Low-carbon energy transitions and global materials outlook

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Division of Nuclear Technology Development and Economics

Stockholm, January 2020

The NEA serves as a framework to address global challenges

The Role of the NEA is to:

- Foster international co-operation to develop the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy.
- Develop authoritative assessments on key issues as input to government decisions on nuclear technology policy.

33 NEA countries operate more than 80% of the world's installed nuclear capacity

Why do we need nuclear?

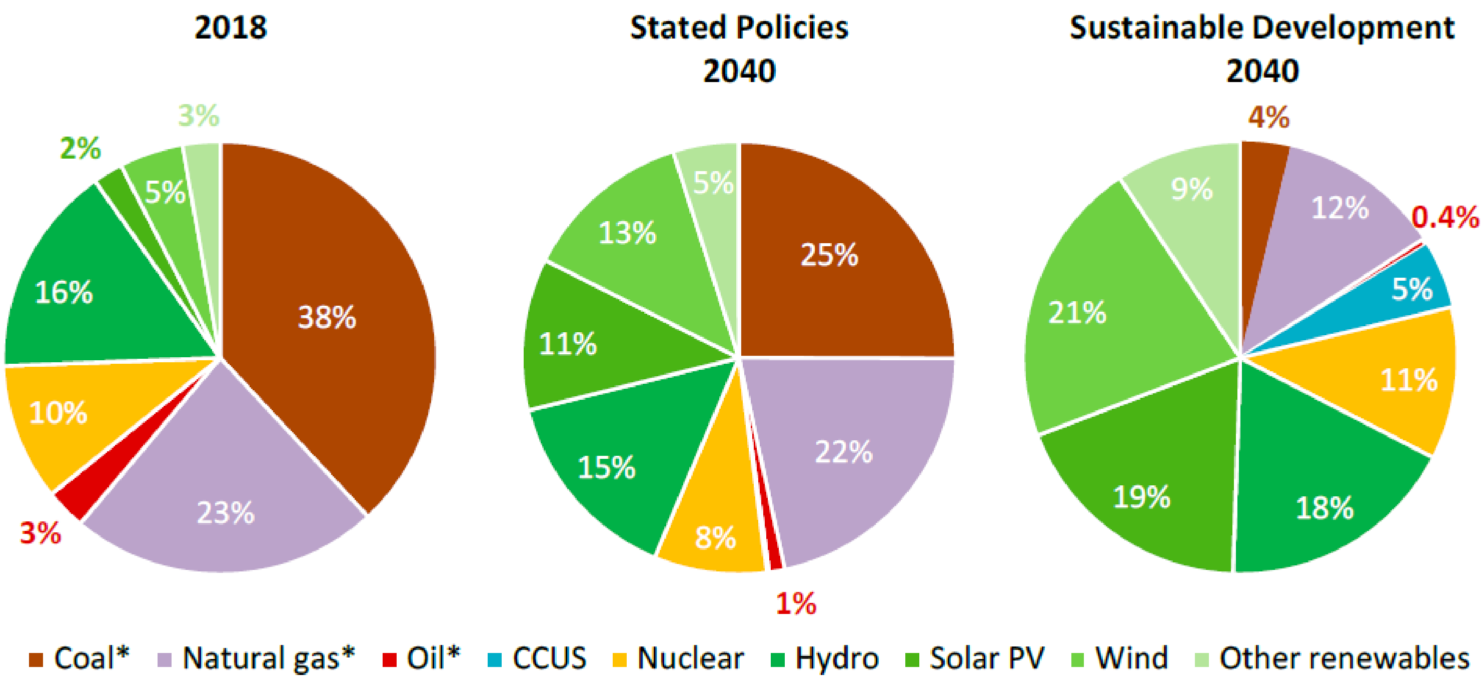
ANSWER: *the economics and environmental benefits of nuclear energy are overwhelmingly convincing*

- cost of 1 kg of enriched fuel is < $2,000
- this yields about 360,000 kWh of electricity
- equivalent to 160 tons of steaming coal

- Nuclear power avoids each year between 1.2 and 2.4 Gt of CO_2 emissions

(assuming this power would otherwise be produced by gas or coal)

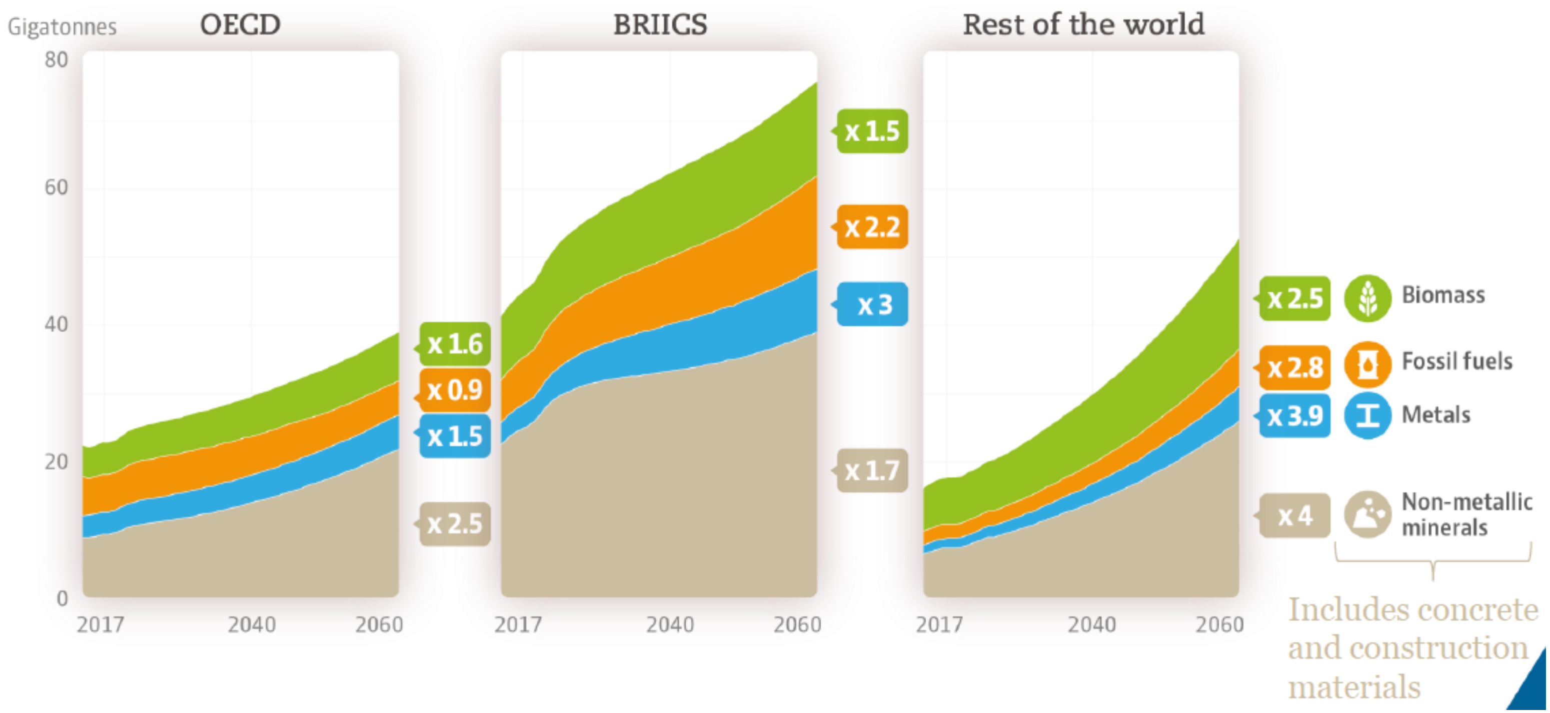
Global electricity generation mix: a view to 2040



Source: OECD-IEA, WEO 2019

- **Achieving global sustainable energy goals will mean using all available fuels and technologies, including large-scale NPPs and small modular reactors (SMRs).**

Growth in materials use despite technology change and productivity



Source: Global Material Resources Outlook to 2060 (OECD, 2019)

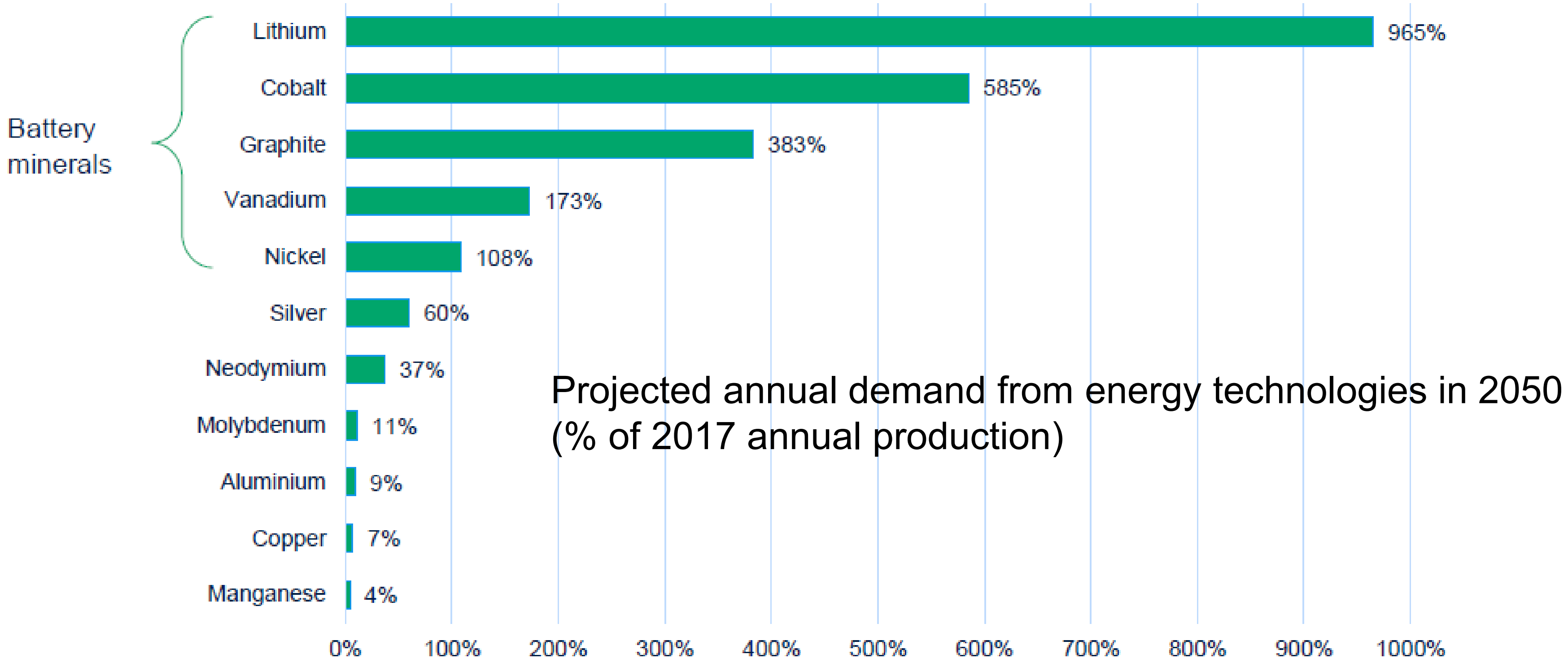
- GHG emissions related to materials management…

Mineral demand in a low carbon future: focus on renewables

- A recent study of World Bank indicates that the renewables technologies are significantly MORE material intensive than current traditional fossil-fuel-based energy supply systems.
- Electric storage batteries - the most significant example - where the rise in relevant metals (aluminium, cobalt, iron, lead, lithium, manganese, and nickel) grow in demand from a relatively modest level to about 1 000% under 2DS.

Source: World Bank Group, Extractives Global Programmatic Support, 2017

Mineral demand in a low carbon future: focus on renewables

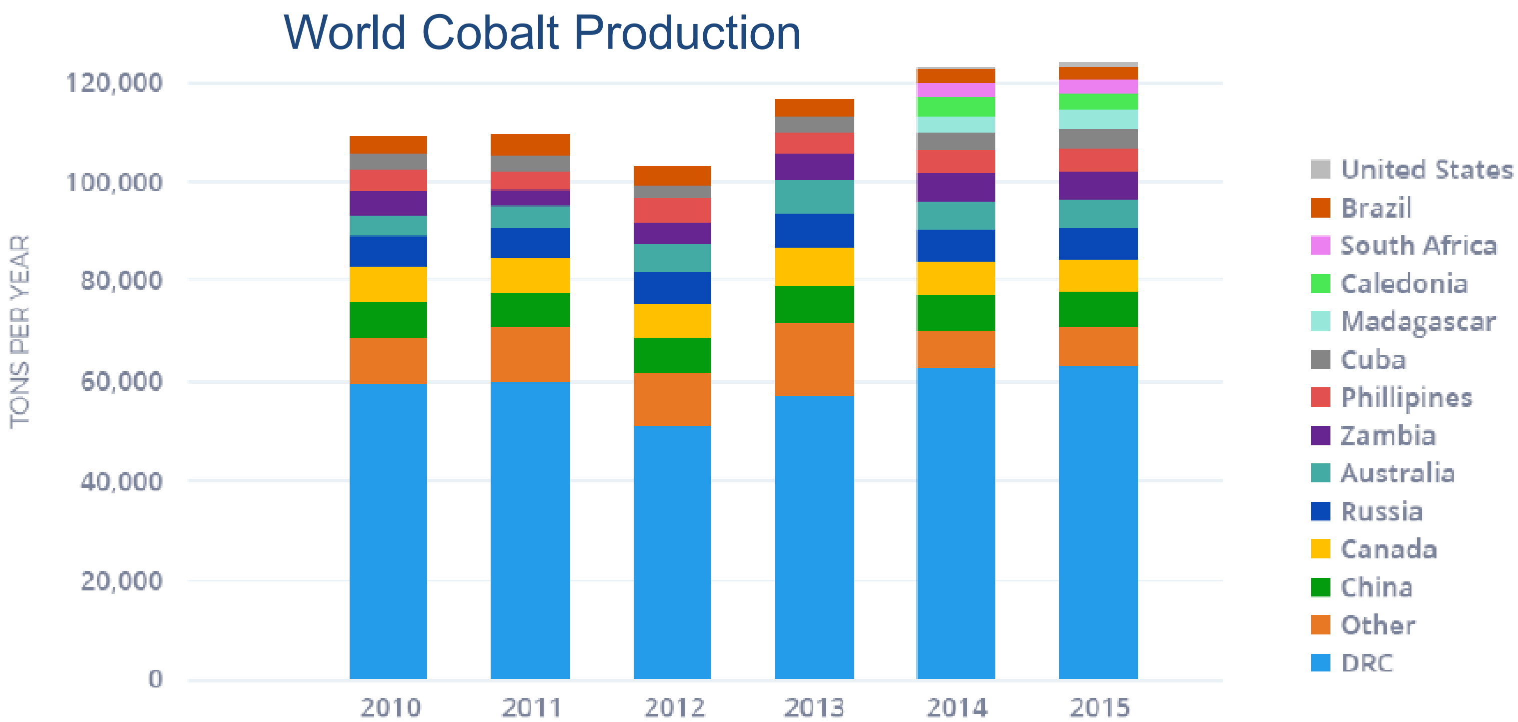


Source: OECD, IEA, 2017; World Bank Analysis, 2018

Where only 5-7% of Li-ion cells produced worldwide are recycled

(estimation P. Toledano, Columbia Center on Sustainable Investment, 2019)

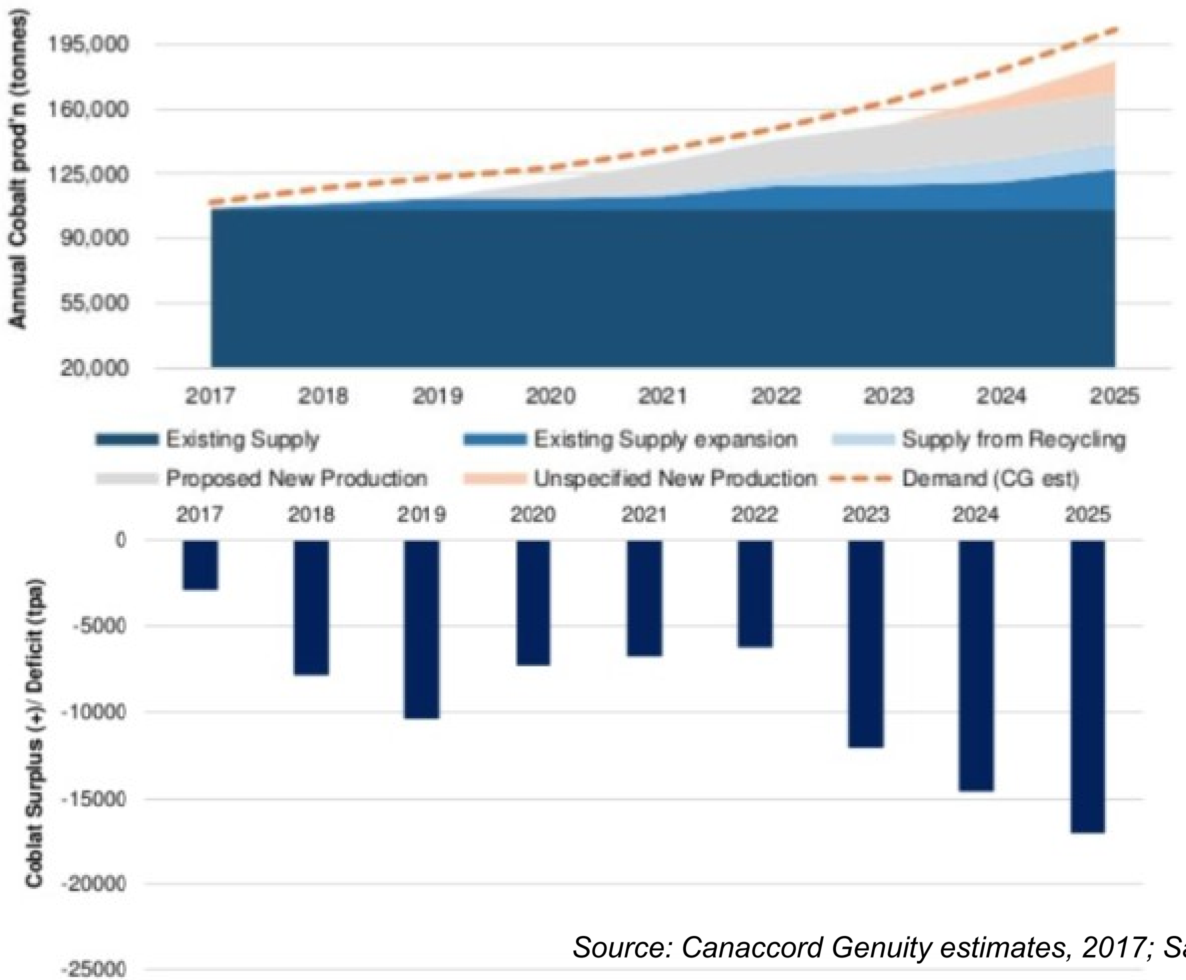
Critical minerals for renewables: Cobalt case study (1)



Source: LiCo Energy Metals, Inc, 2017; Saleem H. Ali, 2018

- 60% of world's supply is coming from Democratic Republic of Congo (political conflict, corruption)
- Almost entirely (90%) produced as byproduct of other ore mining operations (such as Cu, Ni, Pt)
- China has 60% of the refining capacity for cobalt

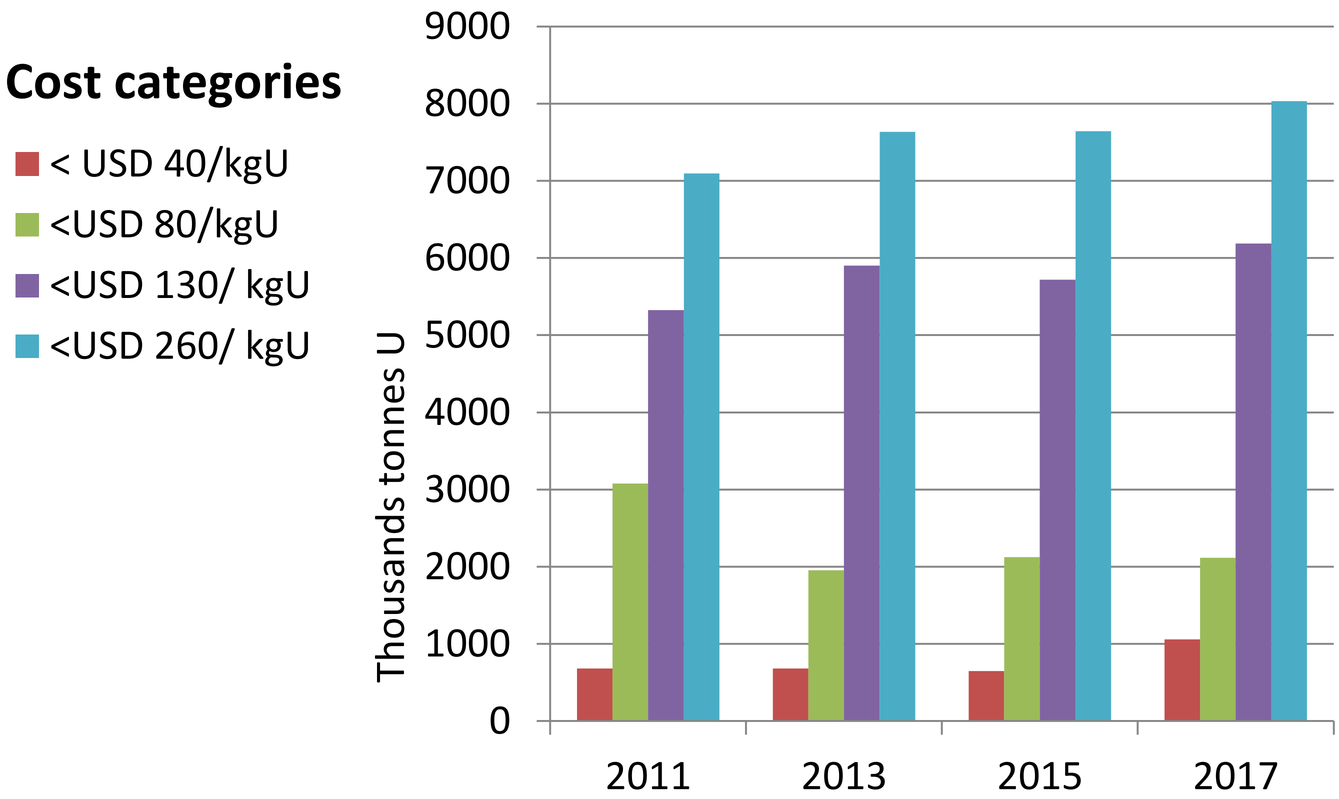
Critical minerals for renewables: Cobalt case study (2)



- Predictions in future cobalt supply, demand and deficit
- Important unbalance between supply and demand for cobalt, based on the high needs of the battery sector.

Source: Canaccord Genuity estimates, 2017; Saleem H. Ali et al, 2018

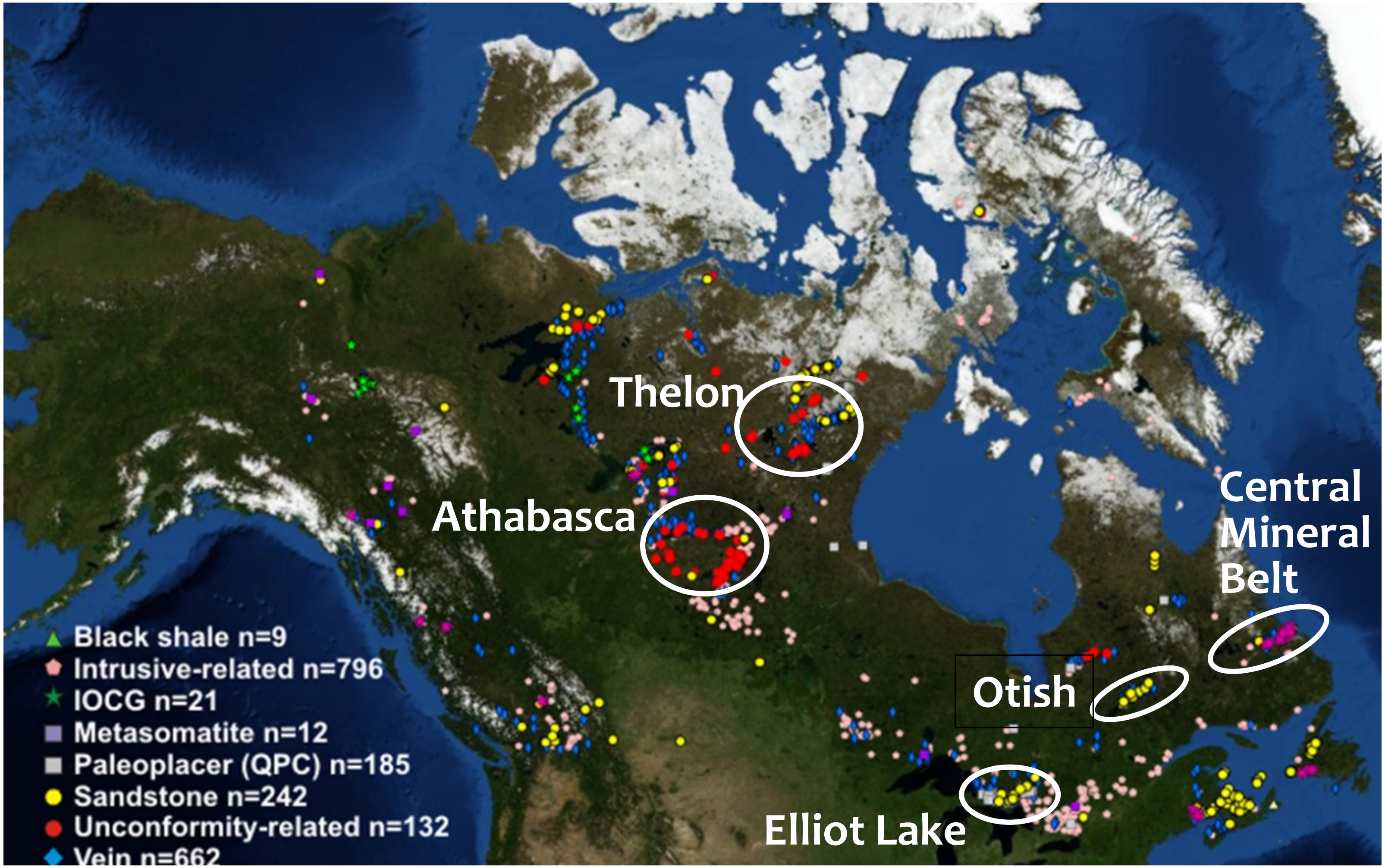
What resources are available to meet the world's demand for nuclear energy?



Source: OECD-NEA/IAEA, Uranium 2018: Resources, Production, Demand (« Red Book »)

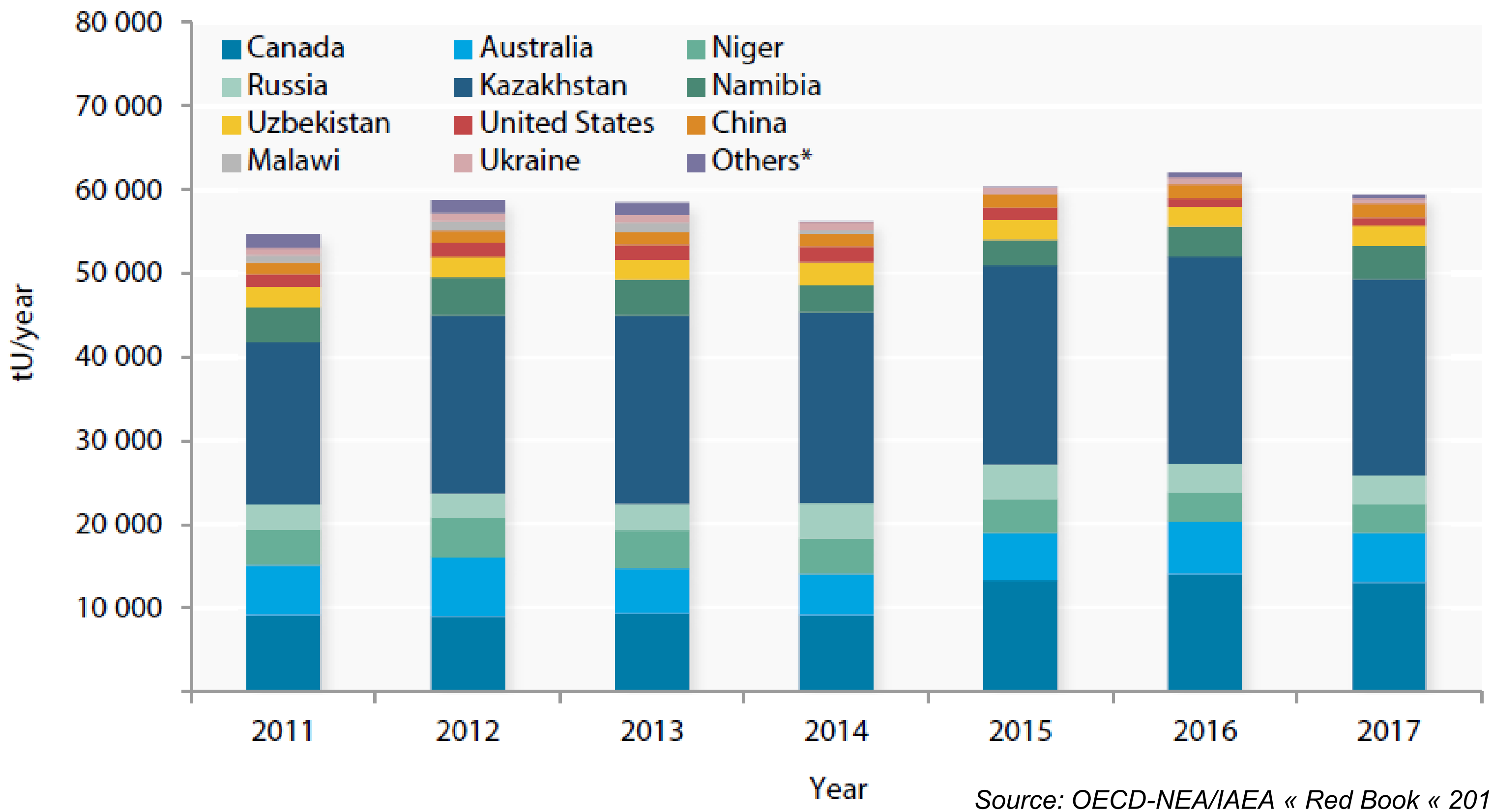
- Global identified conventional uranium resources increased. Widespread distribution.
- Resources have been added at a greater rate than they have been consumed.

Still major uranium exploration sites in Canada



Continued successes in the Athabasca Basin indicate that even 'mature' areas remain highly prospective!

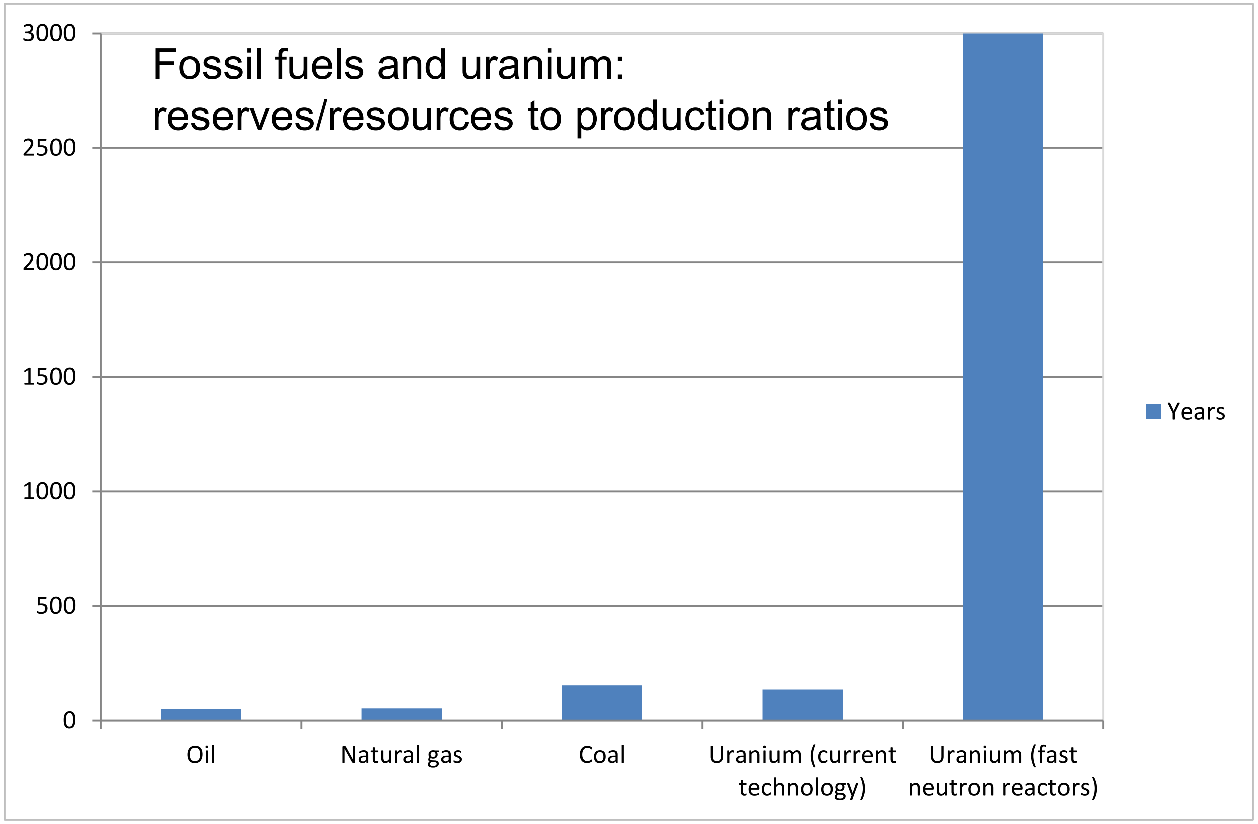
Recent world uranium production



Source: OECD-NEA/IAEA « Red Book « 2018

- Production has started to decline in 2017 as major producers, including Canada and Kazakhstan, limit total production in response to the sustained low price of uranium.

Resources to production ratios



- Identified uranium resources are sufficient for about 130 years of production.

Unconventional resources (28 mil tU) and new reactors technologies can increase significantly the availability of uranium;

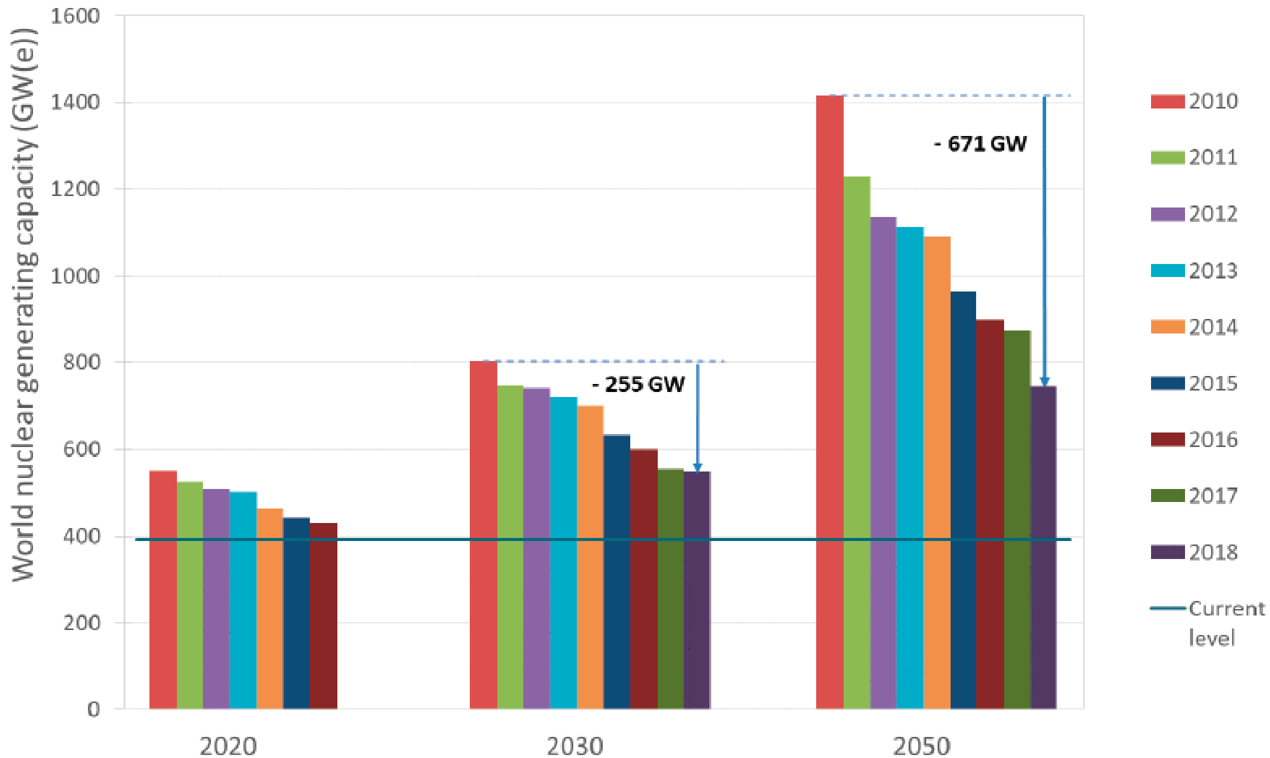
- Global oil and natural gas reserves are sufficient to meet ~50 years of current production.

- What about materials for renewable energy systems?

Major opportunities but remain critical (e.g. cobalt)

Source: BP Statistical Review of World Energy, 2017; OECD-NEA / IAEA « Red Book », 2018

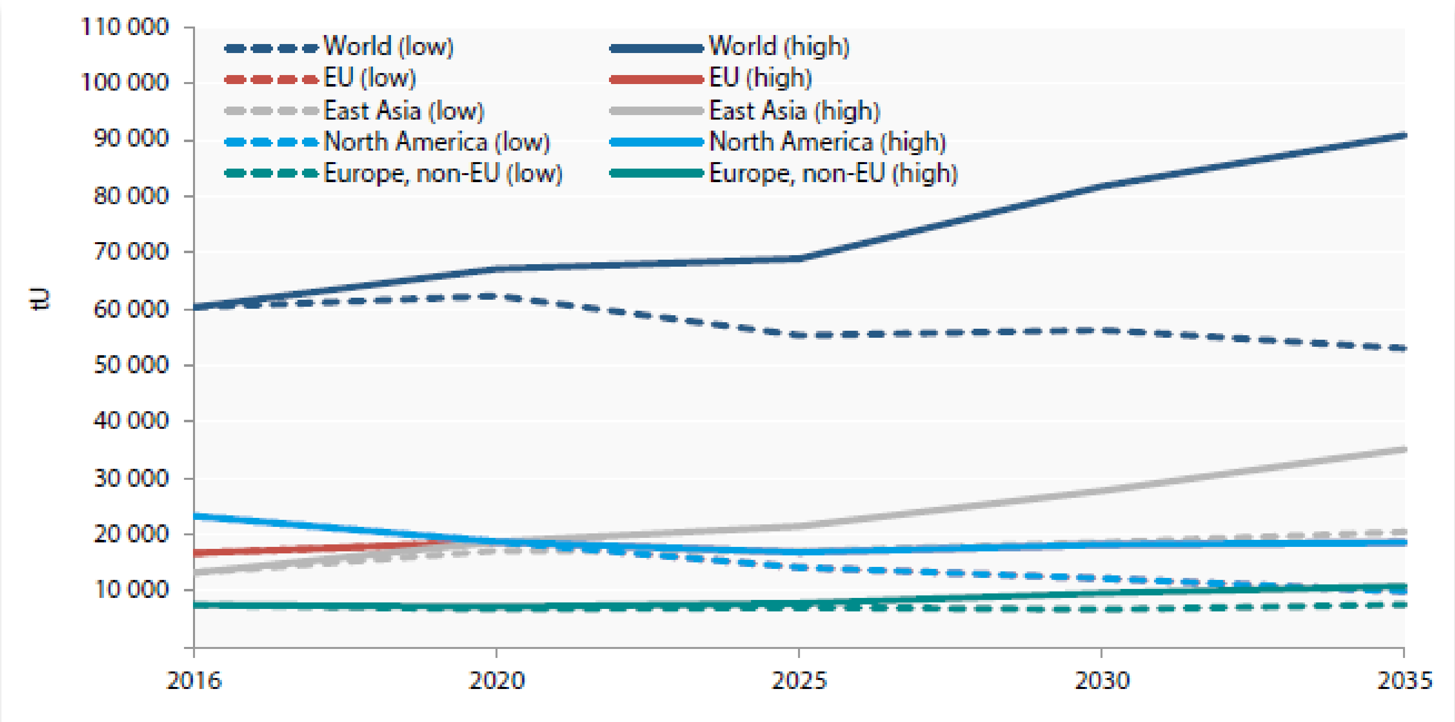
Uranium Demand outlook: changing landscape for the global nuclear capacity projections



Source: IAEA and OECD/NEA

High case projections of future nuclear generation capacity from 2011 to 2018 changed drastically year after year… Induced uranium reactor requirements have also fallen.

Uranium requirements to 2035



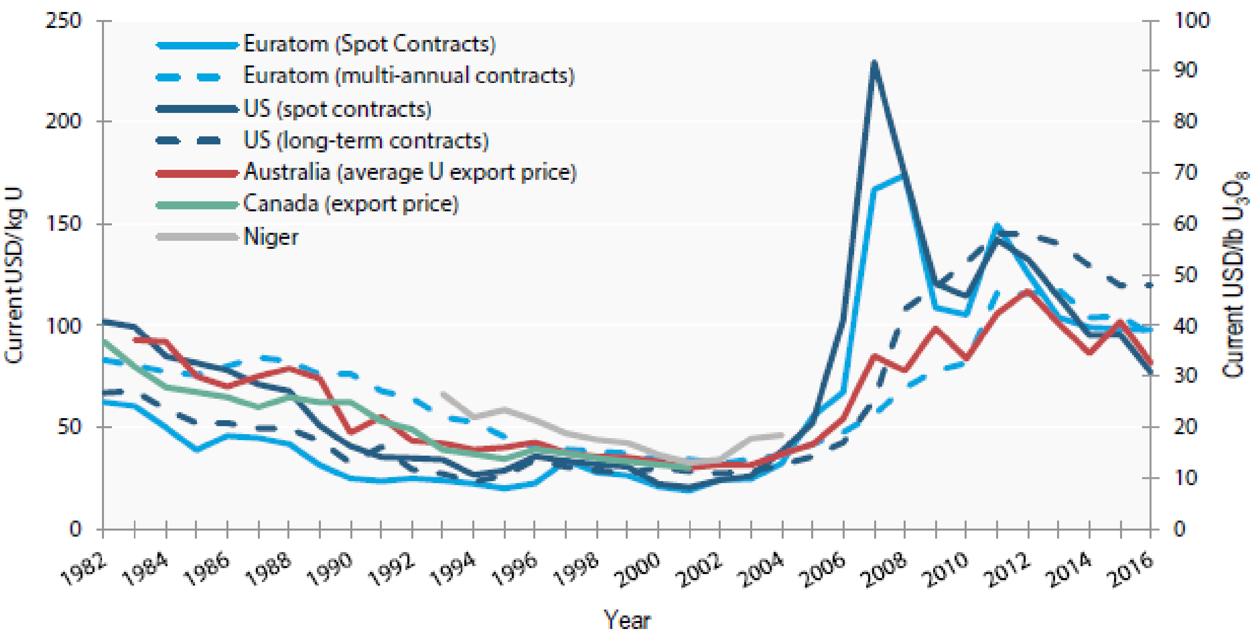
Source: OECD-NEA/IAEA Red Book 2018

- Projections declined considerably as a result of reductions in installed nuclear capacity projections .
- However, demand for uranium is expected to continue to rise in the future (about 91 ktU by 2035 in the high case) as nuclear power is projected to grow especially in regulated markets.

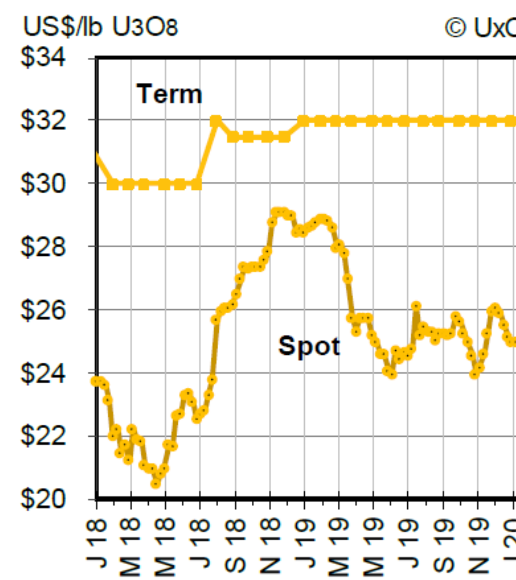
Uranium secondary supply

HEU	Downblended Highly Enriched Uranium - from weapons grade uranium to civil fuel (Russia, US)
MOX (Pu) ERU (RepU)	The recycling source: plutonium (MOX) or reprocessed uranium (ERU)
Uranium stockpiles	Sales of government / commercial inventories
Underfeeding	Tails assays lower: less uranium, more enrichment services
Tails re-enrichment	Re-enrichment of depleted uranium

Uranium market outlook



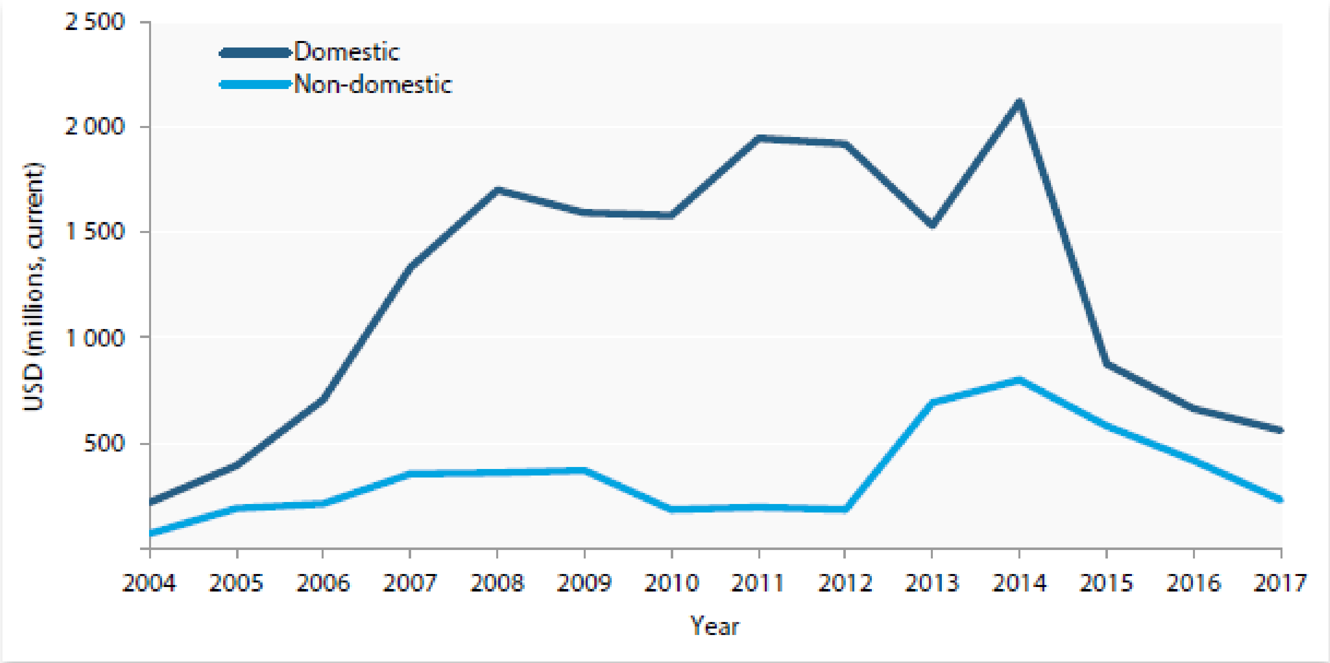
Source: Australia, Canada, Euratom (ESA), Niger and US EIA.



Source: UxC Weekly

- 2011-2017 - Spot and long term contracts prices were generally on a downward trend
- 2017-2018 - Uranium prices have recovered due to the renewed interest from financial investors coupled with production cutbacks by producers.

Trends in global uranium exploration and development expenditures



Source: OECD-NEA/IAEA « Red Book « 2018

- After a peak in 2014 attributed to the development of Cigar Lake mine (Canada) and Husab (Namibia), global expenditures significantly decreased.
- Investment is required to ensure that new resources can be brought into production.

Environmental aspects

- Uranium mining remains controversial principally because of environmental and health issues created during the early phase of the industry
- Negative public perception - lack of information on the evolution of mining practices and much improved management of all impacts today.

"Kyrgyzstan bans uranium mining after protests", Reuters, May 2019

> **It is the focus of remediation work on legacy uranium tailings in central Asia…**

Prohibition of uranium activities in Sweden, 2018?

Uranium mine in the Limousin region of France, before and after remediation
(Source: Orano)

Out-dated historic mining practices contrasted with leading practices

Miners in Colorado plateau in the mid1950s.

Uranium mining “boom” in remote areas of the United States led to employment of workers with no experience or training. Virtually no radiation protection was in place.

Cigar Lake, Canada underground mine, 2019.

Innovative mining solutions were developed for this high grade ore deposit, located 450 metres below ground.


Source: Cameco

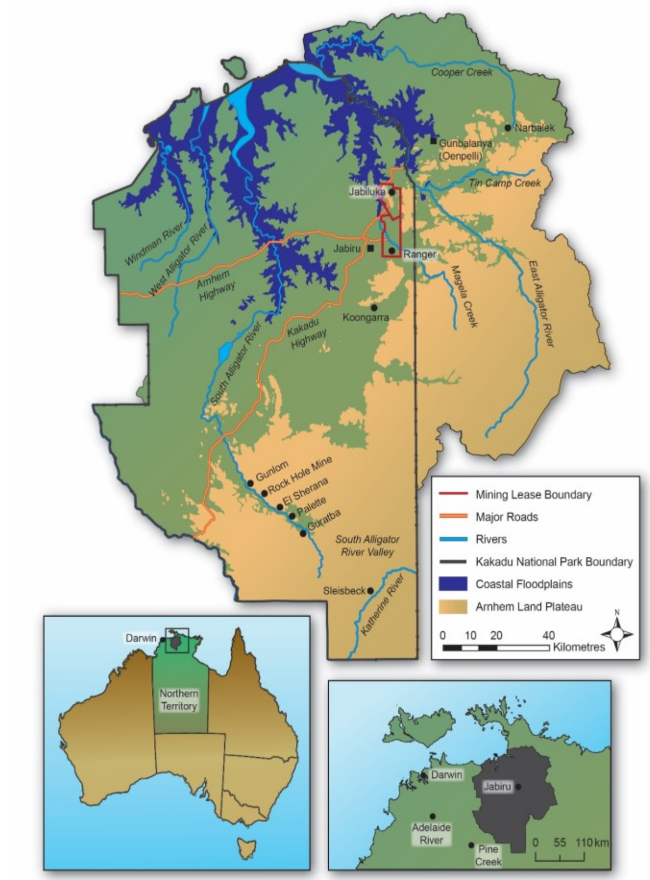
Leading practices today: community engagement and environmental monitoring

- Companies operating in Saskatchewan, Canada have instituted a community-based environmental monitoring programme to provide assurance to local residents that the operations are not impacting the environment

- Allows local residents to assist in the determination of sampling points, the collection of samples and the interpretation of the monitoring data

- Provincial government has established and continues to support *Environmental Quality Committees* staffed by local residents to improve communication between the industry, government and local communities.

Leading practices today: independent oversight - Ranger mine, Australia



Source: Supervising Scientist Technical Report

- Located in the NT, Australia and surrounded by Kakadu National Park – Dual World Heritage listed
- Independent oversight from the Supervising Scientist branch since 1978, in recognition of the conservation significance of the region.
  - Oversees the regulatory process
  - Undertakes scientific research
  - Conduct independent environmental monitoring
    - site-specific standards developed
    - comprehensive monitoring program – water quality, radiation, ecosystem health and function

Demonstrated environmental protection for 40 years of Ranger mine operation

Leading practices today: giving a new life to former uranium mining sites

Source: Orano

Context

Bosc uranium mining site in Hérault, France mined from 1959 to 1997 and remediation work completed between 2001 and 2005 (Orano)

- Open-pit mine and underground mining works, processing plant
- 4 million tonnes of tailings
- Production of yellow cake: 14 630 tonnes

Solution

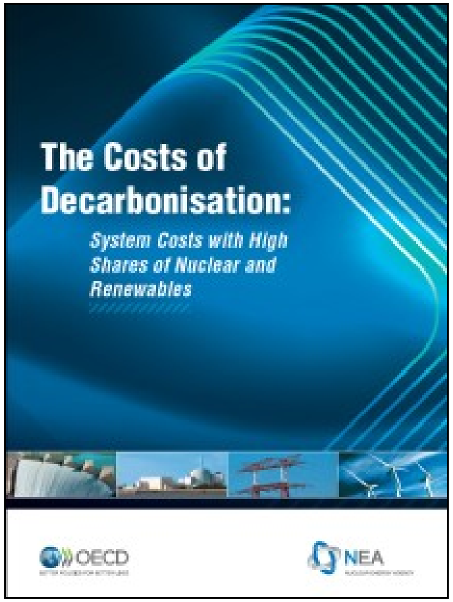
Site reconverted into a zone for artisanal activities and installation of a solar power plant

Result

The Bosc site now has a second diversified life: plans for a Technology Park, the Regional Park of economic activities and 35 354 photovoltaic panels installed, operated by a subsidiary of GDF Suez.

Conclusion

- **Nuclear is an indispensable part of future low-carbon energy systems**
- **Global energy landscape requires more conversations about mineral/metals regarding supply, energy efficiency and environmental footprint.**



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