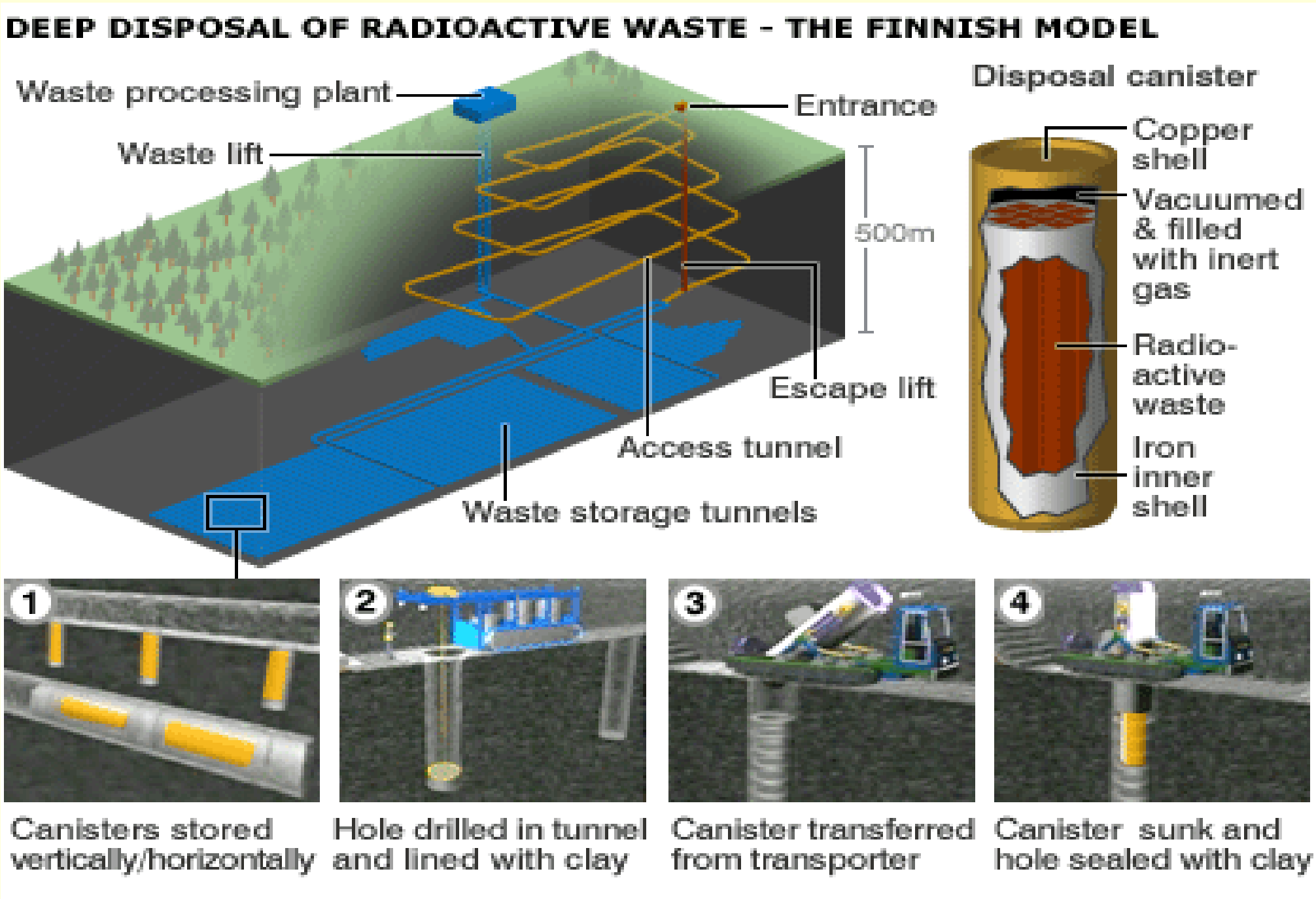
Reprocessing spent fuel and high-level waste (HLW) disposal

- Reprocessing, to retrieve uranium and plutonium for further use, is technically highly complex – probably unattractive for Australia
- Short term disposal in cooling ponds used for heat and radioactivity decay
- Safe long term deep disposal technology for HLW and spent fuel will be employed in most nuclear power countries
- Many parts of Australia suitable for long term deep (>500m) geological disposal of HLW and spent fuel – an opportunity?
- Volumes very small – around one small ensuite bathroom per 1000MW reactor per year
- But deep disposal not needed before 2050 if nuclear power adopted by Australia

Spent nuclear fuel (HLW) storage

Figure 5.4 Dry concrete canister storage of spent nuclear fuel – Wolsong nuclear power plant, Republic of Korea. Eleven canisters are required to store the spent fuel discharged from one reactor over a year

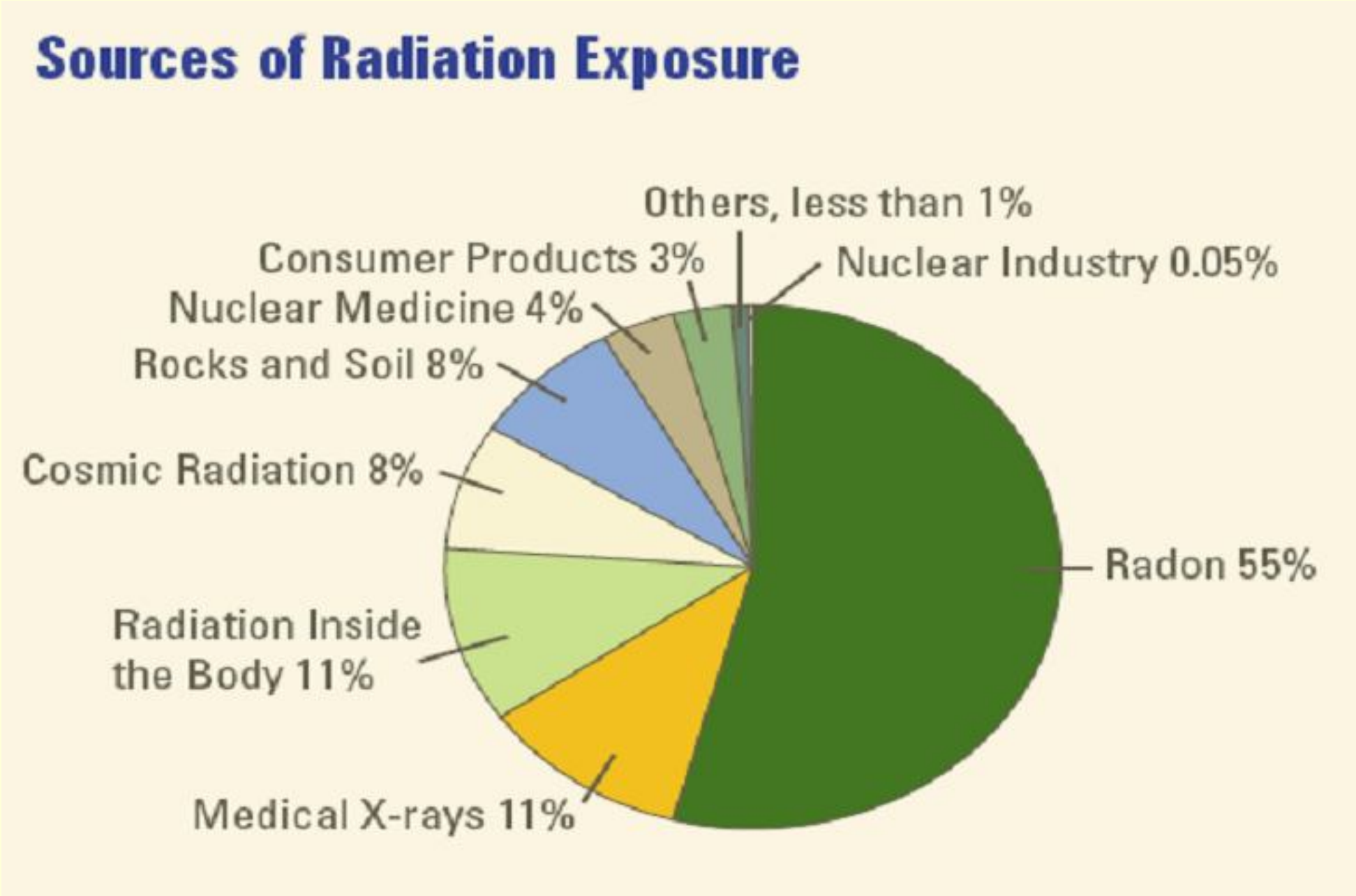
Implementing deep HLW disposal



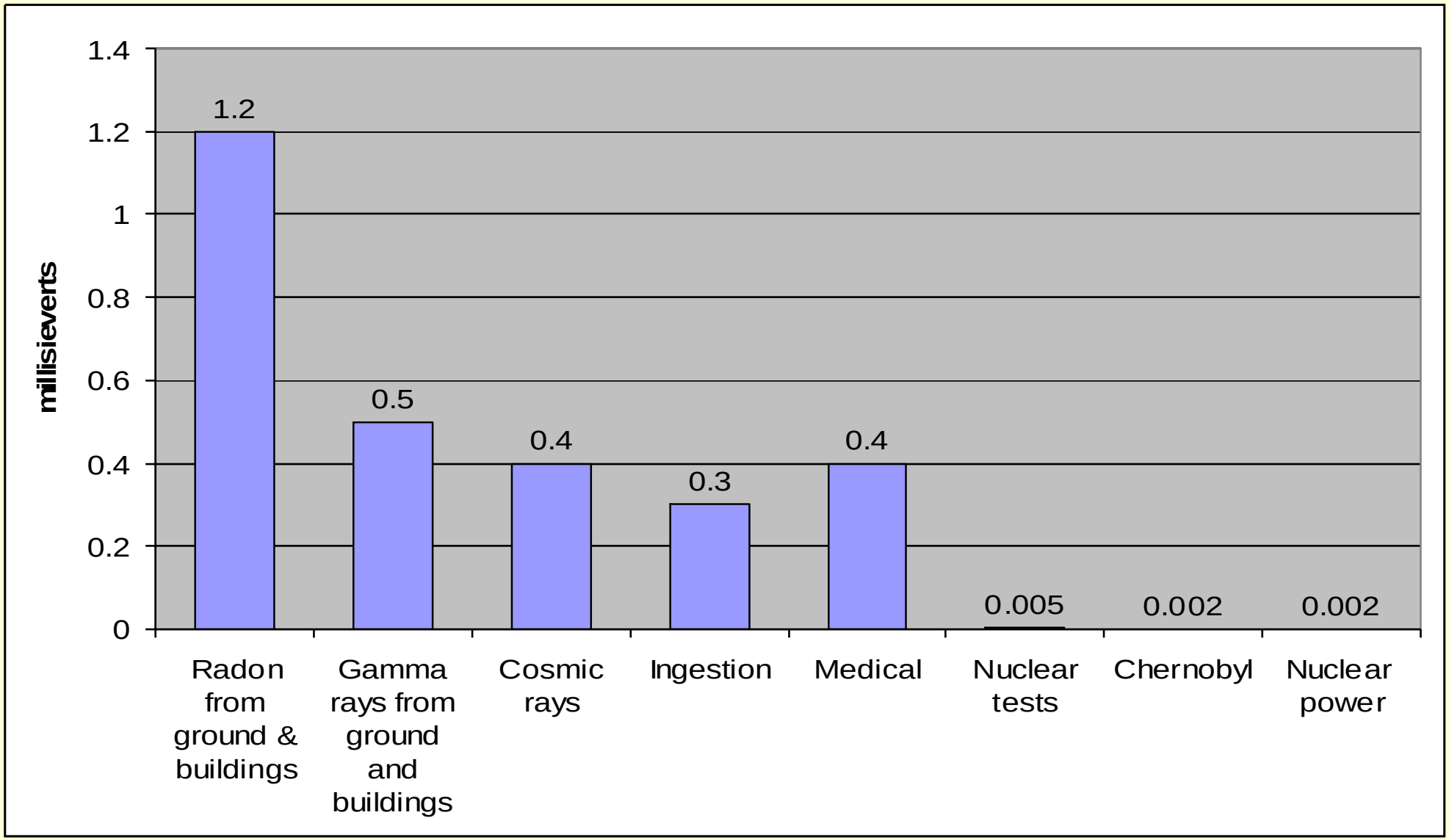
Health and safety

- **Nuclear power has fewer health and safety impacts than coal or hydro generation**
- **Ionising radiation and health impacts very well understood**
- **Established international safety standards well reflected in Australian practices**

Nuclear contribution to radiation exposure



World average radiation dose in 2000



- ***The contribution from nuclear power is minute!***

Nuclear power plant safety

- **Radiation dose return Sydney-London flight greater than living near nuclear power plant for 60 years**

- **Modern reactors have dramatically improved safety systems and operator training post Three Mile Island (1979) and Chernobyl (1986)**

- **Further improvements made and in prospect - new generation reactors are 'inherently safe'**

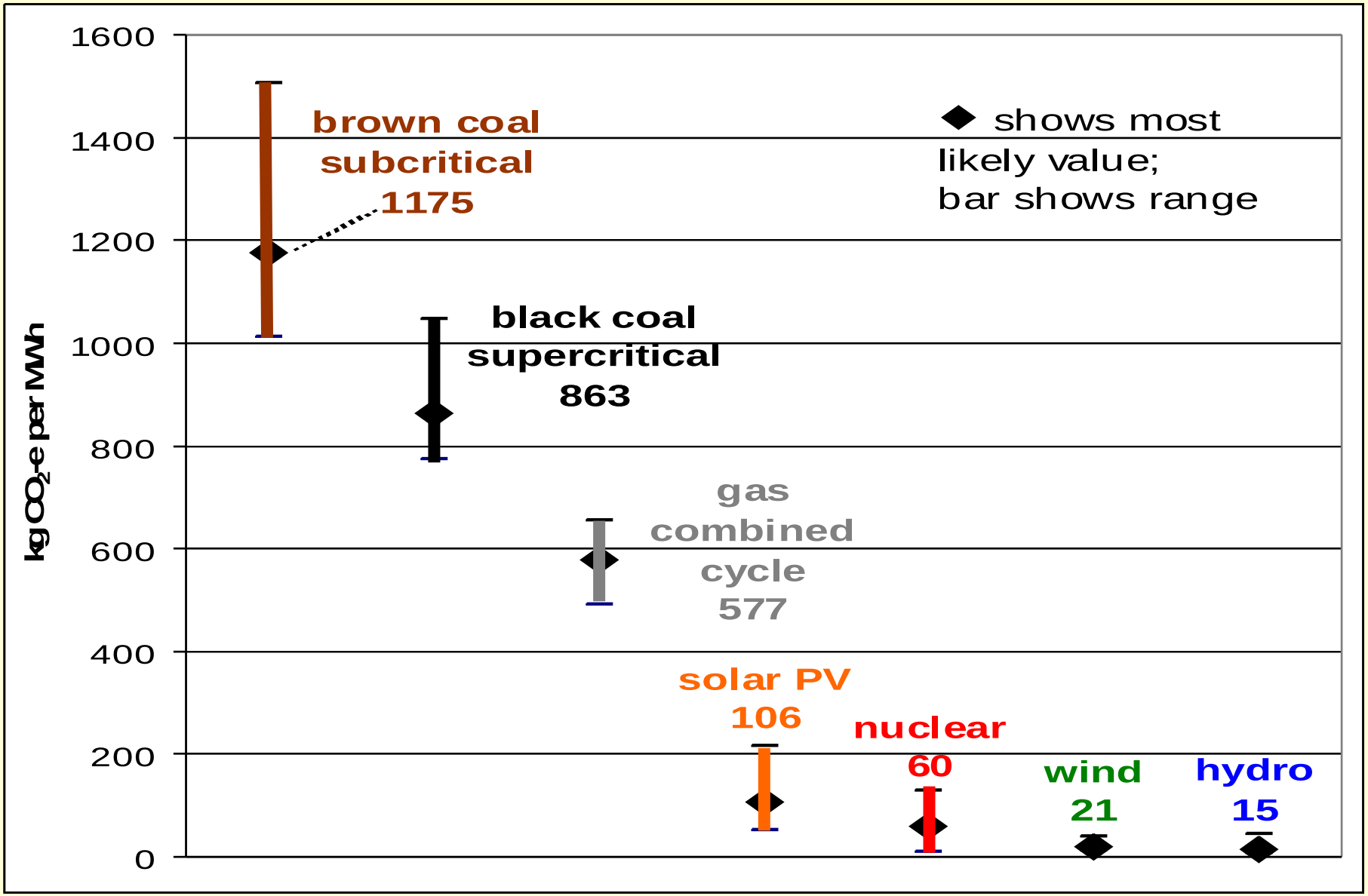
Environment and climate change

- **Full life cycle nuclear power greenhouse gas emissions very low**
  - **Ten times below fossil fuels, similar to renewables**
- **Nuclear power has low impact on most other environmental measures**
  - **Water use can be higher than coal - but can use sea water, air cooling or water recycling**

Nuclear's role in emissions abatement

- **Need deep cuts in emissions**
  - **Nuclear can make important contribution, but other technologies and actions required also**
- **Can minimise cost of emission cuts by allowing market to choose:**
  - **Technology-neutral measures needed (eg carbon pricing and <u>All</u> technologies in mix (RE, CCS, nuclear, etc)**
  - **Internalisation of externalities)**
  - **Let rational markets, not politicians, pick winners**

Life cycle greenhouse gas emissions from electricity generation



Non-proliferation

- **Australian uranium export within international non-proliferation regime**
- **Australia has most stringent requirements for uranium supply**
- **Increase in Australian uranium exports will not increase risk of proliferation**
- **Proven proliferation cases involve:**
  - **illegal supply networks, secret facilities and undeclared materials (see AQ Khan)**

Uranium exports and non-proliferation

- **Uranium needs for nuclear weapon relatively small**
- **Any country developing weapons need not rely on uranium import**
- **Greatest proliferation risk arises from undeclared centrifuge enrichment plants!**

Nuclear security

- **Strict physical protection standards apply to nuclear power plant construction**

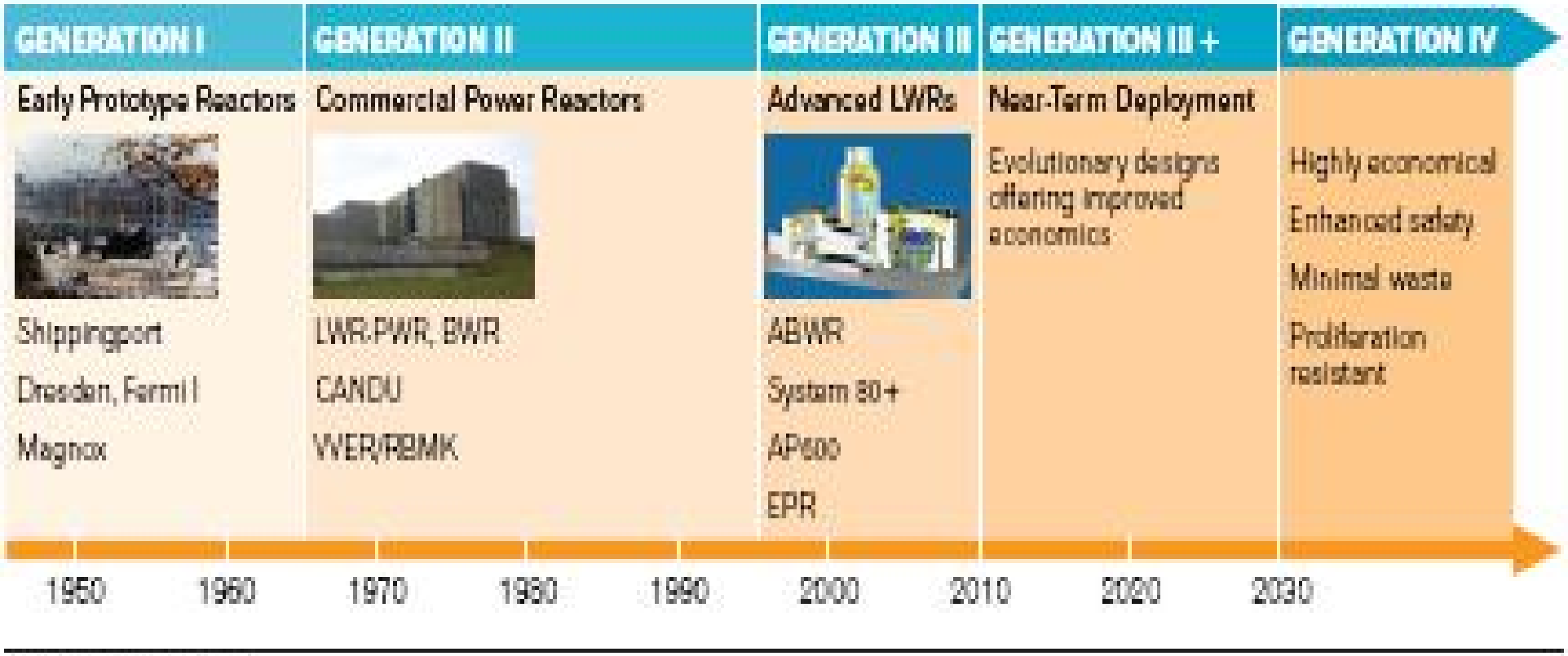
- **Modern reactor containment structures would <u>not</u> be breached by impact of largest airliner!**

Uranium mine regulation

- **Australia's three uranium mines operate under different regulatory regimes!** ***Can you believe it?***
- **Each Australian State currently has a different regulatory regime!** ***Can you believe it?***
- **Uranium mining regulations must be rationalised and harmonised nationally**

Evolution of nuclear power plant designs

Figure L1 Diagram illustrating the evolution of nuclear power plant designs

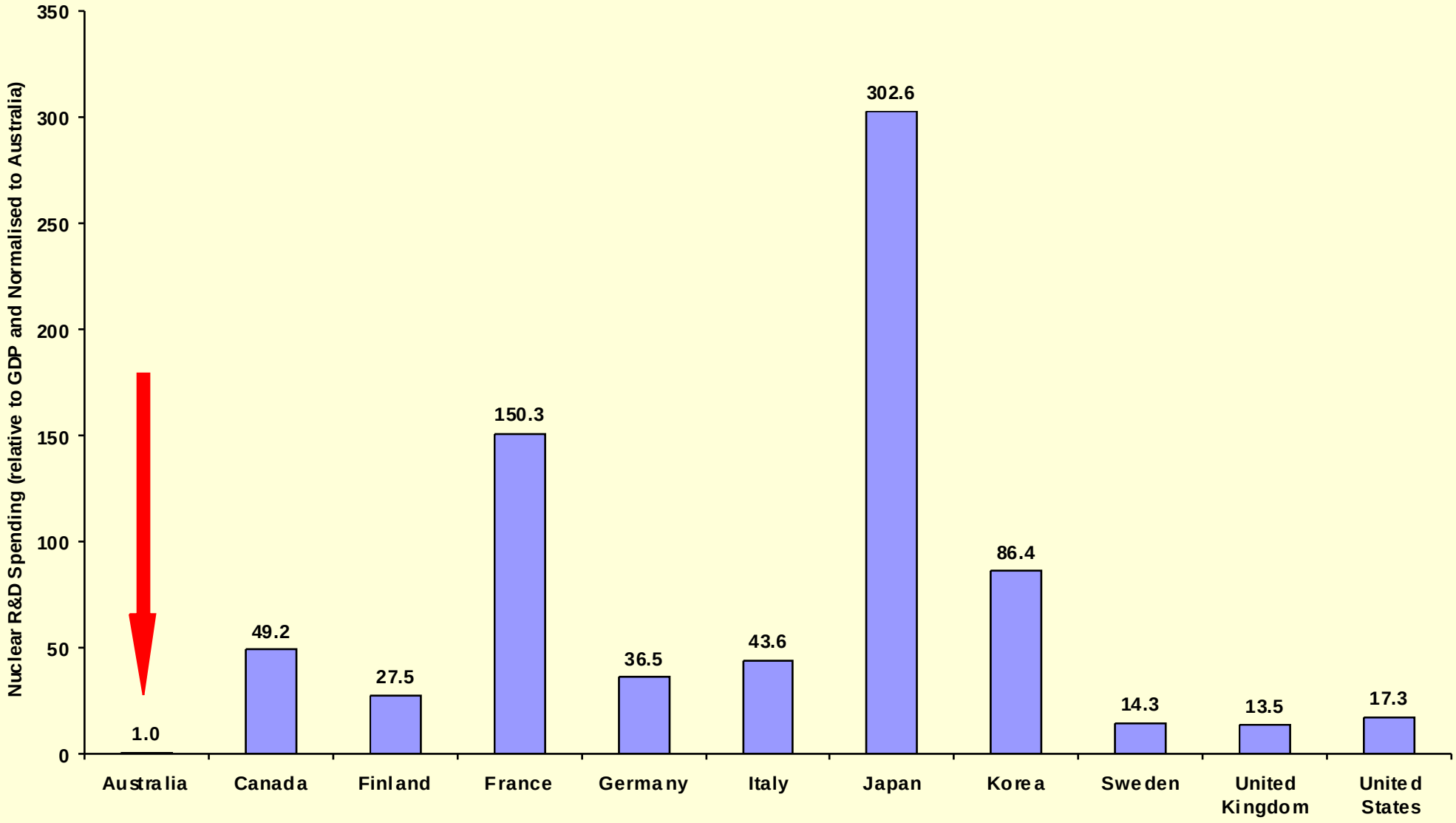


Source: USDoE/GIF[330]

Research and development

- **International support for nuclear R&D fell in decade to 2001, but has since risen sharply**
  - **Around half total OECD energy technology R&D funding is nuclear**
- **Minimal Australian nuclear energy R&D in past 30 years**
  - **Australian R&D focussed on uranium exploration and mining**
- **Australian nuclear R&D must increase significantly**
  - **International collaboration a priority**

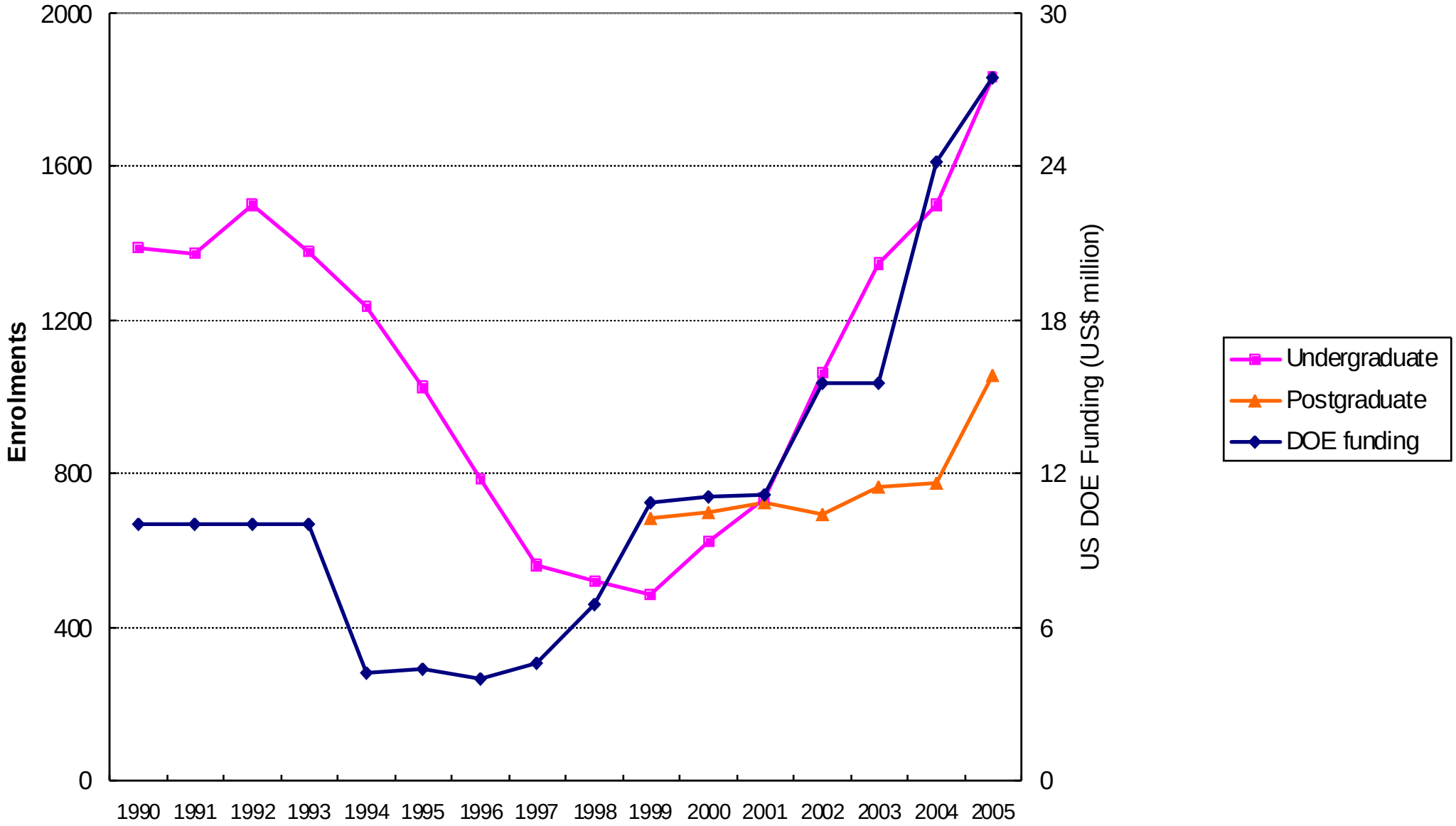
Australia's relative nuclear R&D effort



Education and training

- **Growing international demand for skilled nuclear personnel driven by**
  - **ageing experienced nuclear workforce**
  - **international 'nuclear renaissance' already well under way**
- **Specialist education in Australia must expand if nuclear power adopted**
  - **opportunity to leverage international efforts**
  - **and build international linkages**
- **Institutions and students will respond**
  - **if right policies are in place (as in USA)**

Education Sector can respond (US)



UMPNER conclusions (1)

- **Australia can significantly expand uranium exports**
- **Reserves adequate – much more to be found – especially Australia!**
- **Electricity demand more than doubles by 2050**
- **Nuclear proven choice of many countries – contributes >15% of total world generation**
- **In Australia nuclear generation 20-50% costlier than coal**
- **But carbon pricing makes nuclear competitive for base load**
- **Nuclear costs include waste disposal and decommissioning**

UMPNER conclusions (2)

- Safe LLW, ILW and HLW disposal technology proven
- Deep geological disposal safest long term HLW choice
- Australia has many geologically suitable deep disposal sites
- Radiation impacts well understood and controlled
- Nuclear power has fewer health and safety impacts than fossil - but no technology is risk free
- Nuclear power has acknowledged legacy issues (Chernobyl and TMI) but not representative of modern reactor practice

UMPNER conclusions (3)

- **Deep emissions cuts needed to mitigate climate change – nuclear part of portfolio**
- **Nuclear low emission technology (LET) – over ten times less than fossil - comparable renewables**
- **Emission reduction costs minimised through market measures**
- **Australia has robust highly respected non-proliferation regime**
- **Proliferation risk from secret enrichment facilities, not spent fuel from well protected power plants**
- **Industry regulation must be harmonised and rationalised**

UMPNER conclusions (4)

- **Australian nuclear RD&D investment minimal**
- **Significant skilled human resource increases needed if Australia to deploy nuclear energy**
- **International collaboration commended – especially RD&D and education**
- **From 2020 to 2050 Australia could build fleet of 25 reactors - each 1000MWe**
- **Delivering 25 GWe - one third Australia's power needs, saving 17% emissions relative to BAU**

Thank-you for your attention

The next step is up to us – the people!