



Could Russia Dominate Commercial Uranium Enrichment?

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What's new in international enrichment capacity?

June 8, 2012:

“Yesterday saw the end of operations at Areva's Georges Besse diffusion enrichment plant following 33 years of . . . ‘uninterrupted operation’ since 1979 . . . Accordingly, Areva is bringing online the centrifuge-based Georges Besse II plant. This has a current installed capacity of 1.5 million SWU per year, slated to reach 7.5 million SWU per year in 2016. This plant is owned by SET (*Société d'Enrichissement du Tricastin*), which also counts several foreign shareholders.”

http://www.world-nuclear-news.org/C_Georges_Besse_finally_depleted_0806121.html



What's new in national enrichment capacity?

May 16, 2012, *The Washington Post*, “United States Enrichment Corp., bailed out once, seeks more federal money for new project:”

“The troubled USEC on the brink of closing a Kentucky enrichment plant, has been bailed out in a complex Energy Department accord designed to keep that facility open one more year. But USEC . . . is seeking more federal money to carry out R&D for the American Centrifuge Project, a more efficient enrichment plant in Ohio that the company calls vital to its future. . . **Without new government aid, USEC says it will have to halt work at the Ohio site by month's end** . . . A former government corporation privatized in the 1990s, USEC has struggled financially while blending down highly enriched uranium from decommissioned Russian nuclear warheads. The Russia deal runs out next year, and competing companies can enrich uranium more cheaply. . .”

http://www.washingtonpost.com/business/economy/united-states-enrichment-corp-bailed-out-once-seeks-more-federal-money-for-new-project/2012/05/16/gIQAjOu2UU_story.html



Market Value of US Enrichment Corporation, USEC, is less than \$100M (= dead meat)!

The Washington Post continues (May 16, 2012),

“Despite the push by the Energy Department and USEC’s allies in Congress, investors and credit analysts are not impressed. The stock, already down from its 2007 peak of about \$24 a share, has plunged an additional 31 percent this year, to 74 cents a share, and will be dropped from the New York Stock Exchange if it does not rebound. The entire market capitalization of the company, which was once government-owned, is just \$96 million, a fraction of the amount it is seeking in government assistance. On Tuesday, Standard & Poor’s put USEC’s CCC plus credit rating on ‘negative’ alert because of uncertainty about government funding. ‘We consider the company’s liquidity position to be weak,’ S&P said in a note to investors.” (USU closed down 5% on June 8, market capitalization was \$92.8M)

International Uranium Enrichment: Size and Market Share, 1994-2018:

There will be little change in concentration with the bankruptcy and closure of USEC, but

dominance has moved from the USA to Russia due to USEC's inability to compete in centrifuge technology!

Country	Owner	SWU 1994	Share 1994	SWU 2000	Share 2000	SWU 2006	Share 2006	SWU 2012	Share 2012	SWU 2018	Share 2018
		HHI = 2,927		HHI = 2,777		HHI = 3,142		HHI = 2,893		HHI = 3,278	
USA	USEC	19,200	39%	11,300	23%	8,000	15%	8,000	13%	0	0%
USA	Urenco	0	0%	0	0%	0	0%	3,000	5%	3,000	5%
USA	Areva	0	0%	0	0%	0	0%	0	0%	3,300	5%
Euro	Urenco	3,375	7%	5,250	11%	7,400	14%	13,000	22%	13,000	20%
France	Areva	10,800	22%	10,800	22%	10,800	20%	6,000	10%	10,800	16%
Russia	Tenex	14,000	29%	20,000	41%	26,000	48%	27,500	46%	33,500	51%
Other	Others	1,305	3%	1,905	4%	1,705	3%	2,358	4%	2,458	4%
Total		48,680	100%	49,255	100%	53,905	100%	59,858	100%	66,058	100%



Where's Russian enrichment capacity?

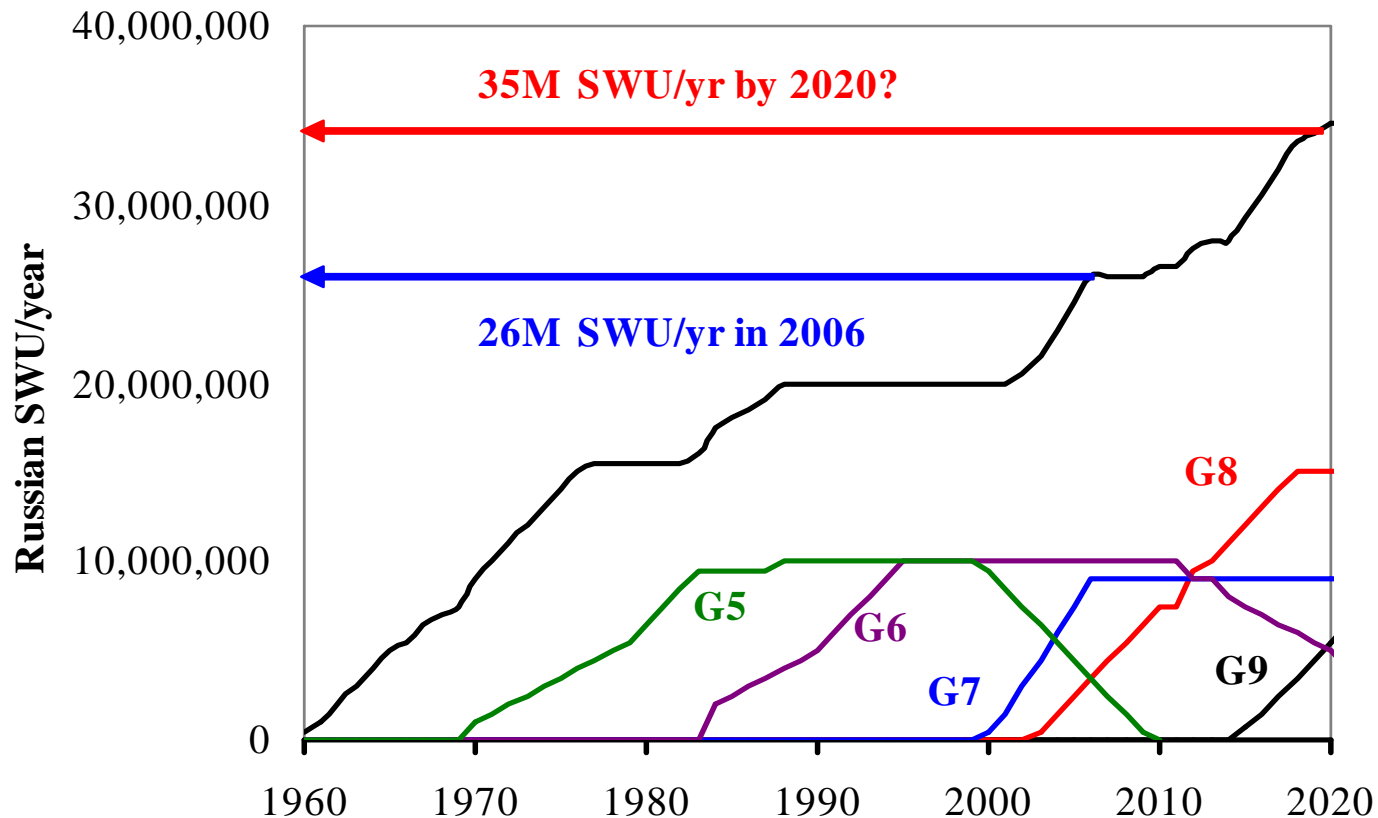
The International Panel on Fissile Materials estimates capacity in 2012 based on the *Global Fissile Material Report 2011*:

Russia:	Millions of SWU/year
Angarsk	2,200-5,000
Novouralsk	13,300
Zelenogorsk	8,700
Seversk	<u>3,800</u>
TOTAL	27,000-30,000 MSWU/yr

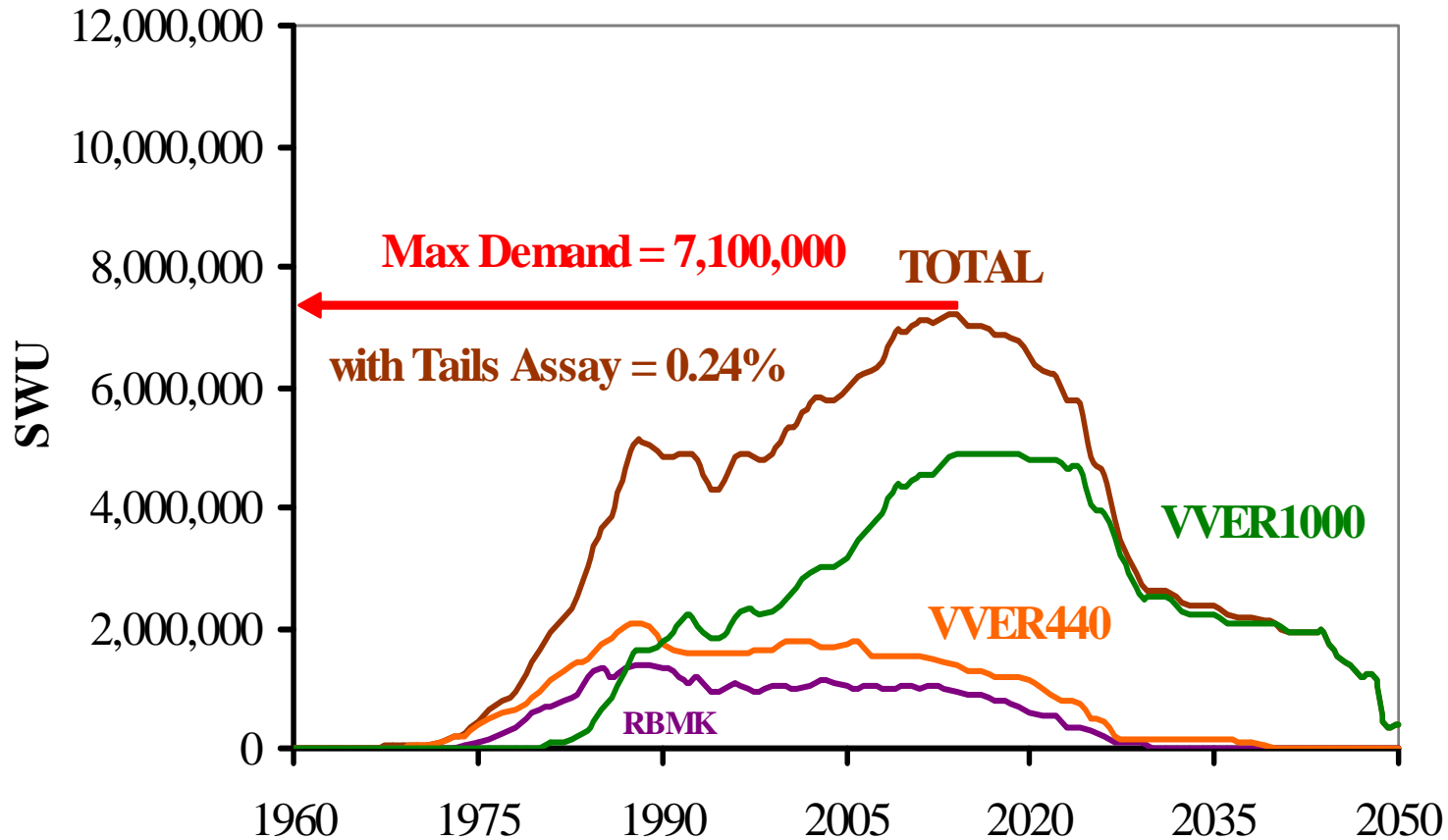
http://fissilematerials.org/facilities/uranium_enrichment.html (accessed June 2012)

How could Russian enrichment capacity grow so fast (and why)?

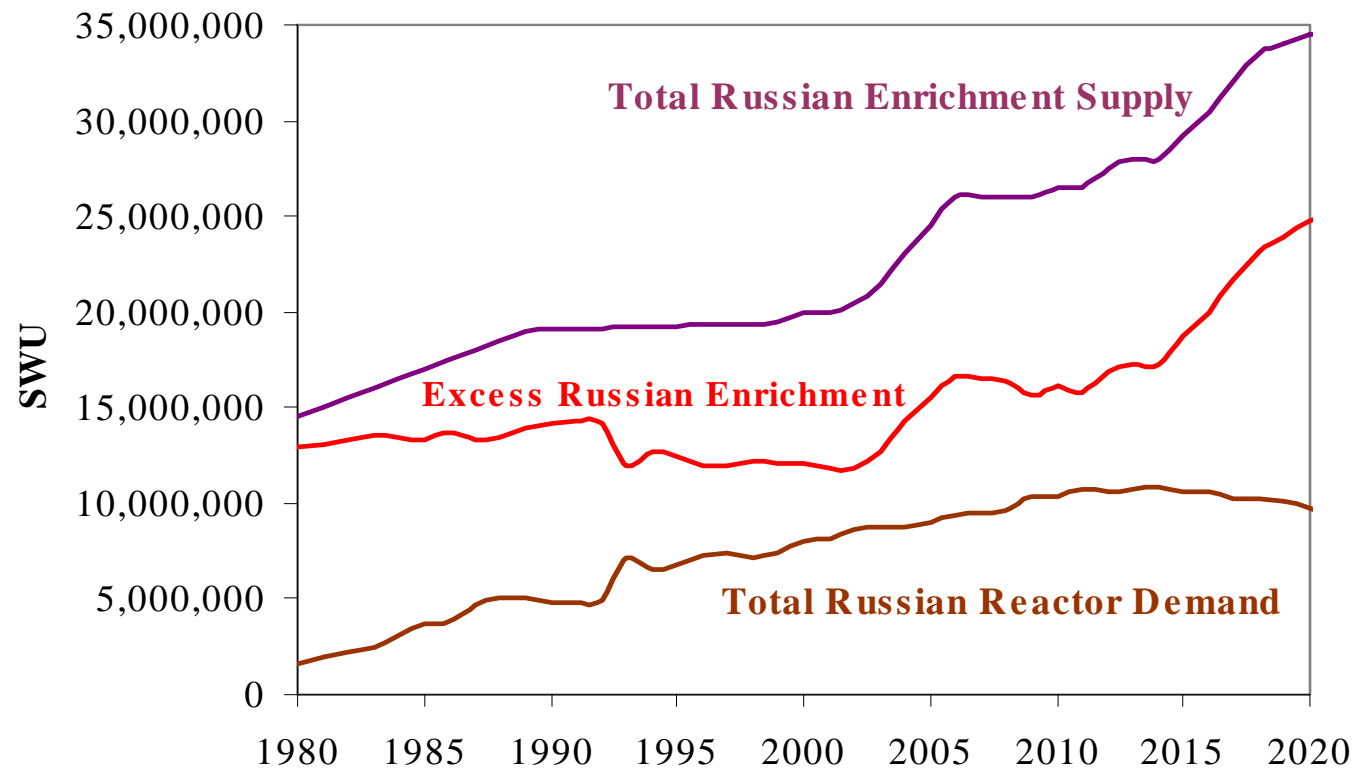
Overlapping Centrifuge Technology Generations: Hypothetical Gen 5 thru 9 Deployment, 1970-2020



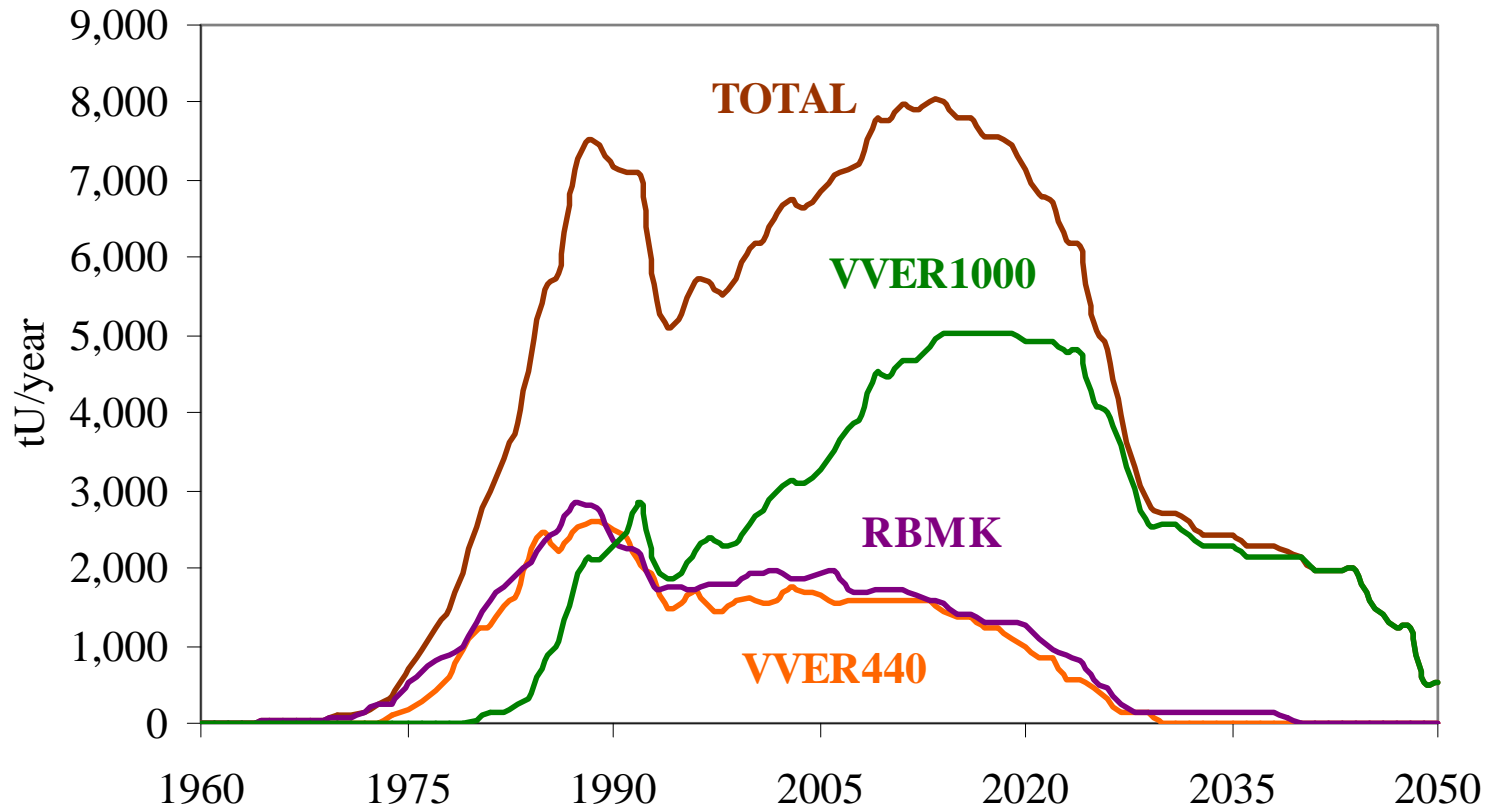
What is Russian-Technology Nuclear Power Plant **Enrichment Demand**?



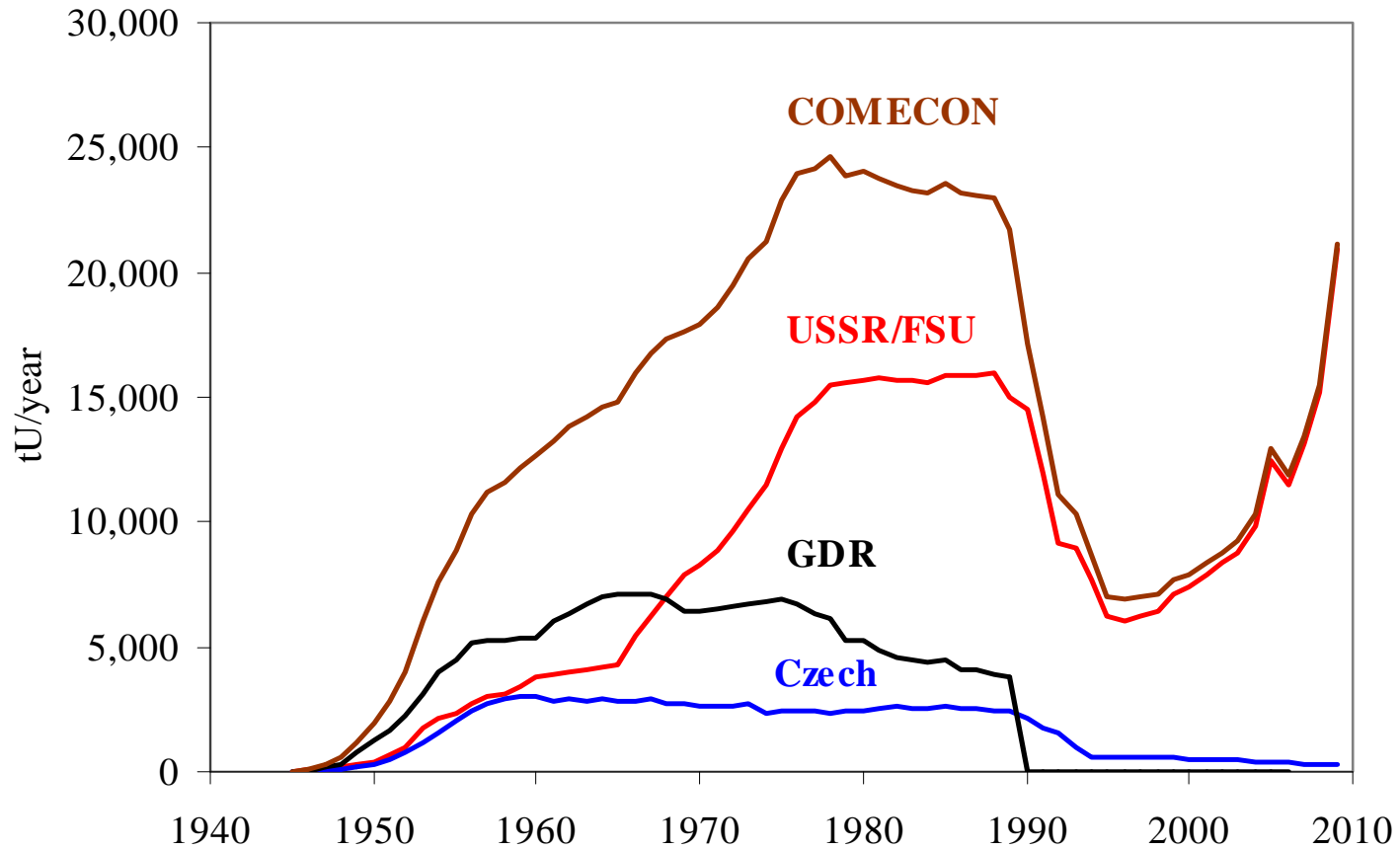
What is Excess Russian Enrichment (with ~0.24% tails assay)?



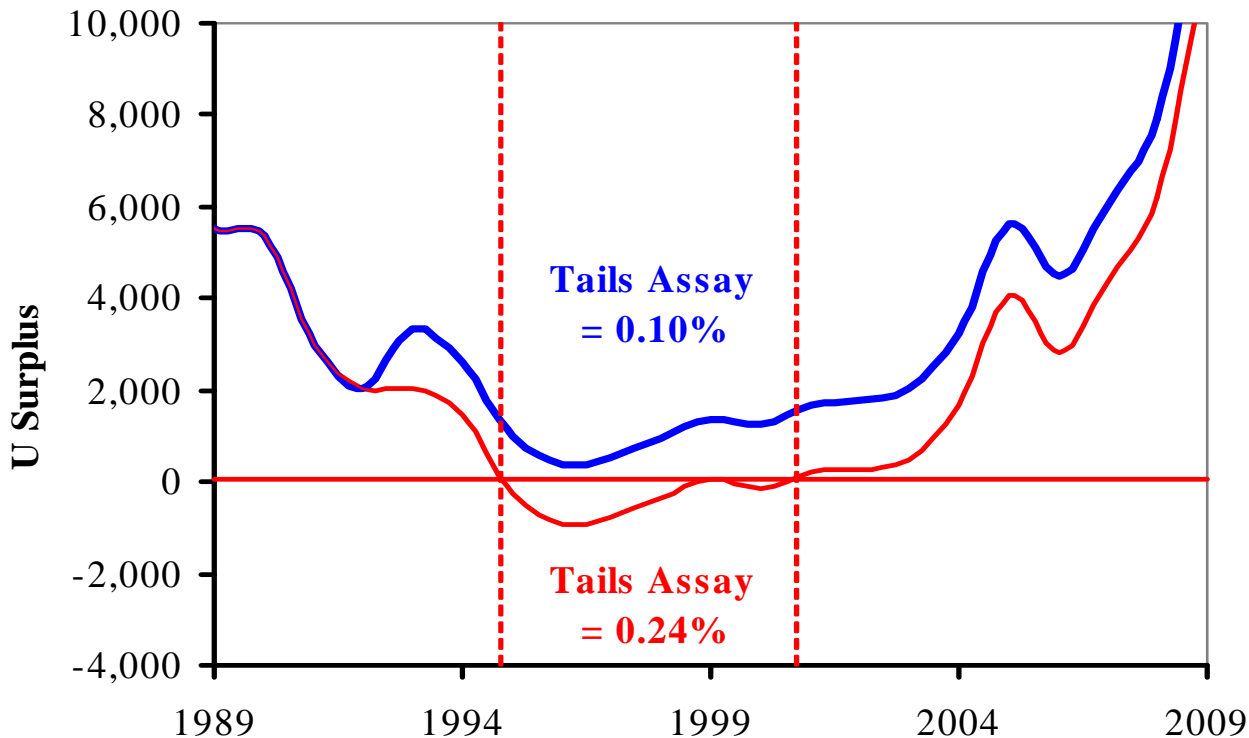
What has been Russian-Technology Nuclear Power Plant Uranium Demand?



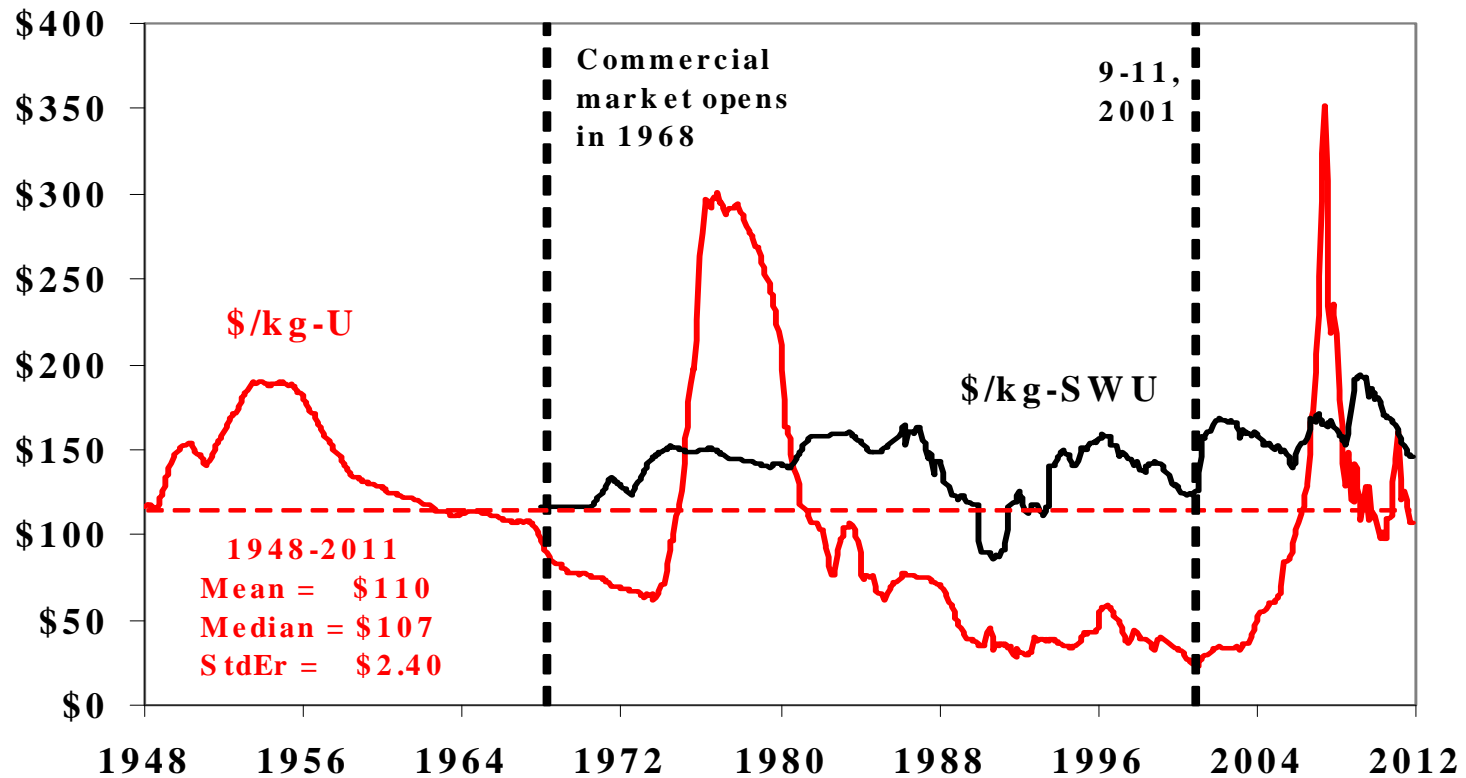
What has been Natural **Uranium** Production for Russian-Technology Reactors?



Was there adequate supply of natural uranium to Russia, assuming a tails assay of 0.24%?

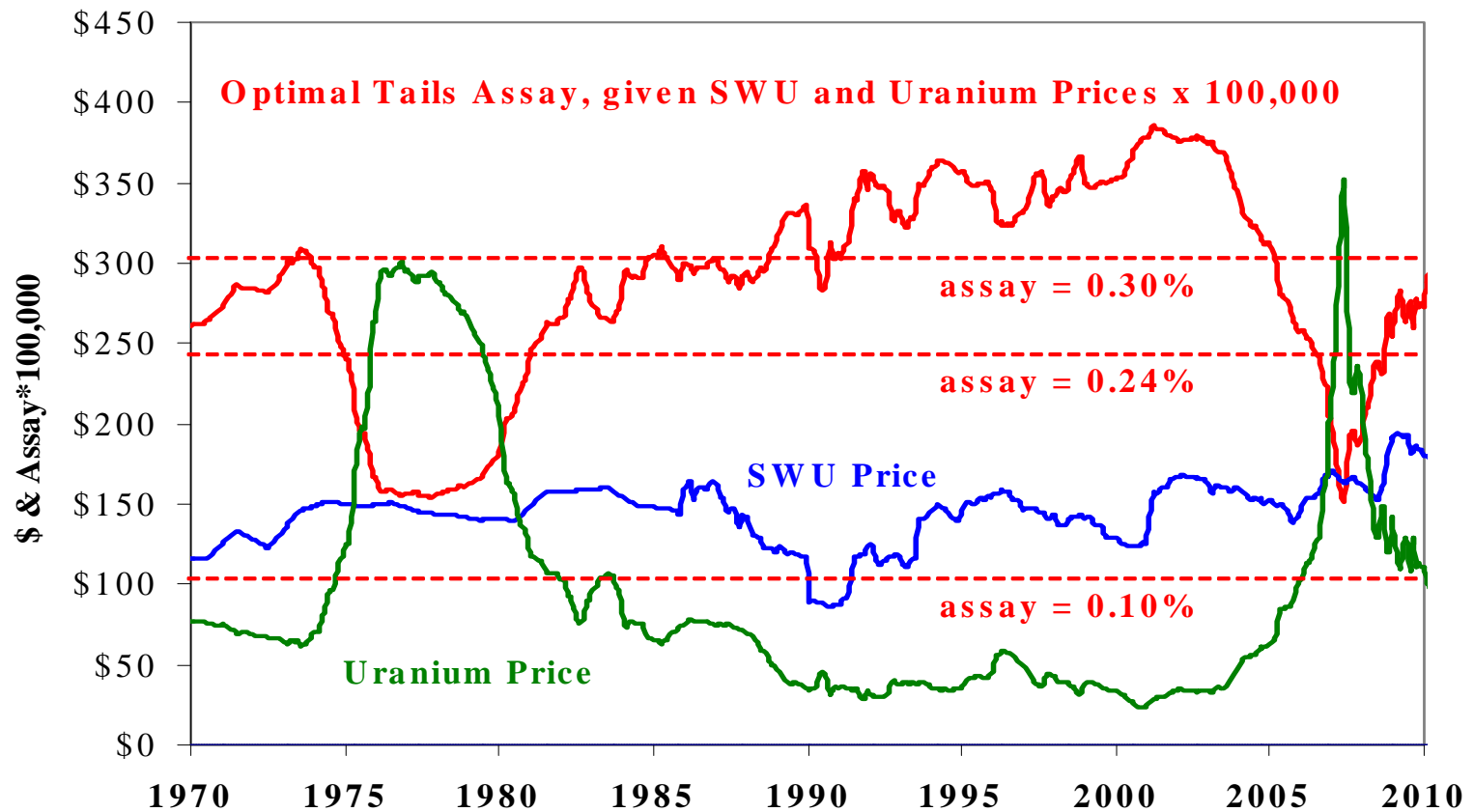


***Has a tail assay of 0.10% been optimal,
given the prices of natural uranium and SWU?
Consider U.S. spot prices, 1948-2012***

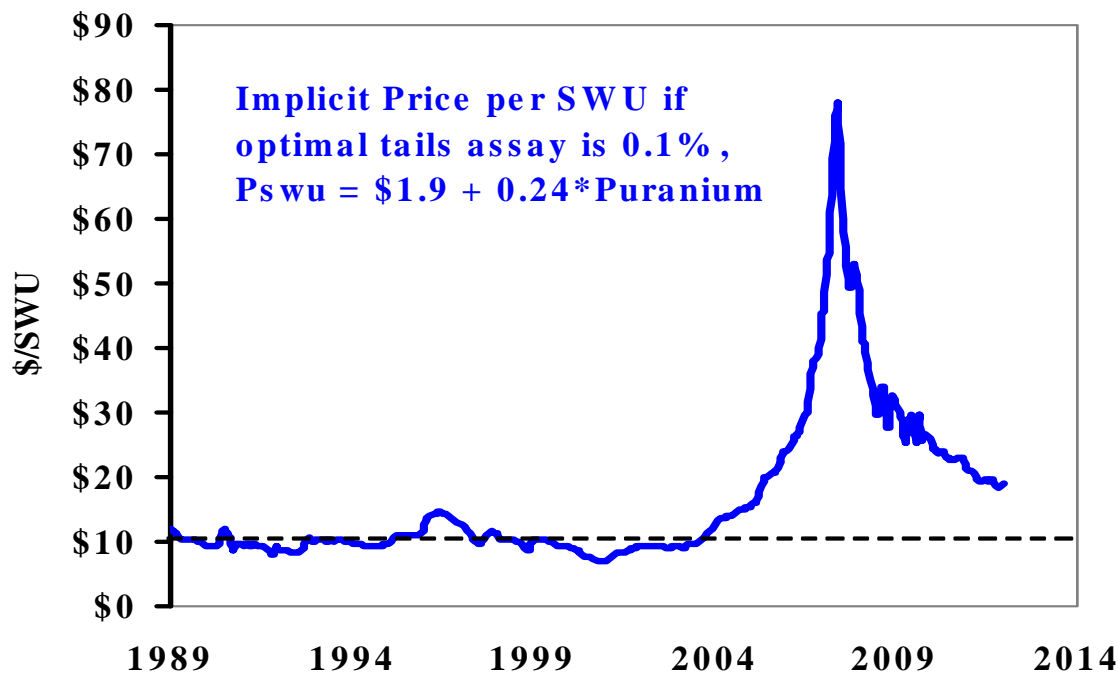


Would a tail assay of 0.10% have been optimal in the U.S.?

No! It should have been between 0.25-0.35%!



Assuming internationally uniform uranium prices, what cost of SWU would have made a tails assay of 0.10% cost minimizing after the USSR/Russia lost access to German and Czech uranium?

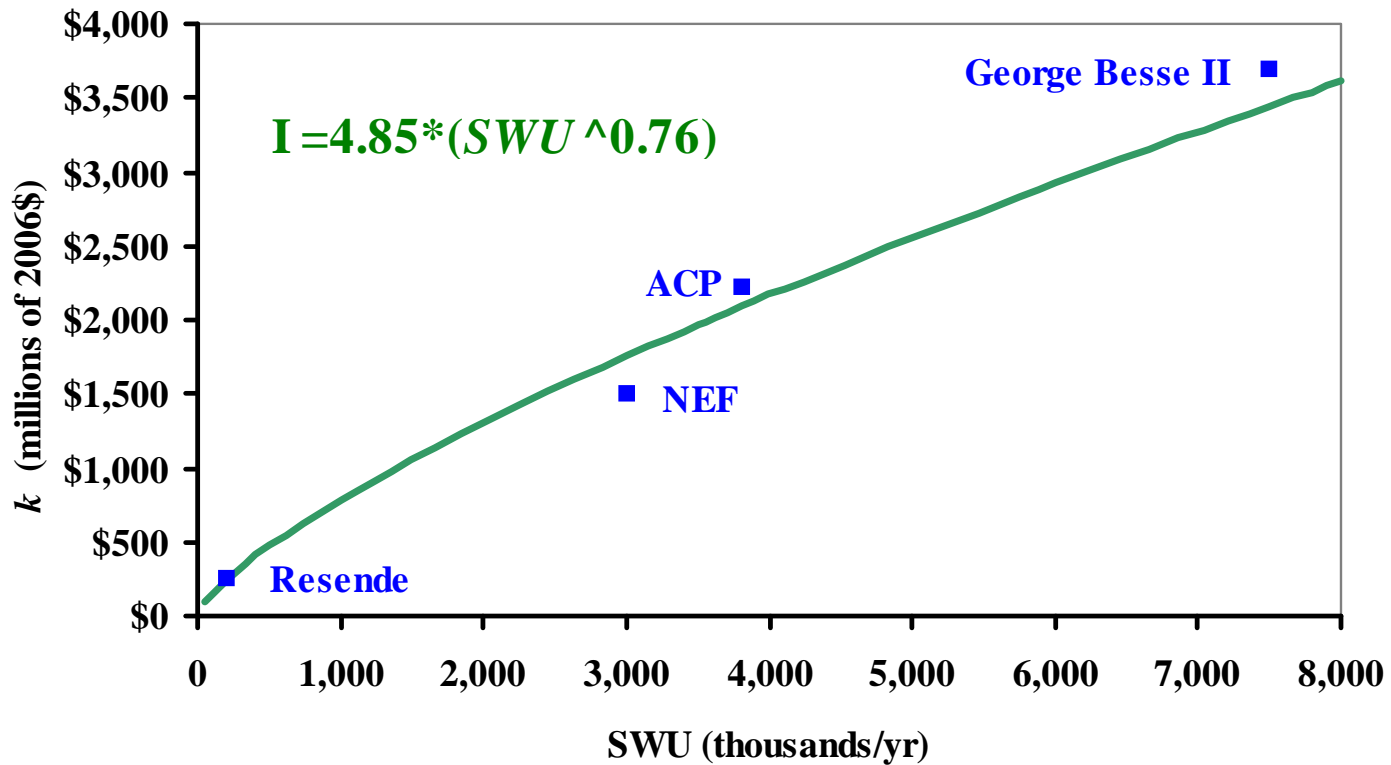




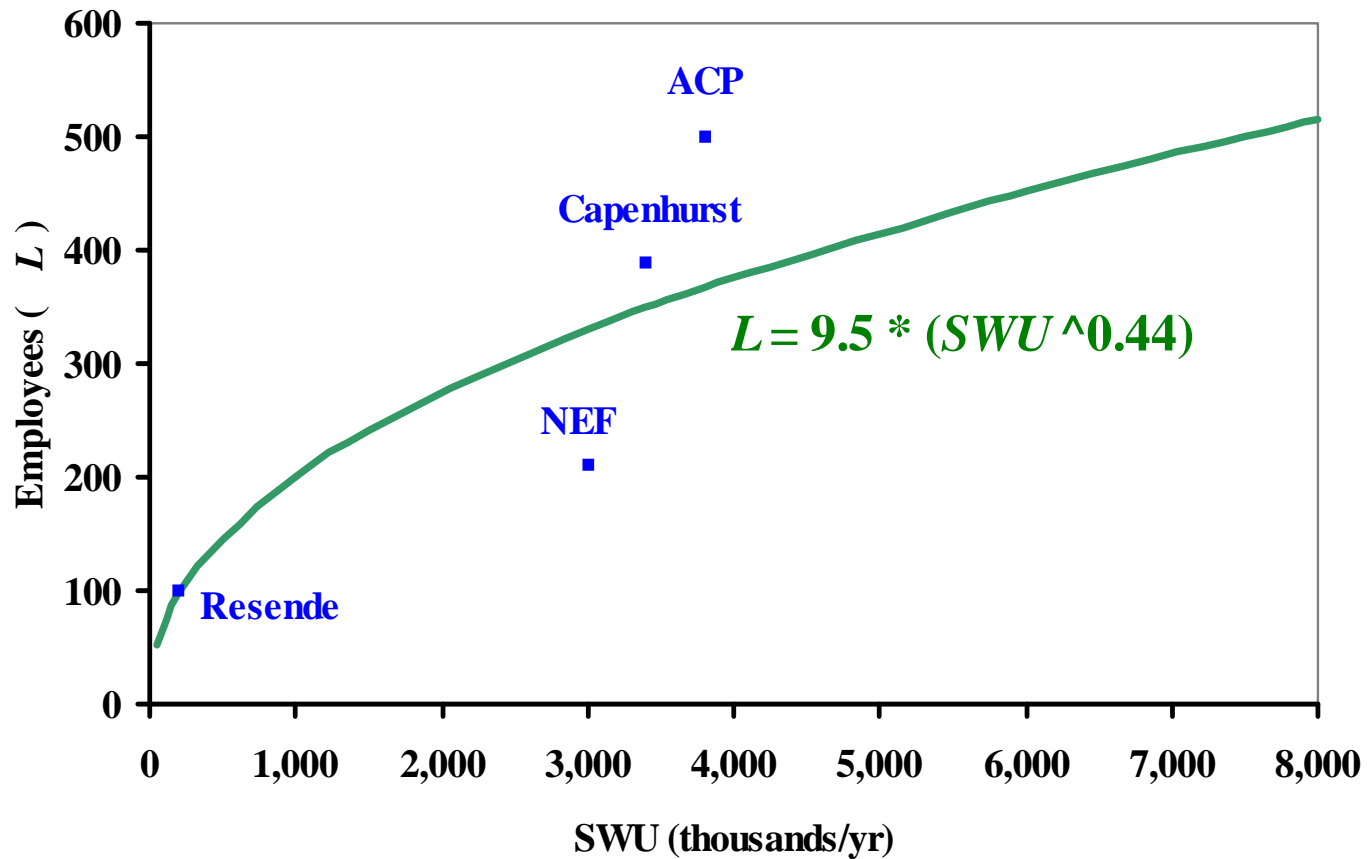
Changes in assumptions in enrichment cost model from Rothwell, “Market Power in Uranium Enrichment,” *Science & Global Security* (2009).

- (1) Investment in capacity before 1989 (USSR) is written off
- (2) Cost of new centrifuge capacity in Russia is half the cost of new capacity in Western Europe and the U.S.
- (3) Annual burdened wage rate is \$30,000 outside of Moscow and \$60,000 inside Moscow

Investment Cost of Additional Centrifuges



Employees as a function of enrichment plant size



Based on cost model in Rothwell (2009):

Firm Plant		Tenex UEKhK	Tenex EKhZ	Tenex SKhK	Tenex Angarsk
Plant Capacity (in tons)	t SWU/yr	12,450	7,390	3,650	2,500
Plant Capacity since 1989	t SWU/yr	3,450	2,640	800	600
Capital Additions since 1989	\$M	\$1,184	\$966	\$390	\$313
Cost of Capital	%/year	2.5%	2.5%	2.5%	2.5%
Capital Recovery Factor	%/year	4.78%	4.78%	4.78%	4.78%
Capital/SWU	\$/SWU	\$4.54	\$6.25	\$5.10	\$5.99
Staff Size	people	601	478	350	297
Annual Fully Burden Salary	\$k/yr	\$30	\$30	\$30	\$30
Labor/SWU	\$/SWU	\$1.45	\$1.94	\$2.88	\$3.56
Electricity Consumption	kWh/SWU	62	62	62	62
Electricity Price	\$/MWh	\$53	\$53	\$53	\$53
Electricity/SWU	\$/SWU	\$3.30	\$3.30	\$3.30	\$3.30
Materials/SWU	\$/SWU	\$0.95	\$1.31	\$1.07	\$1.25
Levelized Average Costs					
Capital/SWU	\$/SWU	\$4.54	\$6.25	\$5.10	\$5.99
Labor/SWU	\$/SWU	\$1.45	\$1.94	\$2.88	\$3.56
Electricity/SWU	\$/SWU	\$3.30	\$3.30	\$3.30	\$3.30
Materials/SWU	\$/SWU	\$0.95	\$1.31	\$1.07	\$1.25
Levelized SWU Cost	\$/SWU	\$10	\$13	\$12	\$14
Weighted Average Cost	\$11.64	\$5	\$4	\$2	\$1

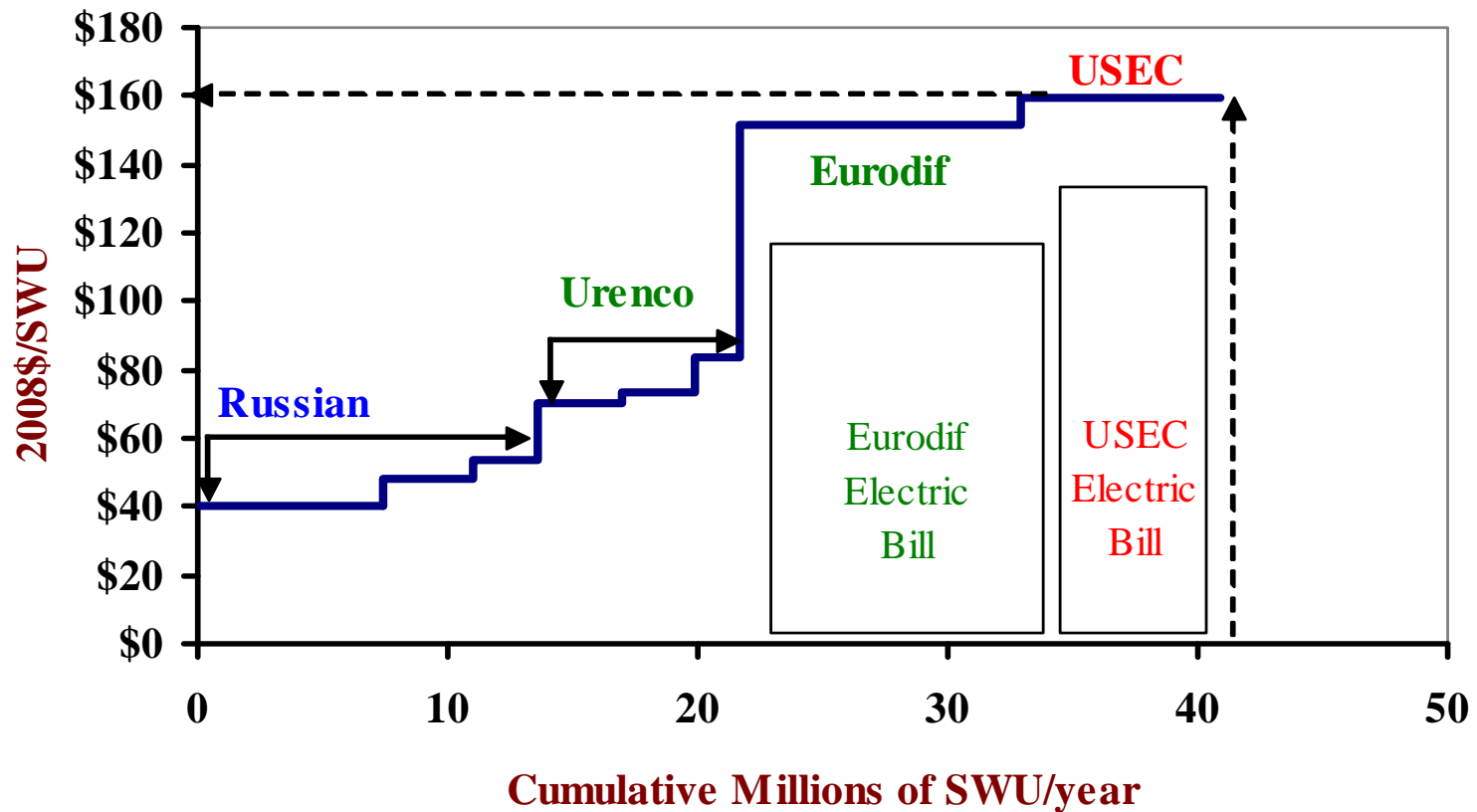


***Assuming uranium prices to be international,
a cost of SWU of approximately \$12
would have yielded an optimal tails assay of 0.10%***

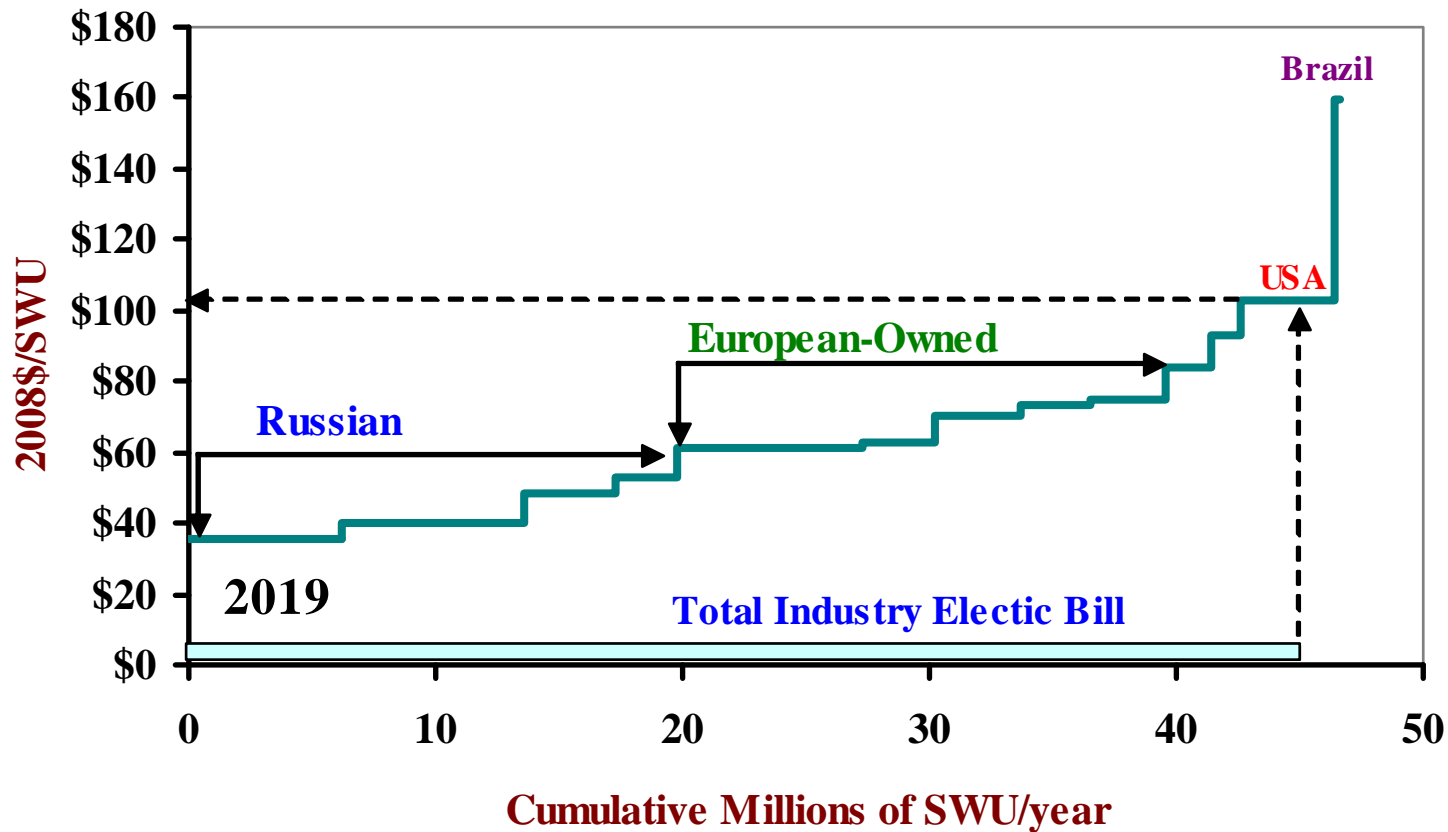
(1) Average enrichment costs across the TENEX enrichment enterprise could have been as low as \$11.64/SWU in Russia between 1989 and 2004. Since 2004, centrifuge costs and wages could have increased, however, profits appear to be very high and can maintain investment in yet higher efficiency (supercritical?) centrifuges.

(2) TENEX could have lowered its tails assay to 0.10% to avoid purchasing natural uranium to satisfy Russian fuel contracts. They used their extra SWU to mine the half billion tons of uranium tails stored at their enrichment sites and retiring capacity to reenriched reprocessed uranium.

The International Uranium Enrichment Services Market, 2005: Low Barriers to Entry due to Diffusion Costs



The International Uranium Enrichment Services Market, 2015: High Barriers to Entry due to Russian Costs





Could TENEX Dominate the Low Enriched Uranium Enrichment Services Market?

(1) Although centrifuge costs could have risen in the last 10 years in Russia, centrifuge manufacturing labor is still probably much cheaper than in Western Europe (there will NEVER be any centrifuge manufacturing in the U.S. because TENEX will always be cheaper).

(2) TENEX has a huge excess capacity that could be dumped on the international market as soon as TENEX is able to sign up customers (or Russia is able to sell more reactors). USEC will NEVER be able to compete with Russian enrichment and will declare bankruptcy soon.

(3) This huge Russian excess capacity in enrichment services, given the decrease in demand from Japan and German after Fukushima, should DISCOURAGE ALL NEW ENTRY, e.g., by Korea.



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**International Panel on Fissile Materials. *Global Fissile Material Report 2011: Nuclear Weapons and Fissile Material Stockpiles and Production.*
www.fissilematerials.org**