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A review of the uranium mining industry in Africa

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List of abbreviations

CGNPC	China General Nuclear Power Company
Cominak	Compagnie Minière d'Akouta
HEU	high-enriched uranium
IEA	International Energy Agency
ISR	in situ recovery
MOX	mixed oxide
MWS	Mine Waste Solutions
NEA	Nuclear Energy Association
Somaïr	Société des Mines de l'Aïr
U_3O_8	uranium oxide
UxC	Ux Consulting Company
WNA	World Nuclear Association
WRTRP	West Rand Tailings Retreatment Project

Uranium ore

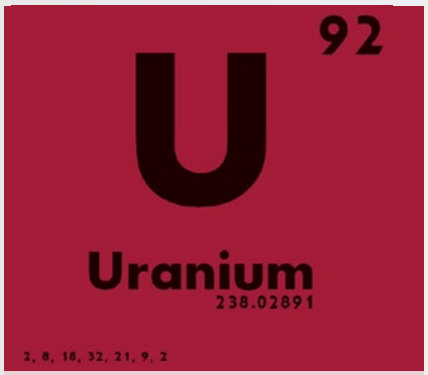
Picture by Flickr – Marcin Wichary

Uranium conversions

Uranium is a relatively common element that is found in the earth all over the world.

The most common uranium product from mines is uranium oxide (U_3O_8) or yellowcake, which contains about 85% uranium.

- Production figures are expressed in terms of U_3O_8 by multiplying by 1.1793.
- One-million pounds of U_3O_8 is equivalent to 385 t of uranium.
- To convert tonnes of U_3O_8 to pounds of U_3O_8, multiply the tonne by 2 205.



Atomic symbol for uranium

Source: World Nuclear Association and Deep Yellow

Key developments

November 2014: Oakbay Resources and Energy, which owns the only dedicated uranium mine in South Africa, lists on the JSE in the general mining sector. The company owns 74% of the Shiva uranium mine, in the North West.

January 2015: Africa-focused Paladin Energy announces it has initiated a feasibility study to consider restarting production at the 3.3-million-pound-a-year Kayelekera mine, in Malawi.

February 2015: Niger's third-highest producing uranium mine, the China-owned Azelik, is placed on care and maintenance, owing to tight cash flow.

July 2015: South Africa starts the procurement process for up to 9 600 MW of new nuclear capacity, which will significantly increase the country's demand for uranium.

August 2015: GoviEx, from Canada, files an integrated development plan for its Madaouela uranium project, in Niger, detailing its ambitions to produce 2.69-million pounds a year of uranium oxide over 21 years.

August 2015: Kyushu Electric's Sendai Unit 1 restarts, becoming the first Japanese reactor to return to service since September 2013. Japan also announces that nuclear power will provide between 20% and 22% of total electricity generation by 2030.

August 2015: Namibia's President Hage Geingob visits the Husab uranium mine, which is expected to give the country's economy a boost when yellowcake production starts in 2016.

August 2015: South African gold mining firm Sibanye Gold announces the outcome of a feasibility study for the West Rand Tailings Retreatment Project, from which low-cost gold and uranium can be extracted. The study points to a lucrative potential go-ahead for the project.

September 2015: Australian developer A-Cap Resources submits a mining licence application for its Letlhakane project, which will turn Botswana into a uranium-producing country.

September 2015: The World Nuclear Association publishes its biannual Nuclear Fuel Report, which details how global nuclear power generation capacity is expected to grow over the next 20 years and how a new pipeline of uranium mines will be needed after 2025 to supply the growing demand trend.

November 2015: Bannerman Resources completes an optimisation study for the Etango uranium project, in Namibia, which improves the project's economics.

Global market

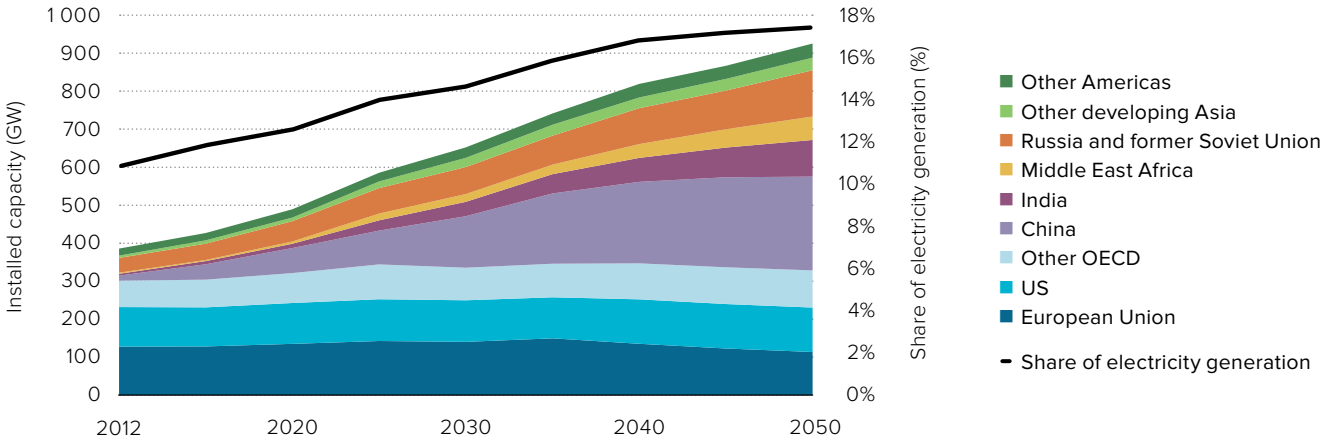
Four-and-a-half-years after Japan's major nuclear disaster, there are signs that the global uranium market is shaking off its post-Fukushima slump. Japan has restarted some of its nuclear power reactors, the US has renewed its commitment to nuclear power and China is progressing with its nuclear expansion. These developments are providing a boost to the uranium market, which has suffered a decrease in demand after the March 2011 triple meltdown of the Fukushima Daiichi nuclear power plant.

Although the accident has not caused any direct radiation-related casualties to date 2015, it has raised concern about nuclear power plant safety and resulted

Tank filled with uranium solution

Picture by Reuters

Nuclear generation capacity in the 2 °C scenario by region



Source: Nuclear Energy Association and International Energy Association (2015)

in a drop in public acceptance for the power source. Some countries, including Germany and Italy have announced their intention to discontinue the use of nuclear power, while France will reduce the share of nuclear in its energy portfolio. However, the disaster has not reversed global nuclear growth, according to the World Nuclear Association (WNA). Globally, nuclear generation capacity is forecast to grow steadily in the next two decades. The WNA believes nuclear is essential to combat carbon emissions, while contributing to security of supply.

According to the WNA's latest biannual 'Nuclear Fuel Report', published in October 2015, global nuclear generation capacity is set to increase from 379 GW of electrical output (GWe) in 2015, to 404 GWe by 2020 and 522 GWe by 2035. A more bullish upper scenario increases capacity to 429 GWe in 2020 and 720 GWe in 2035. In a lower scenario, nuclear capacity stagnates by 2030, before dropping off with several reactor shutdowns before 2035.

While nuclear expansion, particularly in China and India, bodes well for the uranium market, the industry faces headwinds in the form of inventories.

The drop in demand in some countries after the Fukushima disaster has resulted in rapid growth in inventories and analysts are forecasting the overhang of excess supply to persist in the short to medium term.

However, Canadian miner Cameco believes the currently over-supplied market will shift to a demand-driven market in the long term, which will require new supply. The pace of the shift will depend on the timing, development and execution of new supply projects and the continued performance of existing supply.

Demand

For many years, virtually all the uranium that was mined was used in the production of nuclear weapons. This ceased in the 1970s and today uranium is mostly used as a fuel for nuclear power plants. Some uranium is also used in medical treatment and research, as well as in manufacturing processes.

From a small beginning in the 1950s, the nuclear power industry today supplies about 11% of world electricity and is forecast to grow in the next 20 years, owing to concerns about climate change. The greenhouse gas emissions from nuclear power are less than those associated with coal, oil and gas.

Through the United Nations Framework Convention on Climate Change, governments have committed to keep the global average temperature increase below 2 °C relative to pre-industrial levels.

The International Energy Agency (IEA) reports that a 2 °C scenario will require the share of nuclear power to increase from 11% in 2011 to 17% in 2050. The 'Technology Roadmap: Nuclear Energy' report, which the Organisation for Economic Cooperation and Development's Nuclear Energy Association (NEA) and the IEA jointly produced in 2015, states that nuclear

World nuclear reactors by country					
Country	**Operable**	**Under construction**	**Planned**	**Proposed**	**Uranium required 2015**
China	29	22	43	136	8 161 t
India	21	6	35	35	1 579 t
Russia	34	9	31	18	4 206 t
US	99	5	5	17	18 692 t
Japan	43	3	9	3	2 549 t
UAE	0	4	0	10	0 t
Ukraine	15	0	2	11	2 366 t
South Korea	24	4	8	0	5 022 t
All others	173	12	32	85	24 308 t
Total	**439**	**64**	**159**	**329**	**66 883 t**

Source: World Nuclear Association, December 2015

capacity should be expanded to 930 GW by 2050, up from 396 GW in 2014. This will require 25 reactors of an average capacity of 1 GW to be commissioned each year from 2010 to 2050.

According to the WNA, there are currently 438 operable reactors around the world, 65 reactors in the construction phase and 165 reactors in the planning phase. A further 324 reactors are on the drawing board. Most of the new demand for uranium will come from Asian countries, which are spending about $800-billion on reactors in a push for new power plants with lower emissions.

China is the largest single market for nuclear reactors and its nuclear capacity is forecast to surpass that of current forerunner the US by 2030. By 2050, China is expected to have 250 GW of installed capacity, which will be twice the installed capacity of the US.

China currently has 29 operable nuclear reactors and 22 more reactors under construction. Another 43 are planned and 136 are proposed. The 26 nuclear reactors currently operating use 8 161 t of uranium.

The WNA forecasts that China could require about 11 000 t of uranium in 2020 (58 operational reactors) and about 24 000 t in 2030 (130 operational reactors).

India is the second-fastest growing market for nuclear and is forecast to have about 100 GW of capacity in 2050, making it the third largest market for nuclear after China and the US. Other growth markets for nuclear include the Middle East, South Africa and Association of Southeast Asian Nations countries.

The NEA states in its 2014 'Uranium: Resources, Production and Demand' publication that, should nuclear capacity be expanded to between 399 GWe and 678 GWe by 2035, uranium requirements are projected to increase from 59 170 t of uranium metal at the end of 2013 to between 72 205 t and 122 150 t by 2035.

Canada-based producer Cameco forecasts uranium demand to increase from about 155-million pounds in 2015 to 230-million pounds in 2024.

Citing Ux Consulting Company (UxC), fellow Canadian producer Denison Mines forecasts uranium demand to increase from 167.5-million pounds in 2014 to 266-million pounds in 2030.

In the short term, the restart of nuclear reactors in Japan is not expected to have an impact on uranium demand, as Japanese utilities stockpiled nuclear fuel after the Fukushima accident.

However, once the country has worked through its stockpile, its nuclear reactors will add to long-term uranium demand.

Japan has a goal of sourcing about 20% of the nation's electricity needs from nuclear power by 2030. Before

the Fukushima disaster, nuclear contributed about 25% to the energy mix.

Supply

Primary uranium production from mines supplies about 85% of the world's current nuclear demand, with the balance being supplied from secondary sources, which include various forms of uranium that have already been mined and are sitting on stockpiles around the world.

Owing to falling uranium prices and a lack of strong demand, uranium producers in 2014 scaled back on their production. According to the WNA, global output declined from 59 370 t of uranium to 56 217 t of uranium.

This is a reversal of the increasing production trend of the past several years. Most of the production growth in recent years has come from Kazakhstan, which has increased its uranium output from 6 637 t in 2007 to 23 127 t in 2014.

In 2008, Kazakhstan became the world's largest producer of uranium, overtaking Canada, which long held the lead. Canada produced 9 134 t of uranium in 2014, followed by Australia, which produced 5 001 t of uranium. Other significant producers include Niger, Namibia and Russia. These six countries supplied about 85% of the world's mined uranium output in 2014.

State-owned mining companies own most of the world's producing uranium mines.

Large State-owned producers include Kazakhstan's Kazatomprom, Russia's ARMZ Uranium Holding Company, which owns Uranium One, and France's Areva. Cameco, from Canada, is the world's largest publically traded uranium company. Smaller producers include BHP Billiton, Paladin Energy and Rio Tinto.

Prospects of firm future prices spurred a uranium exploration boom between 2004 and the end of 2013.

During this period, $16-billion was spent on uranium exploration and deposit delineation on more than 600 projects, the WNA reports. About 400 new junior mining companies were established to raise $2-billion for uranium exploration.

However, depressed prices over the past two years have curtailed exploration activities and the opening of new mines.

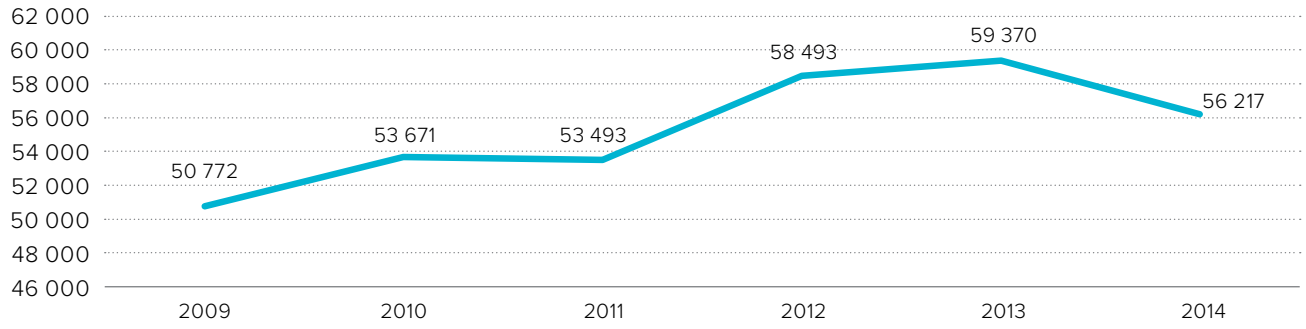
Spot and term uranium prices are not considered high enough to incentivise new mine production, and in some cases, not high enough to keep current mines in operation.

Citing industry analysts, Africa-focused Paladin Energy reports that 12-million pounds of uranium oxide (U_3O_8) a year have been eliminated in 2014 and that one-third of global mine supply is uneconomic at the current spot price.

Paladin closed its uranium mine in Malawi in May 2014, owing to the sustained low uranium price. The company will resume production at this mine when the uranium price provides a sufficient incentive, which it considers to be about $75/lb.

Canada-based, Russian-owned miner Uranium One has placed its *in situ* recovery (ISR) production

World uranium production (in tonnes)



Source: Compiled from World Nuclear Association data

facility at Honeymoon, in South Australia, on care and maintenance, while some US-based ISR mines produced only at their contracted levels.

Two of Cameco's Australia projects are also on hold as the company waits for prices to improve before it brings them into production.

Cameco believes a price of at least $70/lb will be needed to incentivise new mine development projects.

Increased supply is forecast from the Cigar Lake mine, in Canada, which officially started production in September 2015, while the Husab mine, in Namibia, is on the cusp of starting production.

However, Paladin says 2016's aggregate U_3O_8 production is unlikely to exceed 150-million to 152-million pounds, owing to depressed uranium prices.

Owing to the lack of global investment, supply is forecast to decrease over time. Given the long lead times of uranium projects, the industry has been urged to make timely investments to develop new primary supply.

Uranium is one of the most heavily permitted minerals in the mining industry and the WNA states that it takes on average about ten years to develop new production. Explorer Fission Uranium estimates that discovery to production takes up to 15 years.

The world's measured recoverable resources of uranium, estimated at 5.90-million tonnes in 2013, is said to be sufficient to supply conventional reactors for about 90 years. When all conventional resources – uranium as a main product and/or as a major by-product – are considered, another 7.3-million to 8.4-million tonnes are added, which makes known

Mine production by country (tonnes of uranium)

Country	2007	2008	2009	2010	2011	2012	2013	2014
Kazakhstan	6 637	8 521	14 020	17 803	19 451	21 317	22 451	23 127
Canada	9 476	9 000	10 173	9 783	9 145	8 999	9 331	9 134
Australia	8 611	8 430	7 982	5 900	5 983	6 991	6 350	5 001
Niger	3 153	3 032	3 243	4 198	4 351	4 667	4 518	4 057
Namibia	2 879	4 366	4 626	4 496	3 258	4 495	4 323	3 255
Russia	3 413	3 521	3 564	3 562	2 993	2 872	3 135	2 990
Uzbekistan (est)	2 320	2 338	2 429	2 400	2 500	2 400	2 400	2 400
US	1 654	1 430	1 453	1 660	1 537	1 596	1 792	1 919
China (est)	712	769	750	827	885	1 500	1 500	1 500
Ukraine (est)	846	800	840	850	890	960	922	926
South Africa	539	655	563	583	582	465	531	573
India (est)	270	271	290	400	400	385	385	385
Malawi	-	-	104	670	846	1101	1132	369
Brazil (est)	299	330	345	148	265	231	231	231
Czech Republic	306	263	258	254	229	228	215	193
Romania (est)	77	77	75	77	77	90	77	77
Pakistan (est)	45	45	50	45	45	45	45	45
Germany	41	0	0	8	51	50	27	33
France	4	5	8	7	6	3	5	3
Total world	**41 282**	**43 764**	**50 772**	**53 671**	**53 493**	**58 394**	**59 370**	**56 217**
Tonnes U_3O_8	**48 683**	**51 611**	**59 875**	**63 295**	**63 084**	**68 864**	**70 015**	**66 297**
Percentage of world demand	64%	68%	78%	78%	85%	86%	92%	85%

Source: World Nuclear Association

resources at the current rate of consumption sufficient for another 200 years.

Besides production from mines, nuclear fuel is also sourced from secondary supply, including recycled uranium from used fuel, as mixed oxide (MOX), re-enriched depleted uranium tails, ex-military weapons-grade uranium, civil stockpiles held by utilities and governments and ex-military weapons-grade plutonium as MOX fuel. Secondary supply has been filling the gap between uranium demand and production from primary suppliers for more than 20 years. In 2014, about one quarter of demand was met from secondary supply.

Until 2013, the main contributor to secondary supply was the US–Russia High Enriched Uranium (HEU) agreement, which provided about 24-million pounds of uranium.

Under the agreement, Russia supplied the US with low-enriched uranium, obtained from HEU, which was more than Russia's defence requirements. The programme was completed in December 2013.

Civil stockpiles are an important source of secondary supply. Utilities are estimated to hold about 217 000 t of uranium in inventory. The WNA states that utilities in the US hold about 45 000 t of inventory, European utilities about 53 000 t, China about 74 000 t and other East Asian countries about 45 000 t. China might hold more stock, as utilities in that country do not report inventories. UxC estimates China's utility inventory

Yellowcake

Picture by IAEA Imagebank

at as high as 107 700 t of uranium equivalent. UxC estimates Japan's utility inventory to be at least 61 500 t of uranium equivalent. The WNA states in the latest edition of its 'Nuclear Fuel Report', which covers the period from 2015 to 2035, that secondary supply will continue to be important in the world uranium market. Underfeeding of enrichment plants is considered a significant source of secondary supply and will add between 5 000 t/y and 8 000 t/y of uranium to the market up to 2025.

Pricing

Unlike other commodities, uranium does not trade on an open market. Buyers and sellers negotiate contracts privately. Nuclear utilities buy uranium primarily through long-term contracts, with smaller volumes acquired through spot and near-term purchases. Uranium prices have been stuck in a rut ever since the 2011 Fukushima accident. The spot price fell to a nine-year low of $28/lb of U_3O_8 in May 2014.

The price has recovered somewhat, ending 2014 at $35/lb and averaging $37/lb in the first nine months of 2015. However, prices are still comparatively low when compared with pre-Fukushima prices of about $70/lb, which producers say is the level required to incentivise new mine development projects. Prices were above $120/lb in 2007. Some major investment bank analysts are predicting a doubling of the uranium price over the next two years, which indicates how deeply mining analysts and investors believe the uranium price will go up.

Spot price					
	2011	2012	2013	2014	2015
January	72.63	52.13	43.88	35.45	37.00
February	69.63	52.00	42.00	35.38	38.63
March	60.50	51.05	42.25	34.00	38.36
April	55.25	51.63	40.50	30.43	37.13
May	57.00	51.63	40.45	28.25	35.00
June	52.88	50.75	39.60	28.23	36.38
July	51.75	49.50	34.75	28.50	35.50
August	49.13	48.25	34.50	31.50	36.75
September	52.25	46.50	35.00	35.40	36.38
October	51.88	41.75	34.50	36.38	36.13
November	51.63	42.25	36.08	39.50	36.00
December	51.88	43.38	34.50	35.50	–

Source: Cameco (November 2015)

Long-term price					
	2011	2012	2013	2014	2015
January	71.50	61.00	56.50	50.00	49.50
February	71.50	60.00	56.50	50.00	49.50
March	70.00	60.00	56.50	46.00	49.50
April	69.00	60.50	57.00	45.00	49.00
May	68.00	61.25	57.00	45.00	47.50
June	68.00	61.25	57.00	44.50	46.00
July	68.00	61.25	54.50	44.00	44.50
August	64.50	60.25	54.00	44.00	44.00
September	63.50	60.50	50.50	45.00	44.00
October	63.00	59.50	50.00	45.00	44.00
November	62.50	59.50	50.00	49.50	44.00
December	62.00	56.50	50.00	49.50	–

Source: Cameco (November 2015)

Outlook

Although the Fukushima Daiichi nuclear accident has affected nuclear power projects and policies in some countries, nuclear remains a key part of the global energy mix. This bodes well for uranium demand, which is expected to continue to increase for the foreseeable future. Several governments have plans for new nuclear power, with big nuclear expansion forecast in China and India. Japan's nuclear restart will also boost investor confidence in the long-term viability of the global nuclear power industry.

The uranium market is expected to be adequately supplied from primary and secondary sources up to 2025, provided that all mines currently under development or planned enter service. However, beyond 2025, the WNA states that further production will be required to meet nuclear energy demand.

In Africa, the strongest demand will come from South Africa, which is planning to add another 9 600 MW of nuclear energy capacity to its energy mix by 2030. The first reactor is expected to come on line in 2023.

Several other African countries have also stated their intention to pursue nuclear energy programmes, including Ghana, Nigeria, Kenya, Uganda and Sudan.

Uranium mining in Africa

According to the World Nuclear Association (WNA), Africa's largest known recoverable resources of uranium are found in Niger, Namibia and South Africa. Niger is estimated to have a recoverable resource of 404 900 t, Namibia has a recoverable resource of 382 800 t and South Africa has a recoverable resource of 338 100 t.

Together, these three countries account for nearly 20% of the world's total estimated measured resource of 5.90-million tonnes of uranium.

Namibia and Niger are Africa's two leading uranium producers, alternating the first place position.

In 2014, Niger was the largest uranium producer, with output of 4 057 t of uranium, followed by Namibia, which produced 3 255 t. Niger supplied about 7% of 2014's world mined uranium output from its Somaïr and Cominak mines. Namibia supplied about 6% of the global mined output from the Rössing and Langer Heinrich mines.

South Africa is currently the continent's third-largest producer of uranium as a by-product of gold and copper mining. Malawi formally produced uranium from the Kayelekera mine, but operations were suspended in 2014 owing to low prices.

Previously, significant quantities of uranium came from the Democratic Republic of Congo, when it was still known as Belgian Congo in the 1940s, and uranium was also mined in Gabon between 1960 and 1999.

Africa's mined uranium output

Country	2013 production (tonnes of uranium)	2014 production (tonnes of uranium)
Niger	4 518	4 057
Namibia	4 323	3 255
South Africa	531	573
Malawi	1132	369

Source: World Nuclear Association

Possible production in Botswana, Tanzania and Zambia and several projects under investigation in South Africa could contribute to regional production increases in the future should market conditions improve.

Most of the uranium produced in Africa is fuelling nuclear power plants in other parts of the world. South Africa is currently the only country with an operational nuclear energy power station, although many others are said to be pursuing nuclear energy programmes, including Ghana, Nigeria, Kenya, Uganda and Sudan.

Ghana is planning to have its first nuclear power plant operational in 2025, generating 1 000 MW of electricity, while Nigeria has a nuclear electricity target of 1 000 MW by mid-2020 and 4 000 MW by the 2030s. Kenya is planning on establishing a 1 000 MW reactor before 2027 and has a longer term goal of generating 4 000 MW from nuclear power. Uganda's energy planning study mentions 1 000 MW of nuclear capacity between 2026 and 2034. Niger has also announced that it is considering building a nuclear power plant to exploit its own resources, after export prices for the fuel fell in the wake of the Japan nuclear energy disaster.

South Africa's commitment to nuclear power is the strongest on the continent, with the country having indicated that it will pursue a 9 600 MW nuclear build programme over the next 15 years. The country plans to build six new nuclear power plants by 2030 at an estimated cost of between R400-billion and R1-trillion. The Koeberg power station, in the Western Cape, is currently Africa's only nuclear power plant and has an installed capacity of 1 910 MW.

Niger

Niger is the world's fourth-largest uranium-producing country and in 2014 retained its position as Africa's largest uranium producer. The country's production was 4 057 t in 2014, compared with 4 518 t in 2013. Deposits are located in the Tim Mersoï basin and uranium is

mined close to the towns of Arlit and Akokan on the southern border of the Sahara desert. Concentrate is trucked to ports in Benin and the majority is exported to France.

Niger has Africa's largest recoverable uranium resource, which has caught the attention of international mining, exploration and development companies.

However, some foreign companies have ceased their exploration activities after geopolitical tensions in the region started to increase by 2011. According to the Organisation for Economic Development's Nuclear Energy Agency and the International Atomic Energy Agency's 'Uranium 2014: Resources, Production and Demand' report, known as the Red Book, foreign companies were exploring 160 concessions in 2011.

French nuclear energy giant Areva is a shareholder of the two long-standing uranium mining companies, Société des Mines de l'Aïr (Somaïr) and Compagnie Minière d'Akouta (Cominak). Areva owns 63.6% of Somaïr in a partnership with Niger's State mining agency Sopamin and 34% of Cominak in partnership with Sopamin (31%), Overseas Uranium Resources Development Company of Japan (25%) and Enusa of Spain (10%).

The **Somaïr** mine, in the Arlit region, and the **Cominak** mine, in the Akouta region, were established at the end of the 1960s and both of them are nearing the end of their operational life span. In 2014, Somaïr and Cominak produced 2 331 t and 1 501 t of uranium respectively. Areva and Niger signed a strategic partnership agreement in May 2014, which among other things included a five-year renewal of Somaïr's and Cominak's mining agreements.

The **Azelik** mine, located 160 km south-west of Arlit, is smaller than Somaïr and Cominak and was built with Chinese equity and operated in a joint partnership called Société des Mines d'Azelik, or Somina. The ownership is split between the China National Nuclear Corporation (37.2%), the Niger government (33%) and a second Chinese investor, Zhongxing Joy Investment Company (24.8%). Korea Resources Corporation holds a 5% stake.

The mine began operating at the end of 2010, and sent its first uranium shipment to China in 2012. The mine had a projected capability of 700 t/y of uranium, but was placed on care and maintenance in February 2015, owing to tight cash flow. The Azelik deposit has inferred recoverable resources of 15 900 t of uranium.

Areva owns 56.65% of the **Imouraren** mining development, which, with reserves of 174 196 t of uranium, constitutes one of the world's largest deposits.

Envisaged is a mine producing 5 600 t/y of U_3O_8, with an operating life of about 36 years. Production was meant to start in mid-2015, but plans to begin large-scale mining are on hold owing to unfavourable market conditions and security risks.

France's Prime Minister, Manuel Valls, said on a visit to Niger in 2014 that his country was committed to starting operations at Imouraren before "the end of the decade". Areva and the Niger government have established a joint committee to decide on the best schedule for production startup of the mine. Other shareholders in the mining development include Sopamin (33.35%) and Kansai Electric Power (10%).

Canada-based GoviEx is developing the **Madouela** uranium project. The company is envisioning a $359-million mine producing 2.69-million pounds a year of U_3O_8 over 21 years. GoviEx filed an updated National Instrument 43-101 integrated development plan for the project in August 2015, which it based on a measured and indicated mineral resource of 110-million pounds U_3O_8 and 61-million pounds of probable mineral reserves. The base case economics of the project use a long-term uranium price of $70/lb. The company has filed an application for a mining permit.

Australia-based Paladin Energy owns the **Agadez** project, which includes three exploration concessions covering a total area of 990 km^2. The company has suspended all field activities in the area, owing to security risks and has requested a force majeure from government authorities for an indefinite suspension of expenditure requirements.

London-listed URU Metals also previously explored in Niger, but has terminated activities in the country.

Niger ranks low on Canada's Fraser Institute's 'Annual Survey of Mining Companies'. In 2014, it ranked 104 out of 122 jurisdictions on the attractiveness index and in 2013, it was ranked second last – 111 out of 112 jurisdictions surveyed.

Namibia

Uranium is playing a significant role in Namibia's economy. The country has two operational uranium mines, the Rössing and Langer Heinrich mines, which are located in the Namib Desert near the coastal town of Swakopmund, in the Erongo region. Several exploration and development projects are also under way.

According to the WNA, Namibia produced 3 255 t of uranium in 2014 and 4 323 t of uranium in 2013. The country supplied about 6% of the world's mined uranium output in 2014. Namibia is expected to overtake Niger and Australia by 2017, when the major Husab mine becomes fully operational.

The OECD's '2014 Red Book' states that Namibia had recoverable conventional resources of 455 591 t of uranium in 2013.

The **Rössing** mine is Namibia's first commercial uranium mine and the world's longest-running openpit uranium mine. Operating since 1976, Rössing has produced the most uranium of any single mine. Anglo-Australian mining company Rio Tinto manages it and owns a 69% stake in the mine, with the Namibia government owning 3% (and a 51% majority vote on issues of national interest), the Iran government 15%, South Africa's Industrial Development Corporation 10% and local individuals having a combined 3% interest. The mine has a nameplate capacity of 4 500 t/y of uranium, but has operated significantly below that level since August 2014, when Rio Tinto curtailed operations owing to weak prices. The mine is currently operating on a noncontinuous basis and is only producing enough uranium to meet its long-term sales commitments. With the curtailed operations, Rössing produced 1 543 t of U_3O_8 in 2014, down from 2 409 t of U_3O_8 in 2013.

The **Langer Heinrich** mine entered into production in 2007. Australia-based Paladin Energy owns 75% of the openpit mine in a partnership with China National Nuclear Corporation's CNNC Overseas Uranium, which owns 25% of the mine. Langer Heinrich has been expanded three times in recent years. The mine achieved its Stage 1 design capacity of 2.7-million pounds of U_3O_8 a year in 2009, before a Stage 2 expansion increased its capacity to 3.7-million pounds a year, and a Stage 3 expansion lifted capacity to 5.1-million pounds a year in 2012. A Stage 4 expansion to ten-million pounds a year of U_3O_8 is on hold until uranium prices are higher to incentivise new production. Langer Heinrich is operating efficiently and near its design capacity. The mine produced 5.04-million pounds of U_3O_8 in the company's 2015 financial year.

The most significant uranium project is the $2-billion greenfield **Husab** development, which is expected to be the second-largest uranium mine in the world after the McArthur River mine, in Canada, and the largest openpit mine in Africa. The Husab mine is being developed by Swakop Uranium, in which Taurus Minerals owns a 90% stake and Namibia's State-owned mining company Epangelo owns 10%. The China General Nuclear Power Company (CGNPC), Uranium Resources Company and the China-Africa Development Fund own Taurus. Located on the world's third-largest uranium-only deposit, the **Husab** mine contains about 280-million tonnes of uranium ore. The mine is forecast to produce 15-million pounds a year of U_3O_8, which is more than twice the current production of Namibia, and has an estimated mine life of about 20 years. Construction of the mine started in 2012 and first yellowcake production is scheduled for the first quarter of 2016. The mine is expected to generate between N$1.1-billion and N$1.7-billion a year of national revenue and is expected to contribute 5% to the country's gross domestic product.

France's Areva owns 100% of the **Trekkopje** uranium project, which was advanced to the construction stage before development was slowed in 2011, owing to unfavourable market conditions. Trekkopje was placed on care and maintenance in 2012. Nevertheless, the mine is considered a strategic asset. Areva is planning a mine with the capacity to produce 3 000 t/y of U_3O_8.

Other uranium development and exploration projects include Canada-based developer Forsys Metals' Norasa project, Australia-based Bannerman Resources' Etango project and Deep Yellow's Omahola and Tubas Sands projects, as well as the China-owned Zhonghe project.

Forsys Metals owns 100% of the $433-million **Norasa** project, formerly known as the Valencia project. The company completed a feasibility study in March 2015, which confirmed the project's robustness. The mine will have a processing rate of 11.2-million tonnes a year and produce about 5.2-million pounds a year of U_3O_8 over a 15-year mine life. Forsys states that Norasa is one of

very few uranium projects that is construction ready with a mining licence. The company expects to complete mine construction in late 2016, with production expected to start in early 2017.

Bannerman Resources' **Etango** project is one of the world's most advanced undeveloped uranium projects, with a completed definitive feasibility study and a recently completed optimisation study in hand. The optimisation study, which was completed in November 2015, has improved the project economics. Preproduction capital has been reduced from $870-million estimated in the 2012 definitive feasibility study to $793-million.

The optimisation study is based on average yearly production of 7.2-million pounds of U_3O_8 over an initial mine life of 15.7 years. Subject to the remaining study work, requisite sales contract procurement and project financing, first production is scheduled for the first half of 2020. Bannerman in late 2015 also advanced plans to buy out the minority 20% interest in the project for 123.4-million new shares and about A$1-million in cash.

Deep Yellow owns the **Omahola** project, which has the potential to produce at a rate of between 2.5-million pounds a year of U_3O_8 and 3.5-million pounds a year of U_3O_8 over a 10- to 14-year mine life.

The company's **Tubas Sands** project is on hold, owing to difficulty finding offtake partners in the current market. Deep Yellow might develop Tubas Sands as satellite supply for Omahola.

The **Zhonghe** project is being developed by Zhonghe Resources (Namibia) Development. The main shareholders and investors are CNNC subsidiary China Uranium Corporation (58%) and Namibia China Mineral Resources Investment and Development (42%).

The project is expected to be an openpit mine capable of producing between 700 t/y and 1 000 t/y of uranium over a 10- to 15-year period. The total project investment is estimated at between $600-million and $700-million.

China has a major role to play in providing capital to fuel Namibia's uranium development. CGNPC in 2012 paid $2.3-billion for a stake in the Husab mine development. This investment was the biggest since Namibia's independence and the biggest investment by China in Africa. In January 2014, State-owned CNNC paid $190-million to buy a 25% stake in the Langer Heinrich mine through a subsidiary, CNNC Overseas Uranium.

Water supply

Namibia is running short of water for the coastal towns of Walvis Bay and Swakopmund, near which the country's uranium mines and projects are located.

France's Areva completed the construction plant in 2010 that converts 20-million cubic metres of seawater into freshwater every year. The plant was built to supply its now-mothballed Trekkopje uranium project, but through Namibia Water Corp it also supplies water to other mines, including Rössing, Langer Heinrich and Husab. Areva plans to sell the plant to government, retaining only between 10% and 20% to provide water for Trekkopje. The plant can be upgraded to 26-million cubic metres a year using the existing infrastructure.

Rio Tinto's Rössing unit is considering building its own desalination plant with a capacity to supply three-million cubic metres of water, which is more than the mine's yearly consumption of two-million cubic metres. However, should the Namibia government proceed with plans to build its own plant, Rio Tinto will not go ahead with its water project.

Government in 2013 announced its intention to build a desalination plant in a public–private partnership. The plant will have the capacity to produce 60-million cubic metres a year of water.

Sources: Bloomberg News and World Nuclear Association

Namibia is considered Africa's most attractive resource destination, according to the Fraser Institute's 'Annual Survey of Mining Companies 2014'. The report rates Namibia the highest of all African countries on the investment attractiveness index and the twenty-fifth most attractive jurisdiction surveyed. In terms of policy perception, Namibia ranks second in Africa after Botswana.

South Africa

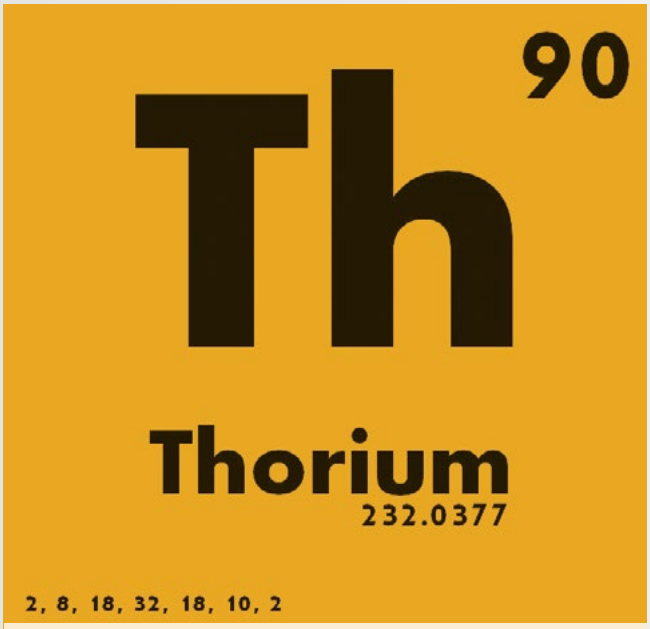
South Africa was previously a large producer of mined uranium and was considered the world's second or third largest producer in the late 1970s and early 1980s. Today, the country produces less than one tenth of the peak production of 6 000 t of the early 1980s. In 2014,

Thorium as an alternative nuclear reactor fuel

Thorium is a by-product of rare earth metals mining, which might hold promise as a replacement for uranium in nuclear power plants.

Dr Anthonie Cilliers from the North-West University's Nuclear Materials and Thorium research group, stated in a 2013 article in *Mining Weekly* that using thorium and uranium in tandem in a reactor would be a more efficient fuel stock for South Africa's nuclear build programme, as a nuclear plant can be run for longer between fuel cycles when thorium is used.

When considering how thorium can be used in tandem with uranium in a pressurised water reactor – the same reactor technology employed at the operational Koeberg nuclear power station, in the Western Cape – Cilliers and his research team proposed the replacement of a percentage of the uranium 238 (filler uranium that does not fission) with thorium in the reactor, while maintaining the same amount of uranium 235 (the fuel that runs the plant and fissions) per volume as usual.



Atomic symbol for thorium

Picture by Flickr

"During the 18 months between refuelling schedules, the uranium 238 absorbs neutrons and turns into plutonium – the fuel that sustains the process up to the 18 months."

Thorium, while working in a similar way, also absorbs neutrons, but instead of turning into plutonium, it turns into uranium 233 – a better breed of fuel.

"It is this ability that enables thorium fuel stock to run the plant for longer on the same amount of fuel," said Cilliers, adding that it was this feature that would ultimately be the driving force behind the adoption of the technology in South Africa.

Source: *Mining Weekly*

South Africa's uranium production was 573 t, which earned it the position as the world's twelfth-largest uranium producer, contributing 1% of global production. The country is currently Africa's third-largest producer.

South Africa's demand for uranium will significantly increase in the coming decades. Government has committed to procure 9 600 MW of new nuclear generation capacity by 2023, which will constitute 23% of South Africa's total new electricity generation capacity.

The planned nuclear reactors and the existing Koeberg nuclear power station, in the Western Cape, will require about 2 000 t/y of uranium.

Owing to South Africa's geology, most of the uranium to support a nuclear build programme is expected to be sourced from the gold-rich Witwatersrand basin, which stretches from Evander, in Mpumalanga, westward through Gauteng and into the southern and western Free State. The basin holds about 81% of the country's total identified resource of uranium, which is mined as a by-product of gold. The geological formation is bound to be the primary source of uranium, as established mining infrastructure is in place to exploit the uranium, in addition to what has been stockpiled on surface or exists in historical tailings storage facilities.

Historical and recent exploration and trial mining results indicate significant uranium resources within the Karoo sediments of the Western Cape, in what has been delineated as the Karoo Uranium province, which extends into the neighbouring Eastern Cape and Free State provinces. In addition, uranium is present in the

'Coal Zone' of the Ecca group, in the Springbok Flats coalfield, north of Pretoria.

About 49% of the national identified resources are found in the Witwatersrand underground operations, 32% in their associated tailings facilities, 14% in the Springbok Flats basin and about 5% in sandstone deposits in the Karoo basin.

Only two primary uranium producers have ever existed in South Africa. The Beisa mine, in the Free State, operated in the early 1980s and the Dominion Reefs uranium mine, in the North West, operated in the early 2000s.

AngloGold Ashanti's **Vaal River** operation on the border of the Free State and North West provinces, is the biggest uranium producer in South Africa. Vaal River produced 1.3-million pounds of U_3O_8 in 2014.

Uranium is produced by processing the reef material from the Moab Khotsong, Great Noligwa and Kopanang gold mines in the Noligwa gold plant/South Uranium plant circuit. Ammonium diuranate, or yellowcake, is sent to the Nuclear Fuels Corporation of South Africa, near Johannesburg, where the material is calcined and packed for shipment to conversion facilities.

AngloGold also acquired the **Mine Waste Solutions** (MWS) project, in the Klerksdorp goldfield of the Witwatersrand basin, from First Uranium for $335-million in mid-2012. MWS comprises tailings storage facilities that originated from the processing of ore from the Buffelsfontein, Hartebeestfontein and Stilfontein gold mines. At the time of the acquisition, AngloGold reported that the MWS acquisition would allow it to increase its long-term uranium production to between 3-million and 4.5-million pounds a year. AngloGold has completed the uranium plant, which First Uranium had started to build at MWS, and started deliveries in the fourth quarter of 2014.

Sibanye Gold's **Cooke** operation is west of Johannesburg and is the country's second-largest uranium producer. The operation, comprising four shallow to intermediate depth mines, is structured as a gold operation with uranium produced as a by-product to reduce gold production costs. The company acquired the Ezulwini uranium mine (Cooke 4) from Gold One in 2014. Between May 2014 and the end of that year, Sibanye had accumulated a uranium stockpile of about 180 000 lb at Cooke. Uranium production is forecast to be about 250 000 lb in 2015, increasing to 275 000 lb by 2016. In the first six months of 2015, Cooke produced about 88 000 lb of uranium. Instead of selling into the spot market, Sibanye is holding out for higher prices and plans to enter into long-term uranium supply contracts. The company's total uranium resource is 282.3-million pounds.

Sibanye is also developing the **West Rand Tailings Retreatment Project** (WRTRP), which consists of about 800-million tonnes of tailings resources, containing about 6.5-million ounces of gold and 98.7-million pounds of uranium. The first phase of the project will process the high gold grade tailings at the Driefontein mine with the high uranium grade tailings of the Cooke operation. These are considered the anchor resources and represent about 30% of Sibanye's total tailings resource base by volume and contain about 53% of the uranium and 35% of the gold contained in the total Sibanye tailings resources. Phase 1 of the project will produce 35-million pounds of uranium and 1.2-million ounces of gold over 16 years at an average steady state production of 2.2-million pounds a year of uranium and 100 000/oz gold. Sibanye has initiated the permitting process for the WRTRP.

The **Shiva** uranium mine is located in the Hartbeesfontein district of the North West province. Oakbay Resources and Energy, which listed on the JSE in November 2014, owns 74% of the mine. The company bought the mine from Uranium One in 2010, when the operation was under a two-year state of care and maintenance. Shiva first produced uranium under Oakbay's ownership in 2011. It has since produced only gold, while the underground uranium mine is being developed. Shiva is expected to produce 1 100 t/y of uranium at maximum capacity. A new bankable feasibility study for the uranium operation is expected to be commissioned in the near future.

Australia-based Peninsula Energy is exploring the **Karoo** project, in the Western Cape. The company has a 74% interest in 40 prospecting rights covering 7 800 km^2 in the Karoo basin. The company bought 35 of these rights from French energy firm Areva in 2013. The Karoo project has an exploration target of between 250-million pounds and 350-million pounds of U_3O_8.

According to the company's website, a scoping study has been completed on the Eastern section of

the projects and a prefeasibility study on a potential mine is under way. In January 2014, Peninsula stated that it planned first production from the Karoo project in 2017/18, building up to three-million to four-million pounds of U_3O_8 a year over three years.

There are a number of other uranium-related projects, although limited public information is available. HolGoun owns a large uranium resource covering 56 682 ha in the Springbok Flats. The company states on its website that the project area has a resource containing about 218-million pounds of U_3O_8. The company will focus on developing a uranium mine with a production capacity of two-million pounds a year of U_3O_8. Aardvark Uranium and empowerment partner Gilstra Exploration own the Namakwa deposit, in the Northern Cape, spanning an area of 58 375 ha. In 2014, Xtract Resources conducted a due diligence on the deposit, near Springbok, but concluded that the project did not meet its investment criteria.

Malawi

Malawi became the fourth African country to produce uranium when the **Kayelekera** mine opened in 2009. Its status as a uranium-producing country, however, was short-lived as weak uranium prices and nonprofitability led to the closure of the mine five years later.

According to data from the WNA, Malawi produced 369 t of uranium in 2014 before Kayelekera was placed on care and maintenance in May that year. This compares with production of 1 132 t in 2013 and 1 101 t in 2012. Before the closure of Kayelekera, Malawi was Africa's third-largest uranium producer and the world's tenth-largest mined-output supplier.

Australia-based Paladin Energy is the 85% owner of Kayelekera and the State owns a 15% stake. The mine, in northern Malawi's Karonga district, has a nameplate capacity of 3.3-million pounds of U_3O_8. During its five years of operations, Kayelekera produced 10.7-million pounds of U_3O_8. About 50% of the project's total reserves and resources remain for future development. Paladin states that Kayelekera could produce at a rate of 2.5-million pounds a year for at least another six years. The company is maintaining the plant, infrastructure and critical aspects of intellectual property and operational know-how while the mine is on care and maintenance to allow for a quick restart. Paladin in January 2015 initiated a feasibility study to restart production at Kayelekera. The company reported in August 2015 that the study was nearing completion. However, market conditions will have to be favourable before it will consider resuming production.

Other African countries

Given Africa's large untapped uranium resources, production from the continent could increase significantly should market conditions improve. Several projects are under investigation, with a large uranium mine in Botswana edging closer to production.

Exploration activities in **Botswana** have focused on the Letlhakane uranium deposit, which Australia-based A-Cap Resources is exploring. The company has advanced the project, near Francistown, to a technical study, which estimates initial capital construction capital of $351-million for a mine producing 3.75-million pounds a year of U_3O_8. A-Cap in August 2015 submitted a mining licence application for Letlhakane, which will be Botswana's first uranium mine. Fellow Australia-based explorer Impact Minerals is exploring nearby Letlhakane for uranium. The company has about 30 000 km^2 of licences containing significant strike extensions to the host rocks found at Lethlakane.

Australian explorer Aura Energy has a near-term project in **Mauritania**. The Tiris project has progressed to the definitive feasibility study stage and is scheduled for completion at the end of 2016. Depending on the availability of an adequate flow of funds, the company plans to have the project in production in early 2018. The Tiris project has an initial production profile of up to one-million pounds a year of U_3O_8 with the scoping study indicating an average life-of-mine production of about 800 000 lb over 15 years.

Russia's ARMZ subsidiary Uranium One operates the Mkuju River project, in southern **Tanzania**, and has a minority shareholding in Australia-based Mantra Resources, which owns the development project. The definitive feasibility study for Mkuju River was completed in December 2013. Pre-front-end engineering and design initiatives continued until June 2014. Current activities at the project are focused on licensing and permitting matters and ongoing value engineering opportunities to optimise the capital and operating costs. The Tanzania government has issued a special mining licence for the project. Mantra Resources also owns two projects in Tanzania, but did not undertake

any work on these projects in the 2014/15 financial year to the end of June. London-listed Kibo Mining has started work at its Pinewood joint venture project in 2015, with the immediate focus on updating a 2009 study and report on prospectivity and exploration potential in the region. The Pinewood portfolio comprises 43 licences, offers, applications and tenders with a combined surface area of about 9 033 km^2.

In **Zambia**, the Lumwana copper mine, which Barrick Gold acquired through the acquisition of Equinox in 2011, contains about 7 492 t of uranium in 11.2-million tonnes of ore. Uranium is extracted as by-product, but is not being processed. The Zambia Mining Magazine reported in 2014 that Barrick Gold had accumulated a stockpile of more than five-million tons of uranium at Lumwana. Equinox completed a uranium feasibility study in 2008 that showed output of two-million pounds a year of U_3O_8 and 15 000 t of copper could be mined simultaneously from the discrete uranium-enriched zones. Canada-based Denison Mines owns the Mutanga project, in the Zambezi Rift Valley. The project has a total measured and indicated mineral resource containing 7.8-million pounds of U_3O_8 and an inferred resource containing 41.4-million pounds of U_3O_8. The company's efforts in 2015 focused on generating additional exploration targets through soil and radom sampling, excavator trenching and geological mapping. The Mutanga project is part of the African portfolio, which Denison plans to spin-out or dispose of. Australia's African Energy owns the Chirundu project, which it unsuccessfully tried to sell to Canada-based Karoo Exploration in 2014. African Energy states on its website that the Chirundu and nearby Gwabe deposits contain a combined resource of about 11.1-million pounds of U_3O_8.

A barrel of uranium ore

Picture by IAEA Imagebank

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Uranium 2015:
A review of the uranium mining industry in Africa

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