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Highlights from the Nuclear Fuel Report - 2019

Speaker: James Nevling (Exelon)

International Uranium Fuel Seminar

Nashville TN, 28th October 2019

Fuel Report Working Group:
Chairs from the World Nuclear Association member companies

Co-Chairs of the Fuel Report Working Group

Thomas Cannon*	Arizona Public Service
Riaz Rizvi	Kazatomprom

Chairs of sub-groups

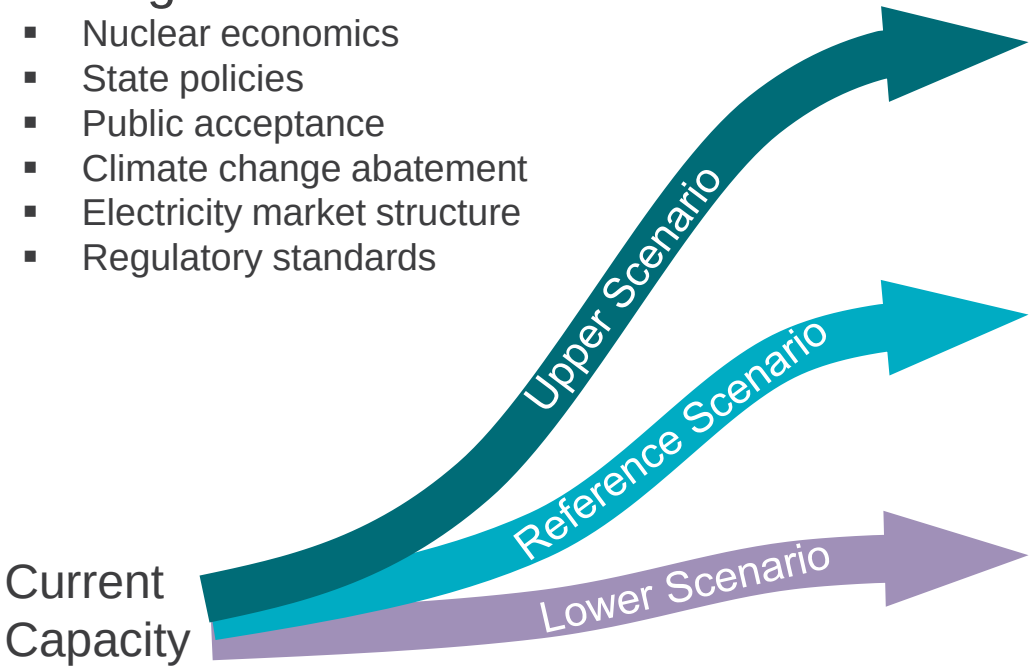
Carole Marot	EDF	Demand
Brandon Munro	Bannerman Resources	Demand
Frank Hahne	Fluor-BWXT Portsmouth	Uranium
Nikko Collida	ConverDyn	Conversion
Rolf Kwasny	Consultant	Secondary Supply
Francisco Tarin	ENUSA	Enrichment
Lawrence Mercier	Framatome	Fabrication

* Thomas Cannon carried on his responsibilities as the Co-Chair of the Fuel Report WG until his retirement from APS at the end of June, 2019.

Demand methodology: three scenarios

Taking into account:

- Nuclear economics
- State policies
- Public acceptance
- Climate change abatement
- Electricity market structure
- Regulatory standards

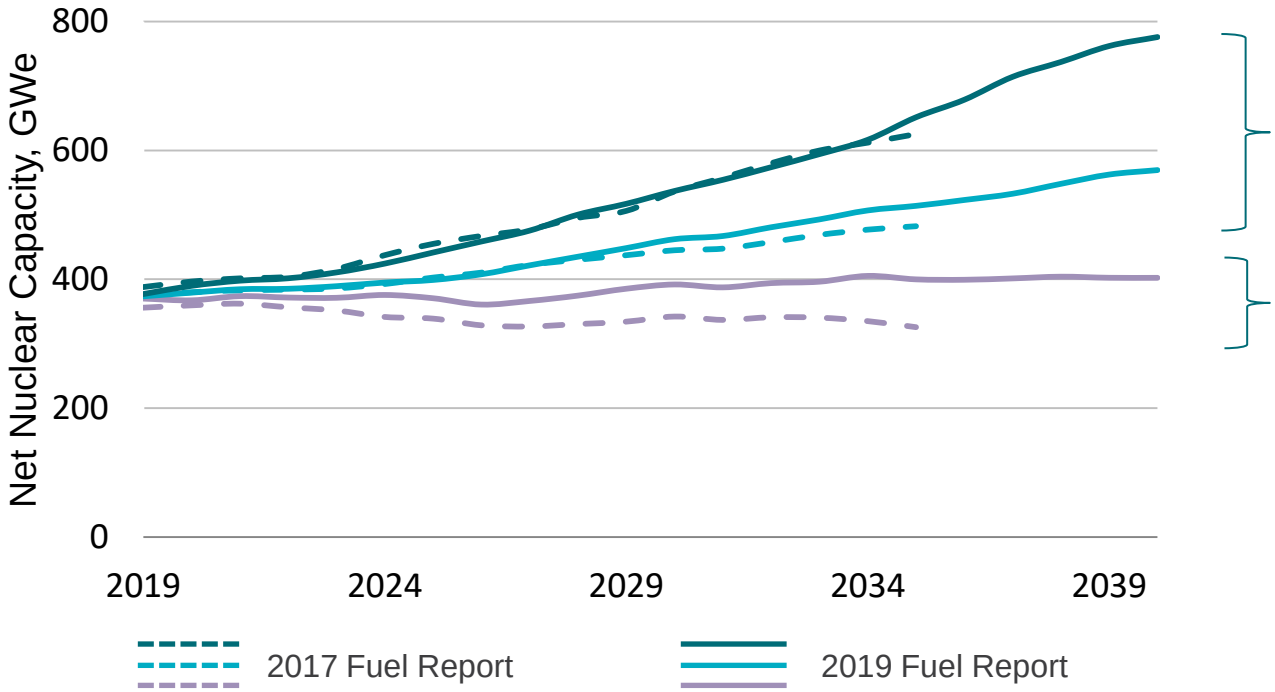


- Improved nuclear economics
- Increased public acceptance & political support
- Stronger recognition of nuclear's contribution to climate change abatement

- 'Business as usual'
- Announcements and ambitions by states and companies
- Partial recognition of nuclear's contribution to climate change abatement

- Deteriorating public acceptance
- Lack of political support
- Nuclear economics are more challenging

Projections: comparison with previous edition



- Upper and Reference Scenarios maintain noticeable growth rates
- Lower Scenario is significantly lifted, no longer showing a downward trend.
- **First increase** in capacity projection in past eight years.

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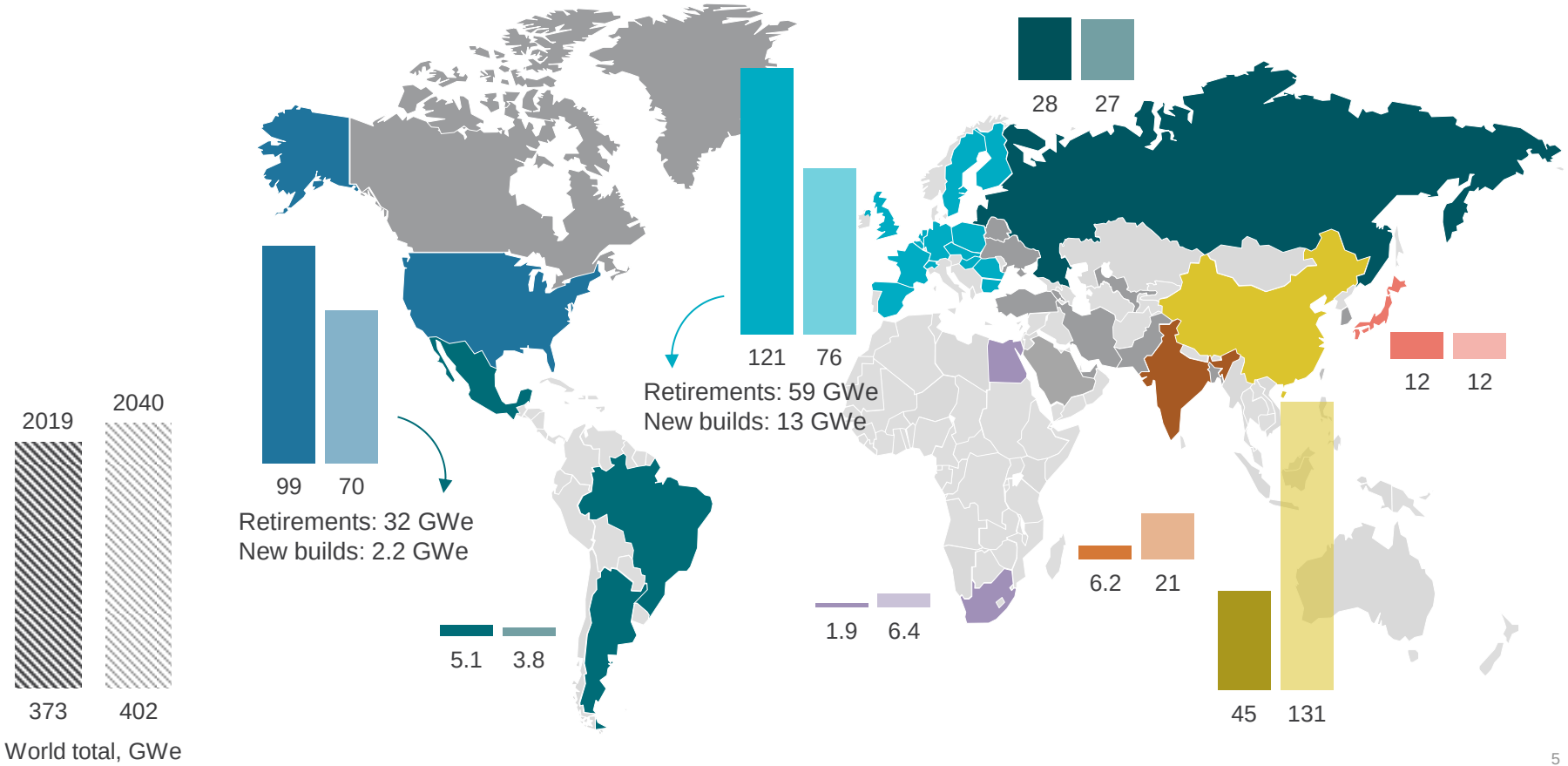
Nuclear capacity in the Lower Scenario



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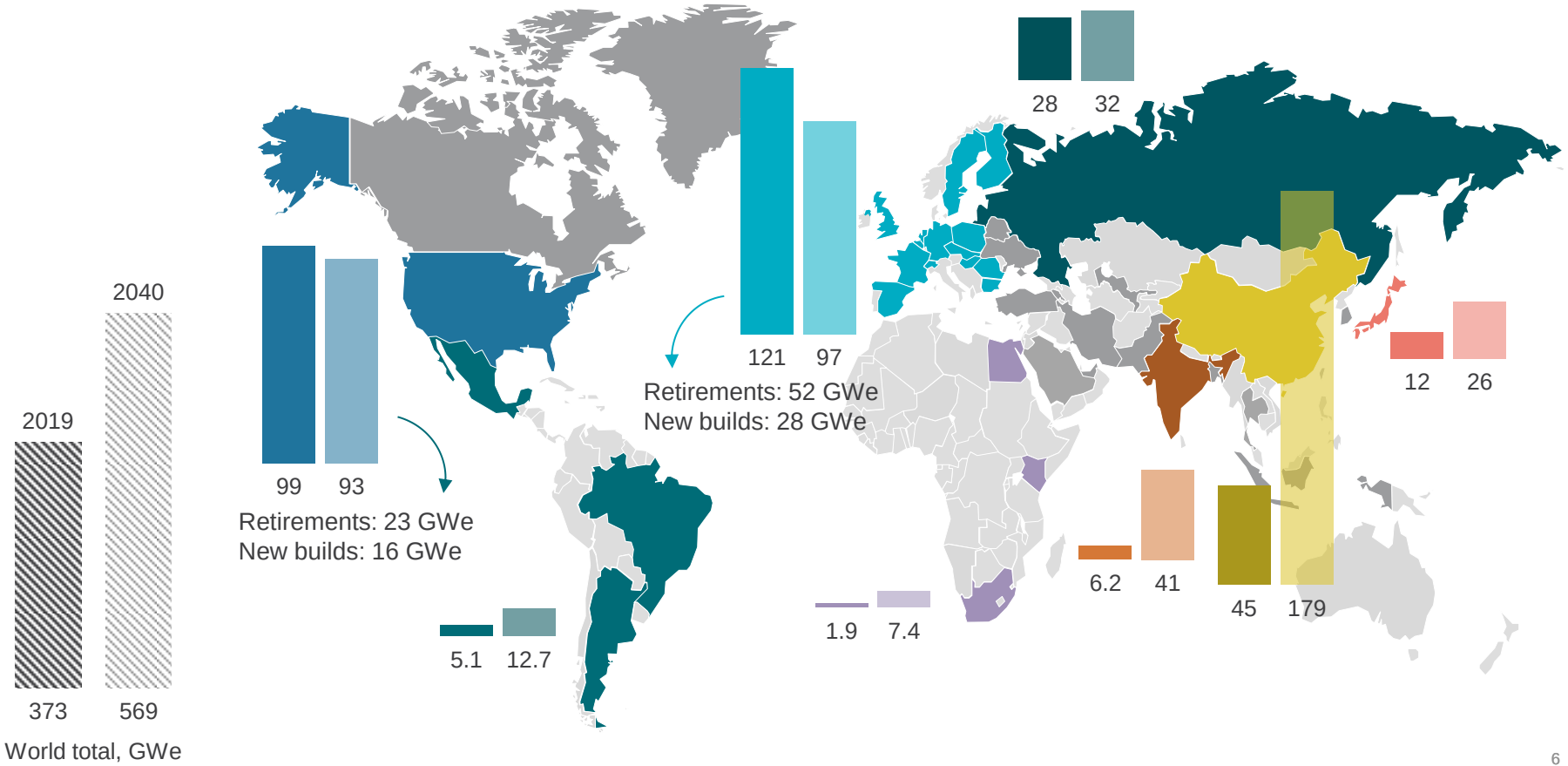
Nuclear capacity in the Reference Scenario



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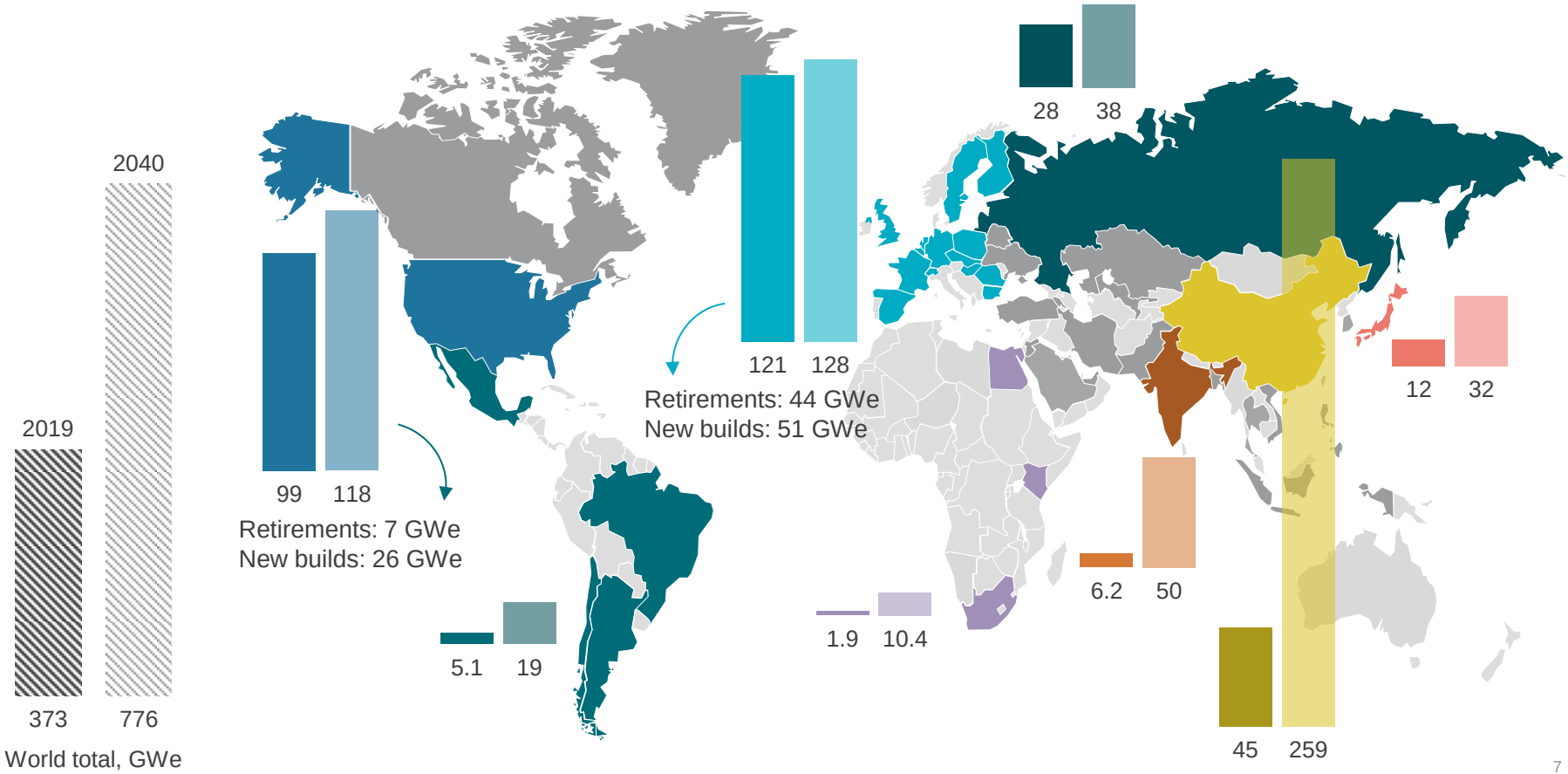
Nuclear capacity in the Upper Scenario



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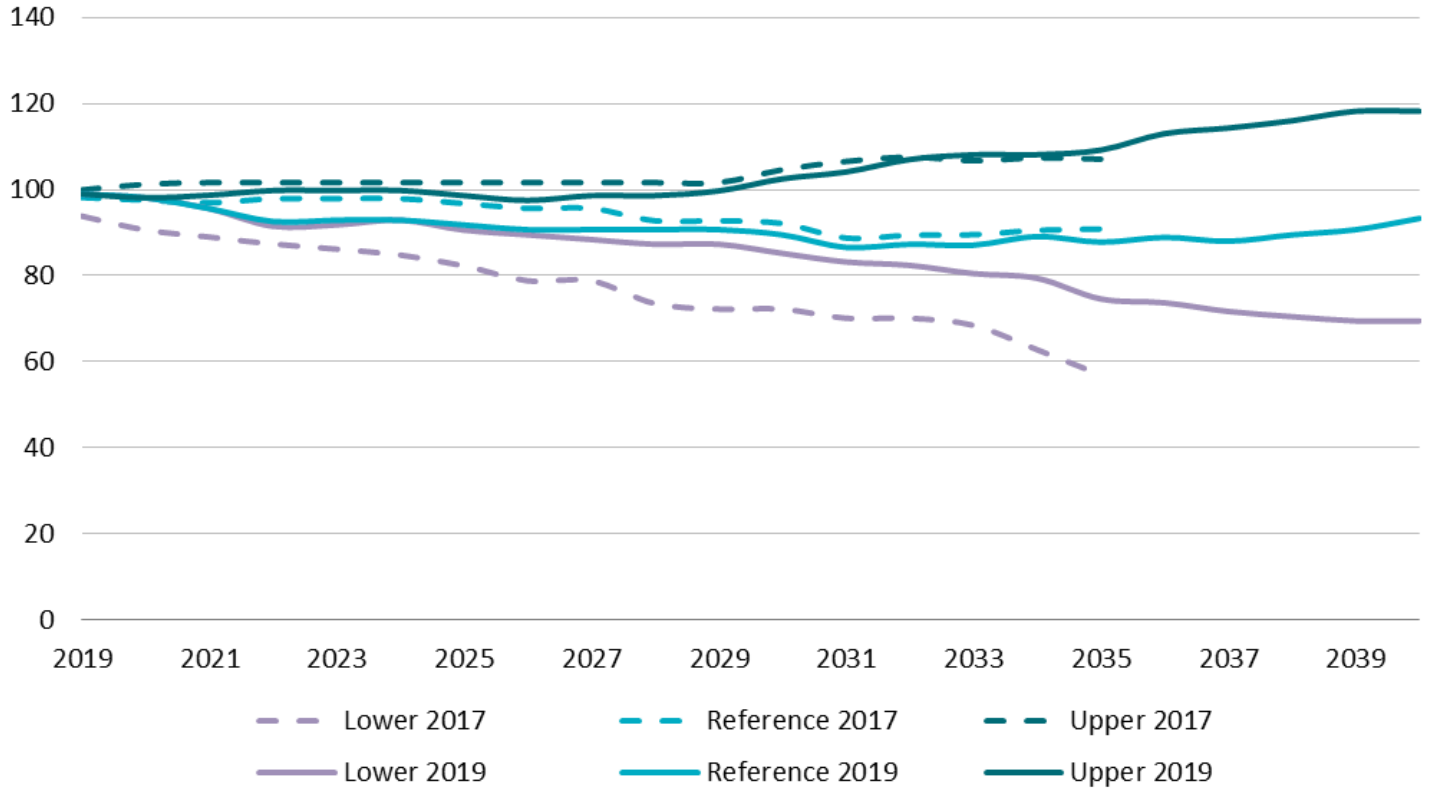
USA nuclear generation projections: 2019 vs 2017



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Uranium production in recent years

	Production (tU)				Capacity utilization (%)			
	2015	2016	2017	2018	2015	2016	2017	2018
Kazakhstan	23,800	24,576	23,321	21,705	93	96	78	73
Canada	13,313	14,039	13,116	7,001	78	86	79	100
Australia	5,654	6,315	5,865	6,517	56	84	55	61
Namibia	2,993	3,507	4,224	5,525	55	62	38	60
Niger	4,116	3,479	3,448	2,911	94	97	96	81
Russia	3,055	3,004	2,916	2,904	63	61	63	63
Uzbekistan	2,385	2,404	2,404	2,404	99	100	80	80
China	1,616	1,616	1,692	1,885	108	89	94	98
Ukraine	1,223	1,005	836	1,180	74	61	51	71
USA	1,238	1,125	960	582	16	40	27	35
India	385	385	423	423	63	63	69	69
South Africa	393	490	308	346	31	39	40	45
Others	315	276	116	116	39	34	100	100
Total	**60,486**	**62,221**	**59,629**	**53,498**	**73**	**83**	**68**	**72**

McArthur River idled

Ramp-up of Husab

Langer Heinrich idled

Reduction that led to Section 232 investigations

Kazatomprom's reduction plan announced in 2017 and 2018

Curtail by Orano

If included idled capacity, then this would be 58%

Total idled capacity: 17,840 tU

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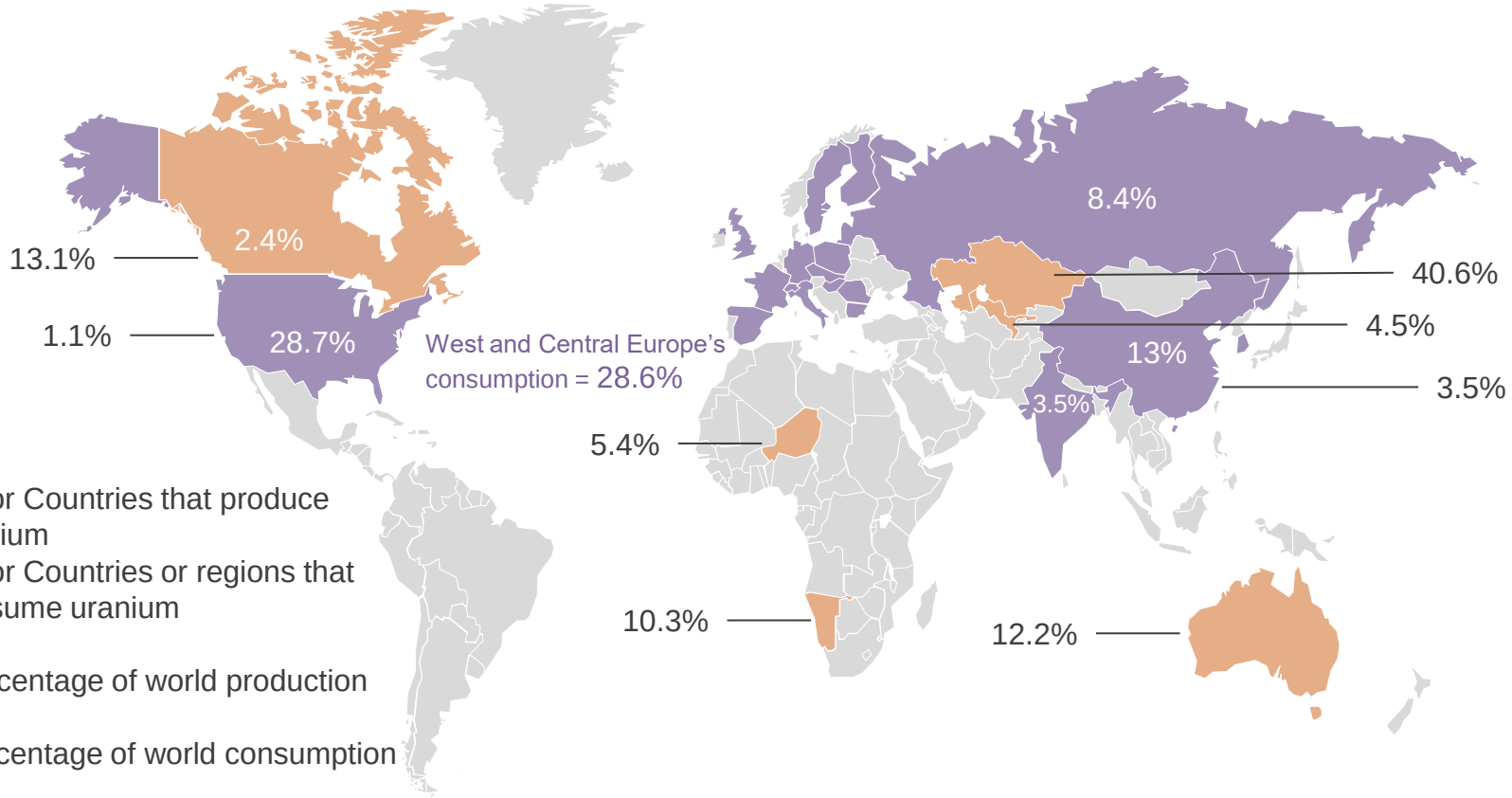
Uranium production and consumption in 2018



- Major Countries that produce uranium
- Major Countries or regions that consume uranium

% Percentage of world production

% Percentage of world consumption

Uranium production in 2018 by company

2018 World uranium production by company		
Company	**tonnes U**	**% of world**
Kazatomprom	11,704	21.9
Orano	5,809	10.9
Cameco	4,613	8.6
Uranium One	4,385	8.2
CGN	3,185	6.0
BHP Billiton	3,159	5.9
ARMZ	2,904	5.4
Rio Tinto	2,602	4.9
Navoi Mining	2,404	4.5
Energy Asia	2,204	4.1
CNNC	1,983	3.7
Others	8,546	16.0
Total	**53,498**	**100**

Traditional major producers: decrease

- Cameco, Kazatomprom, Orano, Uranium One

Australian producers: stable or small increase

- BHP, Rio Tinto, Quasar

Chinese producers: expanding

- CGN, CNNC

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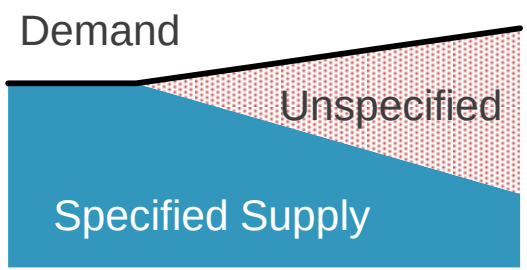
Categories of uranium supply



Specified Supply:

- Current capacity
- Mines under development
- Planned mines
- Prospective mines
- Specified secondary supply

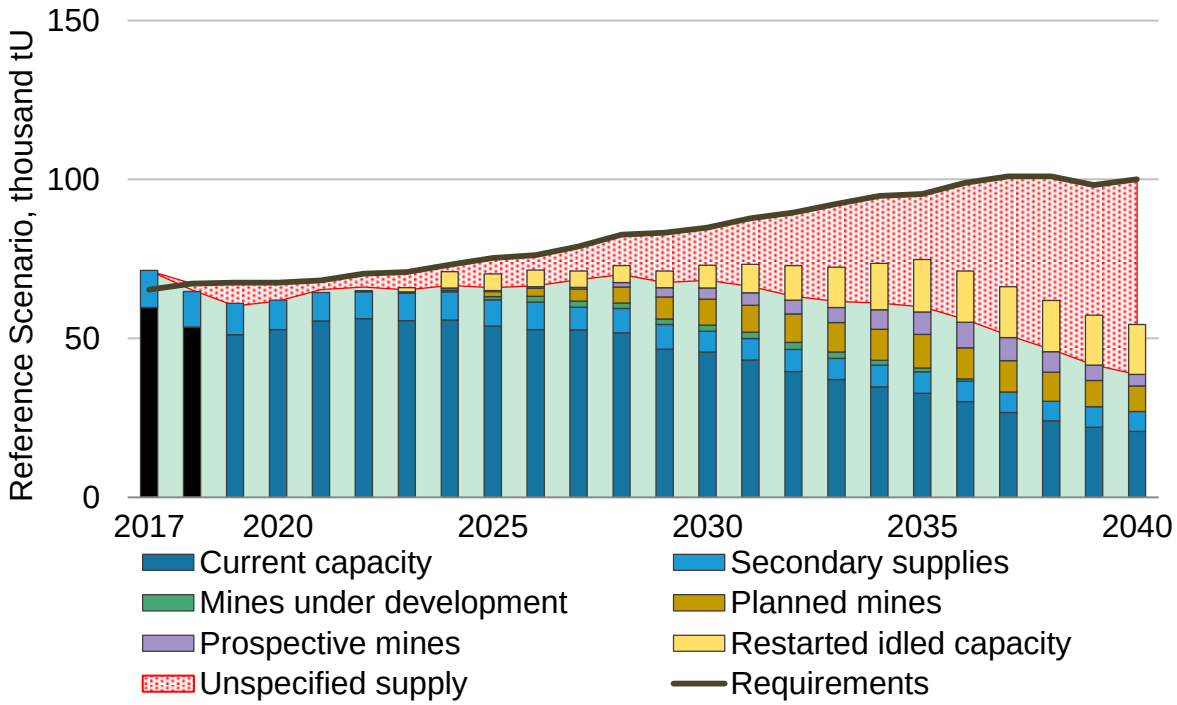
Unspecified Supply:

- Idled production capacity
- Unspecified secondary supplies
- Capacity expansions
- Reserve projects

	Reference		Upper		Lower	
	Delay (y)	Expected utilization (%)	Delay (y)	Expected utilization (%)	Delay (y)	Expected utilization (%)
Current capacity	0	90	0	95 - 100	0	85
Restarted idled capacity	-3	30 - 90	-2	40 - 100	-5	30 - 50
Mines under development	-2	60 - 90	-2	80 - 100	-4	30 - 50
Planned mines	-3	60 - 90	-2	75 - 100	0	0
Prospective mines	-4	50 - 90	-3	70 - 100	0	0

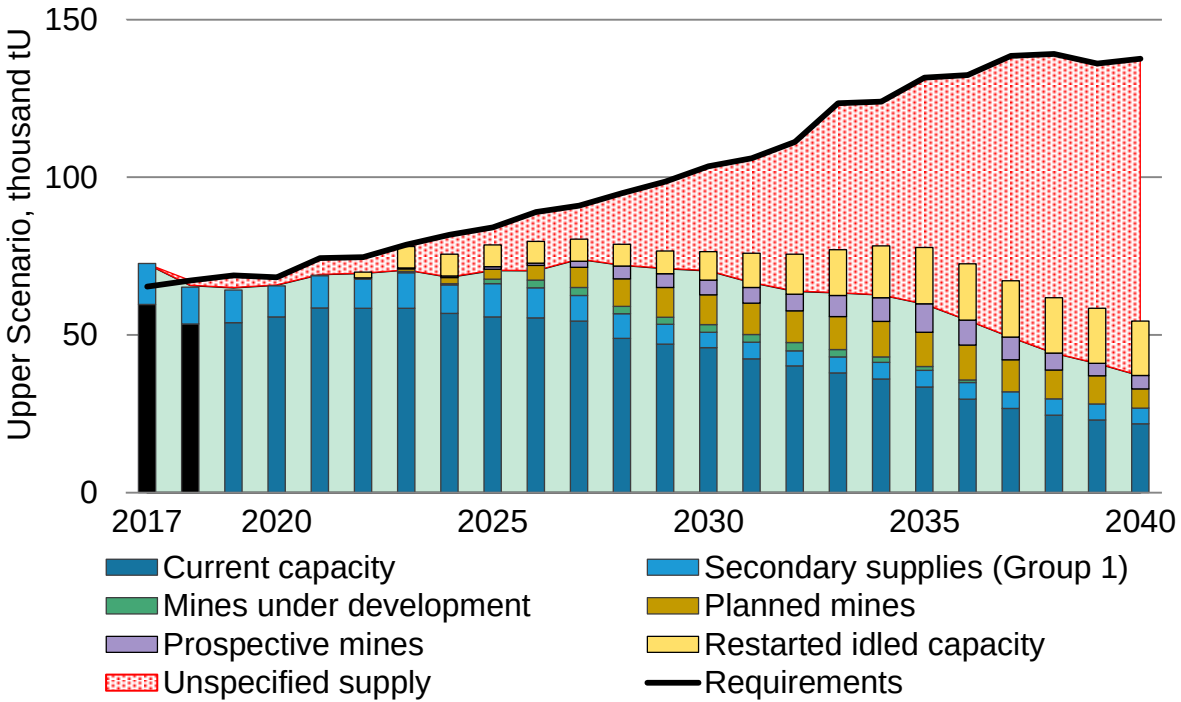
Uranium supply-demand: Reference Scenario

- The oversupply in the past years is alleviated by idling of mines and reducing utilization of operating mines.
- Near term: Supplies and reactor requirements are at a comparable level, but rely on inventory drawdown.
- Long term: Restarted idled mines + other unspecified supplies are needed to fill the supply-demand gap.



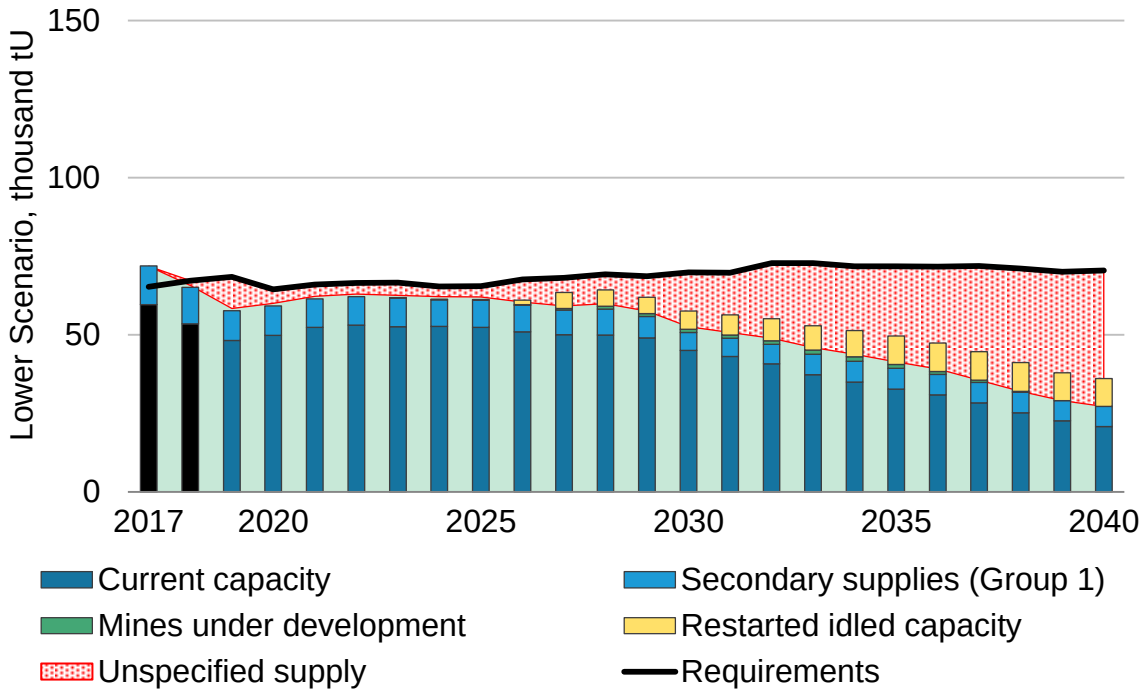
Uranium supply-demand: Upper Scenario

Uranium requirements are expected to rise in all three scenarios, even to double in the Upper Scenario in 2040.



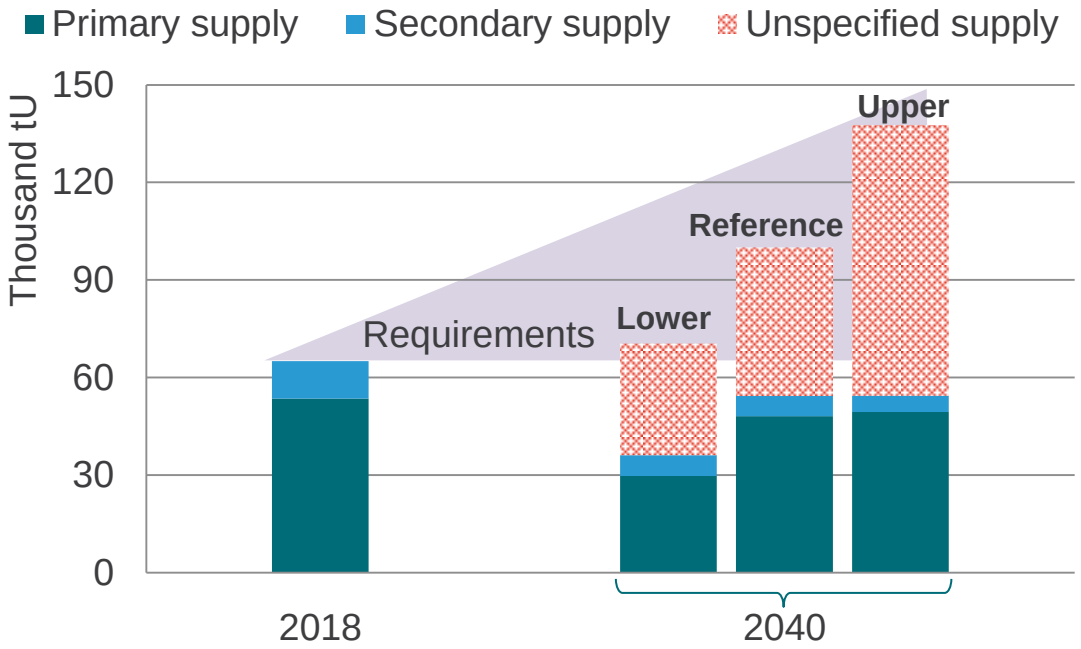
Uranium supply-demand: Lower Scenario

The Lower Scenario provides a solid baseline as existing reactors support the currently operating production facilities.



Uranium supply-demand: conclusions

- 3 of the top 10 mines (Rössing, Arlit (SOMAÏR) and Ranger) representing 10% of 2018 production are scheduled/ expected to close before 2030.
- Long lead time to develop a new mine.
- In the supply side, regardless of particular scenario (Reference, Upper or Lower), the industry needs to at least double its infrastructure for current, idled, under development, planned and prospective projects by 2040.
- Uranium resources, project extensions, reserve projects are sufficient to meet requirements, but work has to start or move on the development.



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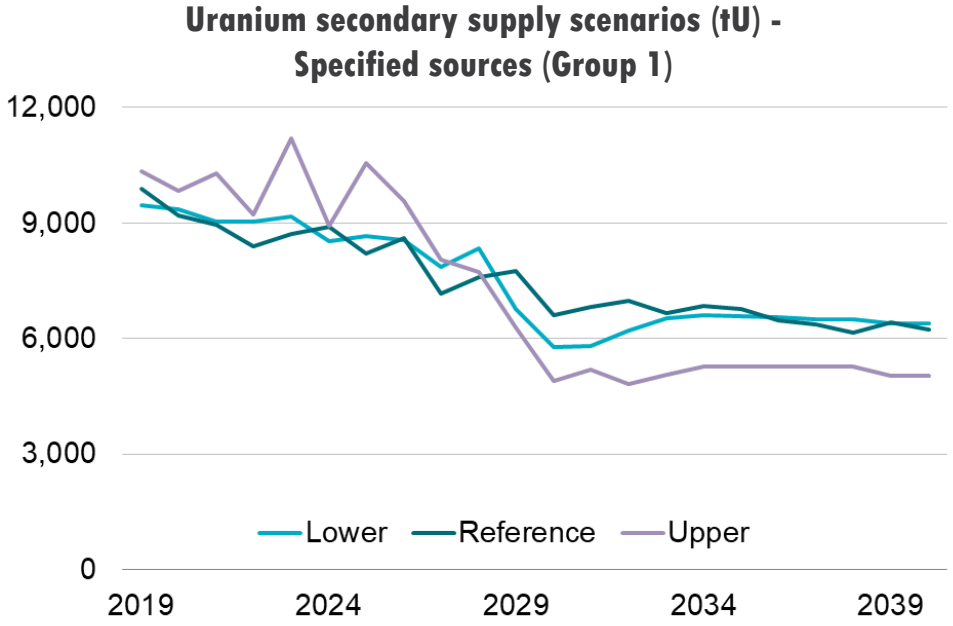
Unspecified supply: reserve projects

Country		Project/Mine	Operator	Estimated capacity (tU)
African countries	Namibia	Trekkopje	Orano	3,200
	Niger	Imouraren	Orano	5,000
		Dasa	Global Atomic Fuels	2,154
		Madaouela	GoviEx	1,000
		Azelik/Teguida	CNNC	692
	Malawi	Kayelekera	Paladin	1,269
	South Africa	Ezulwini (Cooke 4)	Sibanye-Stillwater	500
Australia		Yeelirrie	Cameco	2,968
		Kintyre	Cameco	2,308
		Valhalla/Mount Isa	Paladin	1,923
		Westmoreland	Laramide Resources	1,539
		Wiluna	Toro Energy	695
		Manyingee	Paladin	385
Canada		PLS	Fission Uranium	5,000
		Arrow	NexGen	5,000
		Nunavut (Kiggavik)	Orano	3,000
Canada		Millennium	Cameco	2,500
		Shea Creek	Orano	2,500
		Michelin	Paladin	1,923
		Midwest	Orano	1,500
Kazakhstan		Zhalpak	Ortalyk	500
USA		Cameco US ISR expansion	Cameco	615
		Reno Creek	UEC	577
		Church Rock/Crownpoint	Laramide Resources	385
		Hobson (Palagana etc.)	UEC	385
Other	India	KPM	UCIL	340
		Gogi	UCIL	130
		Lambapur-Peddagaltu	UCIL	130
	Mongolia	Zoouch Ovoo	Orano	2,050
	Peru	Macusani	Plateau Uranium	2,300
	Turkey	Temrezli	Westwater Resources	308
World total				**52,777**

- More prospective projects / potential expansions exist in the world.
- In 2040, the above mentioned projects, together with restarted idled capacity, would sufficiently cover the supply-demand gap (unspecified supply) in the Reference Scenario, and about 2/3 of unspecified supply in the Upper Scenario.

Secondary supply scenarios for uranium and conversion



- The supply-demand gap in the near term is largely covered by commercial inventories.
- Secondary supplies of uranium gradually decrease from the current 14-15% of reactor requirements to 4-9% in 2040.
- Recycled uranium as ERU and plutonium as MOX fuel will play a continuing role.

Conversion supply and demand

Near term

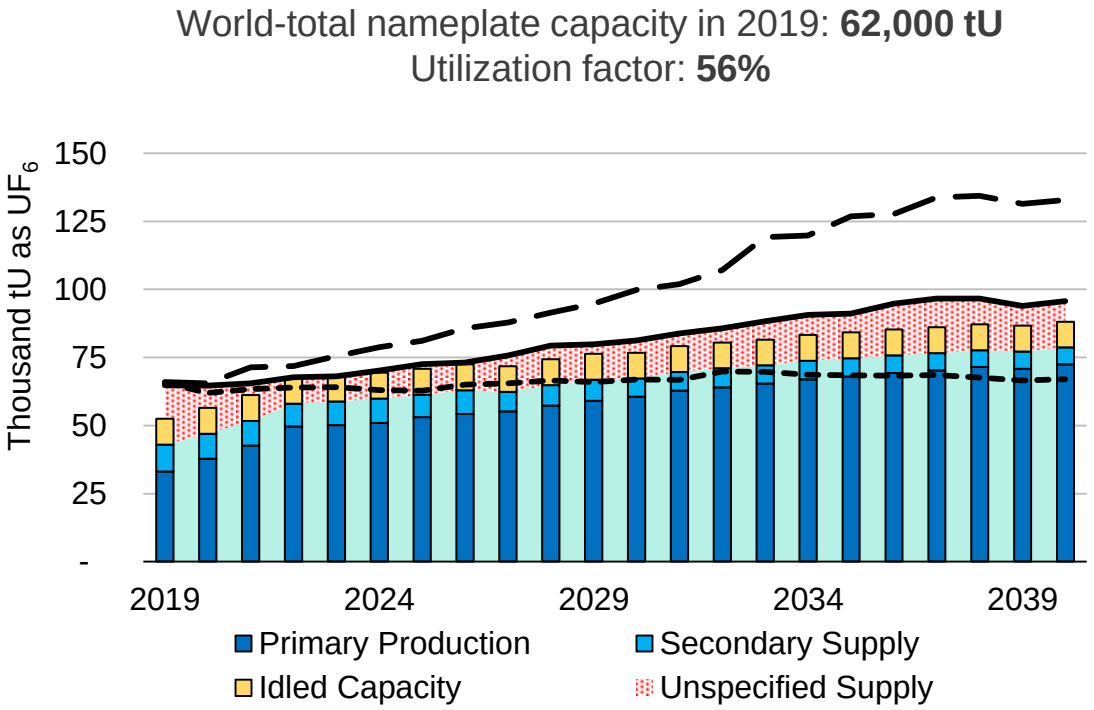
Inventories consumption

Mid-term

Return of idled capacity

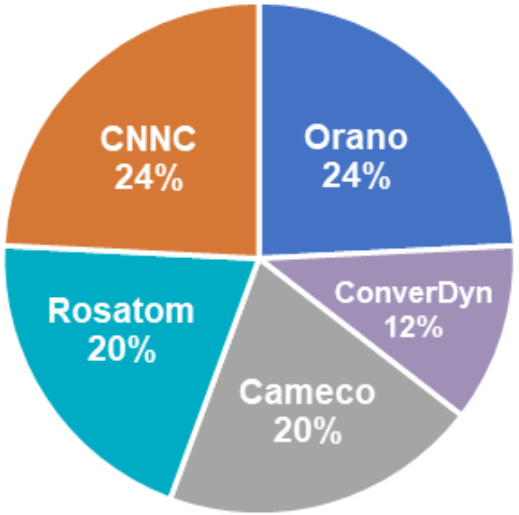
Long term

Expansion or new facility

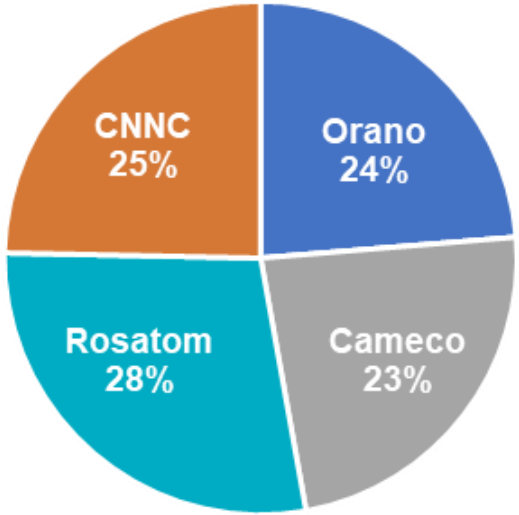


Near-term conversion supply

Five-year capacity (310,000 tU total)



Five-year production (213,000 tU total*)



ConverDyn**

* Total production includes the ramp-up of Orano's Phillipe Coste Plant.
** ConverDyn restart would add 7,000 tU per year (3% per year added)

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Conclusions:

1. For the first time in many years, the projections for nuclear generating capacity increase in all three scenarios.
2. In the projection period to 2040, nuclear generating capacity is expected to increase to 402 GWe, 569 GWe and 776 GWe in the Lower, Reference and Upper Scenarios from the current 373 GWe.
3. Uranium: idled capacity and low capacity utilization are bringing supply and demand back to equilibrium.
4. Conversion: inventory is consumed due to idled capacity.
5. In the long term, the amount of material coming from underfeeding and tails re-enrichment will be reduced due to increasing demand.

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