

DYNAMIC RELATIONSHIPS BETWEEN URANIUM & SWU PRICES: A NEW EQUILIBRIUM

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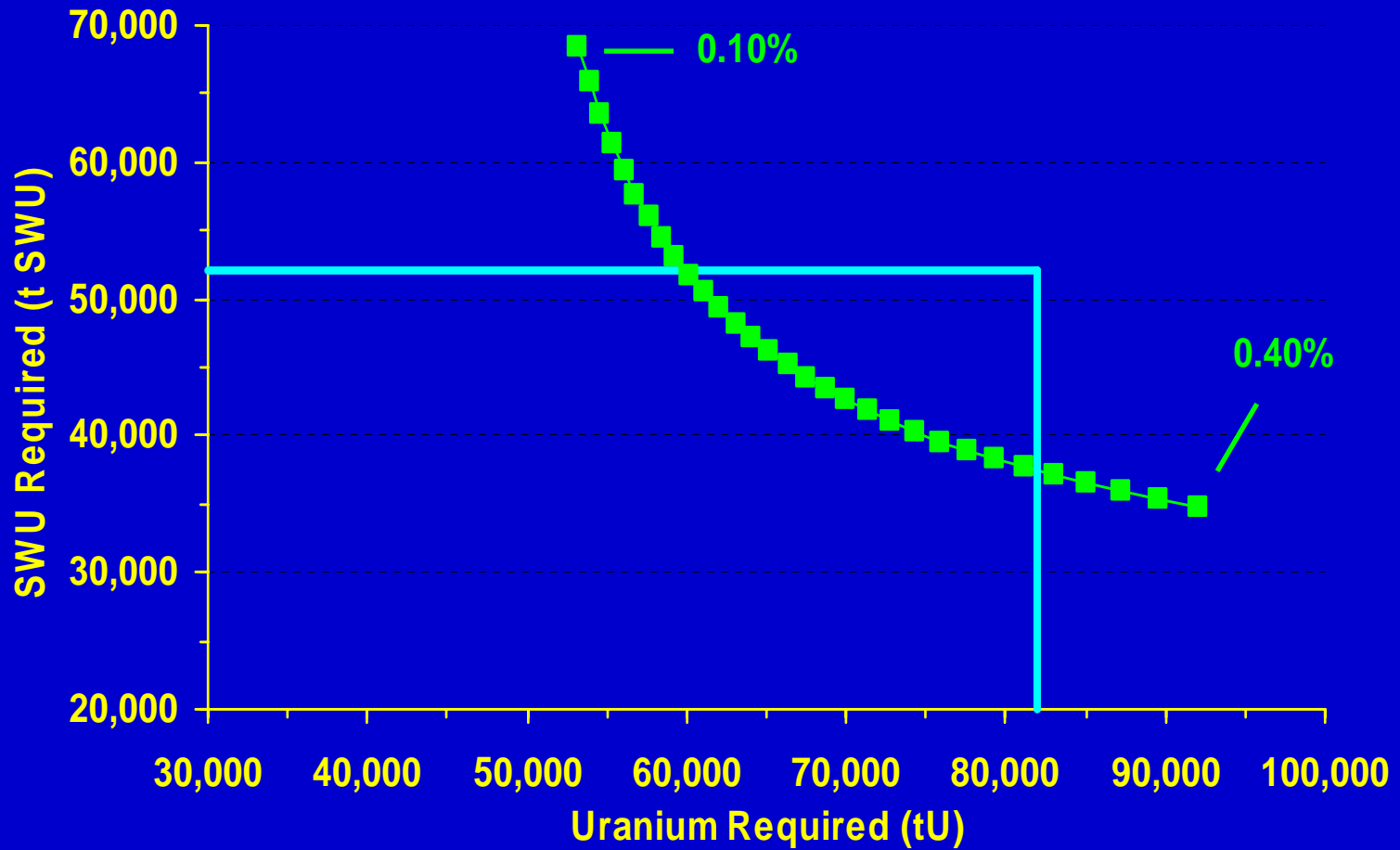
RELATIONSHIPS BETWEEN URANIUM AND ENRICHMENT - I

- ❑ Uranium and enrichment are substitute factors in the production of nuclear fuel
- ❑ In most production processes, a change in price of one factor results in a change in price of its substitute
- ❑ This has not been true for uranium or enrichment – oversupply has allowed prices to be set independently

RELATIONSHIPS BETWEEN URANIUM AND ENRICHMENT - II

- ❑ Oversupply situation is ending and prices for uranium and enrichment will be strongly coupled, and significantly higher
- ❑ Scarcity of uranium and enrichment are aggravated by decades of oversupply and under-investment in new capacity
- ❑ Low uranium prices and high tails assay have led to lack of enrichment capacity to substitute for uranium
- ❑ Look at price dynamics on 2015 horizon

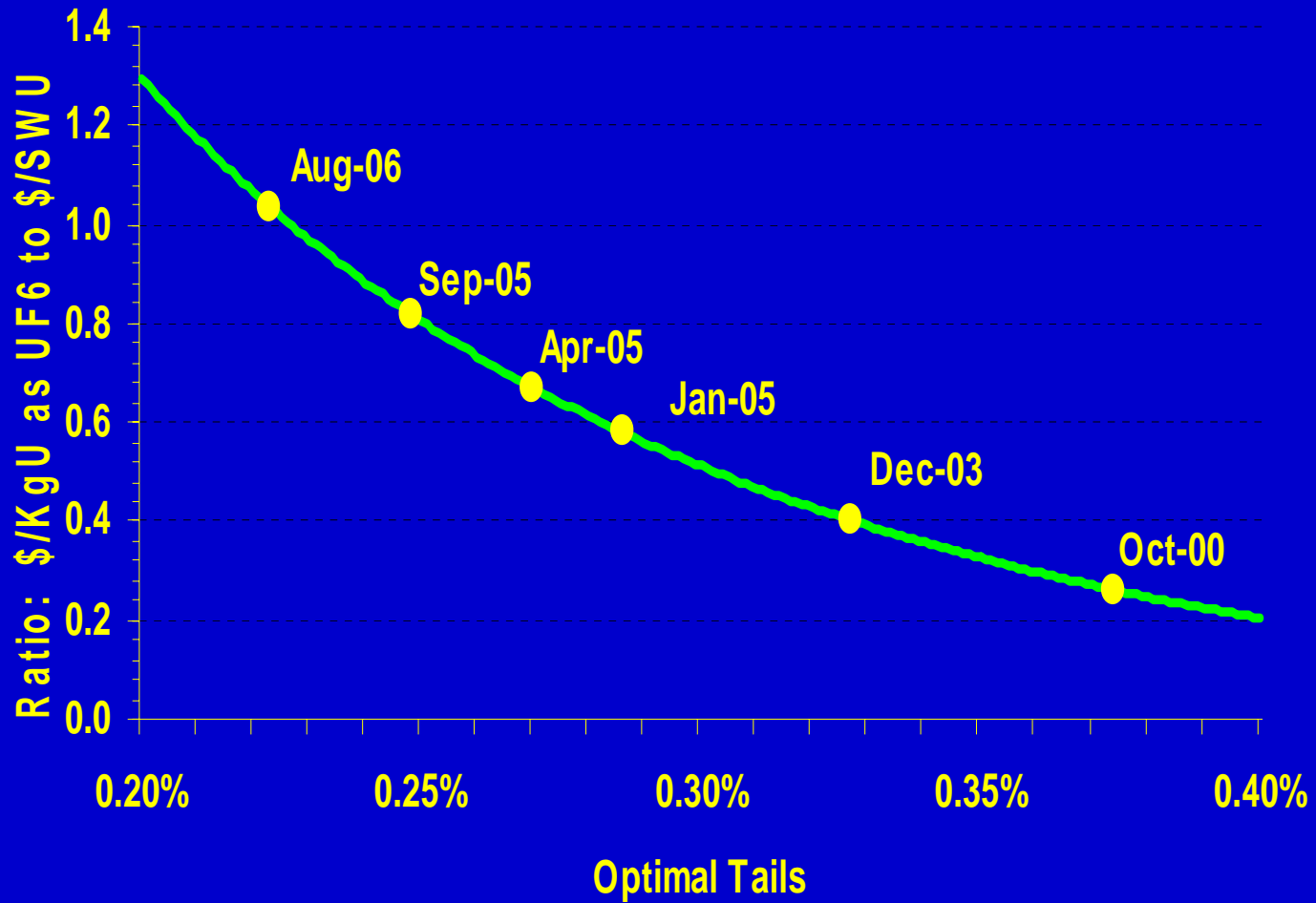
URANIUM & SWU SUBSTITUTION IN OVER-SUPPLY SITUATION



EFFECT OF OVERSUPPLY

- ❑ Low cost of substitution between uranium and SWU (low cross-elasticity of supply)
- ❑ Depressed prices & flexible contract terms
- ❑ Effective utility control of market, prices, contract terms
- ❑ Optimal tails set by relative prices for uranium and enrichment, but fuel cost not very sensitive due to low prices for both
- ❑ Rapidly moving from oversupply to scarcity – first effects seen in uranium

OPTIMAL TAILS AS FUNCTION OF RATIO OF URANIUM TO SWU PRICE



URANIUM & ENRICHMENT PRICE DYNAMICS

MARKET OF TIGHTENING SUPPLY

- ❑ Rising uranium price implies rapid decline in optimal tails since 2006—would result in reduction in uranium requirements by 28% and increase in SWU requirements by 32%
- ❑ As tails assay declines, more SWU are required to accomplish an incremental reduction in tails assay
- ❑ Legacy contracts result in suboptimal allocation of uranium and SWU – set stage for more disruptive adjustment later
- ❑ Look at supply in 2015, compared to WNA reference requirements (may be low if new cores)

WESTERN ENRICHMENT SUPPLY - 2015

Facility	Planned Capacity	Potential Additional	Total
Urenco	11	4	15
GBII (Areva)	7.5	-	7.5
NEF	3.0	3.0	6.0
USEC	3.5	3.5	7.0
Other	2.8	-	2.8
MOX	1.0	1.0	2.0
TOTALS	28.8	11.5	40.3

ISSUES IN ENRICHMENT SUPPLY

- ❑ Western capacity plans seem to reflect assumed high tails assays
- ❑ Capacity requirements would be 24% higher at 0.22% tails than at 0.33%
- ❑ Urenco, NEF, GBII will require substantial expansion of centrifuge manufacturing capacity
- ❑ Additional SWU: from Russia, continued operation of a GDP, or new plants
- ❑ Can we depend on Russia to make up a western deficit?

WESTERN URANIUM SUPPLY - 2015

	WNA Lower	WNA Reference	Existing & Planned Capacity
Primary Supply:			
Australia	9,202	17,702	13,800
Canada	15,167	16,567	15,380
Kazakhstan	9,219	11,219	8,000
Namibia	1,000	4,038	4,850
Niger	3,282	3,282	3,500
South Africa	755	2,295	2,000
USA	2,738	3,328	3,260
Uzbekistan	2,016	2,516	2,500
Other	1,415	2,265	1,800
Total Primary Supply	44,794	63,212	55,090

WESTERN URANIUM SUPPLY - 2015

	WNA Lower	WNA Reference	Existing & Planned Capacity
Total Primary Supply	44,794	63,212	55,090
Secondary Supply:			
Tails Re-Enrichment	1,500	2,500	
Ex-Military MOX	400	400	
MOX + RepU	2,264	2,264	
U.S. DOE Sales	0	1,500	
Total Secondary Supply	4,164	6,664	5,400
TOTAL SUPPLY	48,958	69,876	60,490

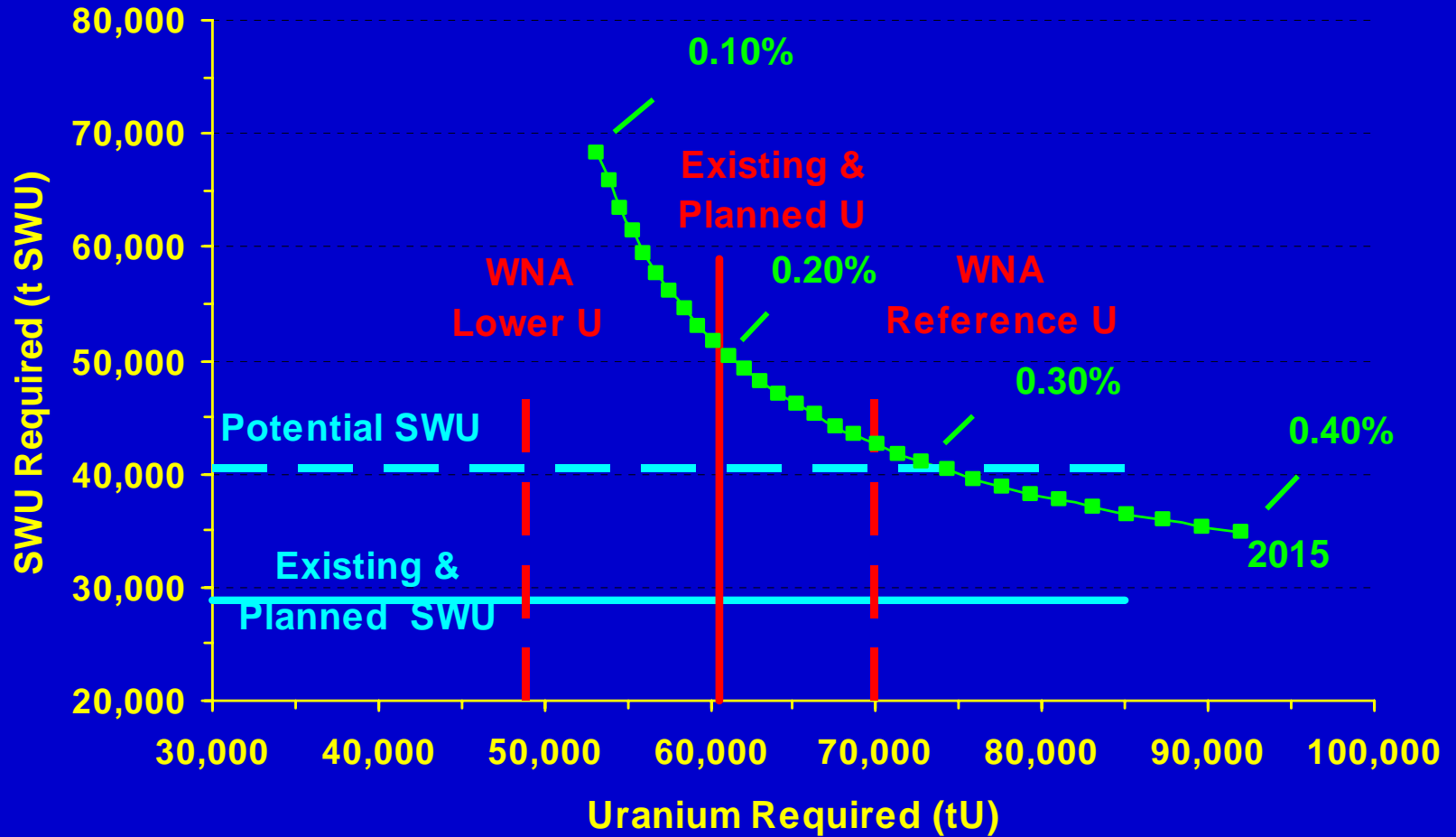
ISSUES IN URANIUM SUPPLY - I

- ❑ Western production in 2005 was about 37,000 tU
- ❑ Production increases by 2015 will have to come from known deposits and primarily from production centers now in development
- ❑ “Existing & Planned” primary production capacity expansion comes largely from Canada, Australia (Olympic Dam adds 9,000 tU) and Kazakhstan
- ❑ Total “Existing & Planned” increase by 2015 is 18,000 tU over 2005 levels (50% increase)

ISSUES IN URANIUM SUPPLY - II

- ❑ WNA Reference Case assumes “Existing & Planned” volumes plus Jabiluka (4,500 tU) and about 3,000 tU additional in Kazakhstan – a total of 26,000 tU over 2005 production (70% increase)
- ❑ Forecasts assume new production equal to capacity but historical average is closer to 90%
- ❑ Substantial contributions come from secondary supply – 6,700 tU-equivalent in the WNA Reference Scenario

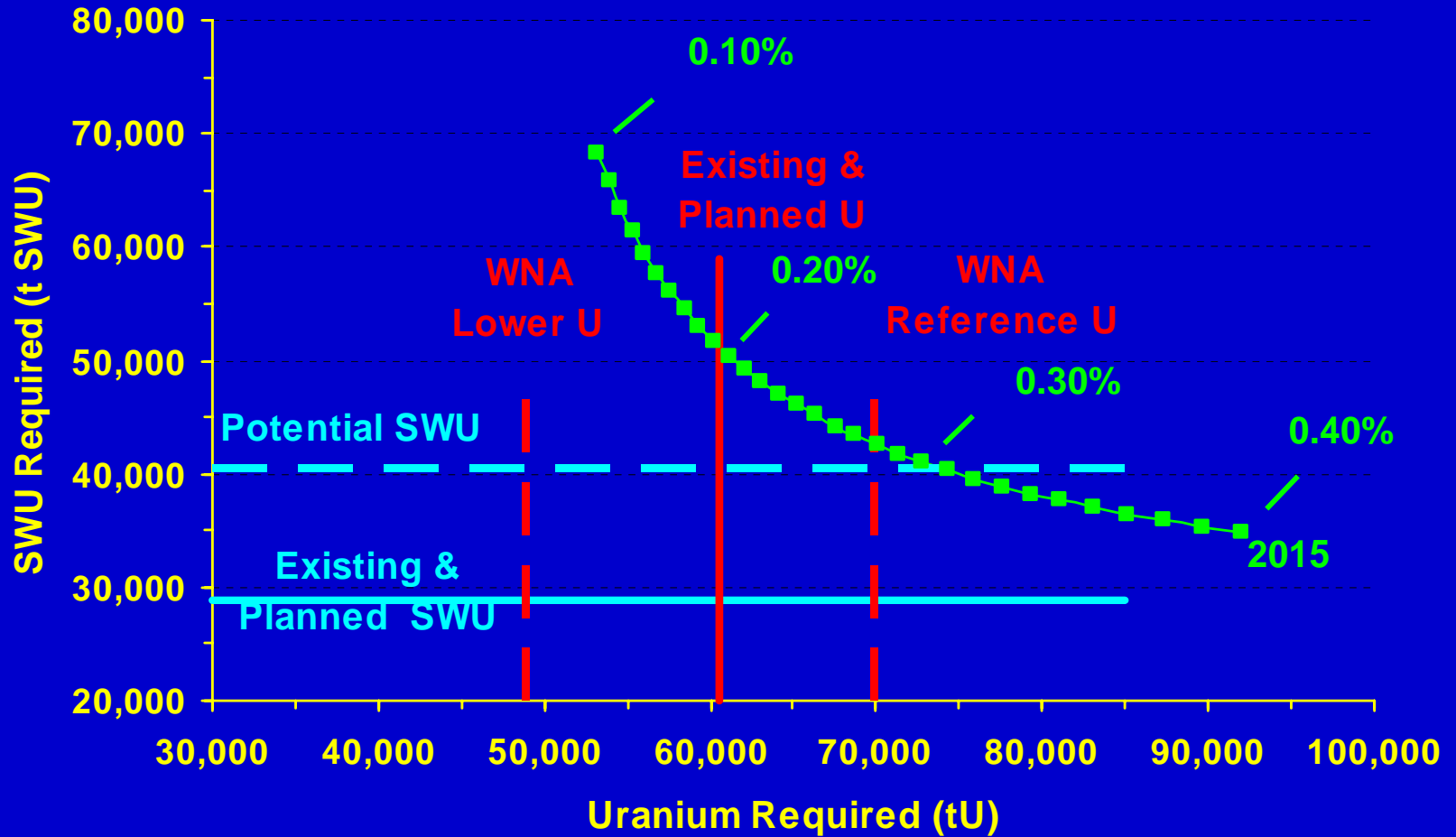
WESTERN REQUIREMENTS VS PROJECTED WESTERN URANIUM & ENRICHMENT SUPPLY CAPACITY



EXISTING & PLANNED URANIUM & SWU SUPPLY 2015

- ❑ Existing & Planned uranium and enrichment supply (including secondary supply) fall far short of meeting western requirements
- ❑ Need 22 million SWU more than planned western enrichment capacity, or 10.7 million SWU more than planned and potential additional enrichment capacity
- ❑ Lower uranium supply means tails assay would have to be 0.20%
- ❑ Higher uranium and/or SWU prices would be necessary to secure additional supply

WESTERN REQUIREMENTS VS PROJECTED WESTERN URANIUM & ENRICHMENT SUPPLY CAPACITY



WNA REFERENCE CASE URANIUM & SWU SUPPLY

- ❑ Assumed uranium supply would allow requirements for western reactors to be covered at 0.27% tails assay
- ❑ Requires 43 million SWU, or about 17 million SWU more than WNA primary western enrichment capacity
- ❑ Remainder would have to come from secondary supplies, Russia, continued operation of a GDP, or new plant

URANIUM AND ENRICHMENT PRICING IN ERA OF SCARCITY

□ In era of scarcity:

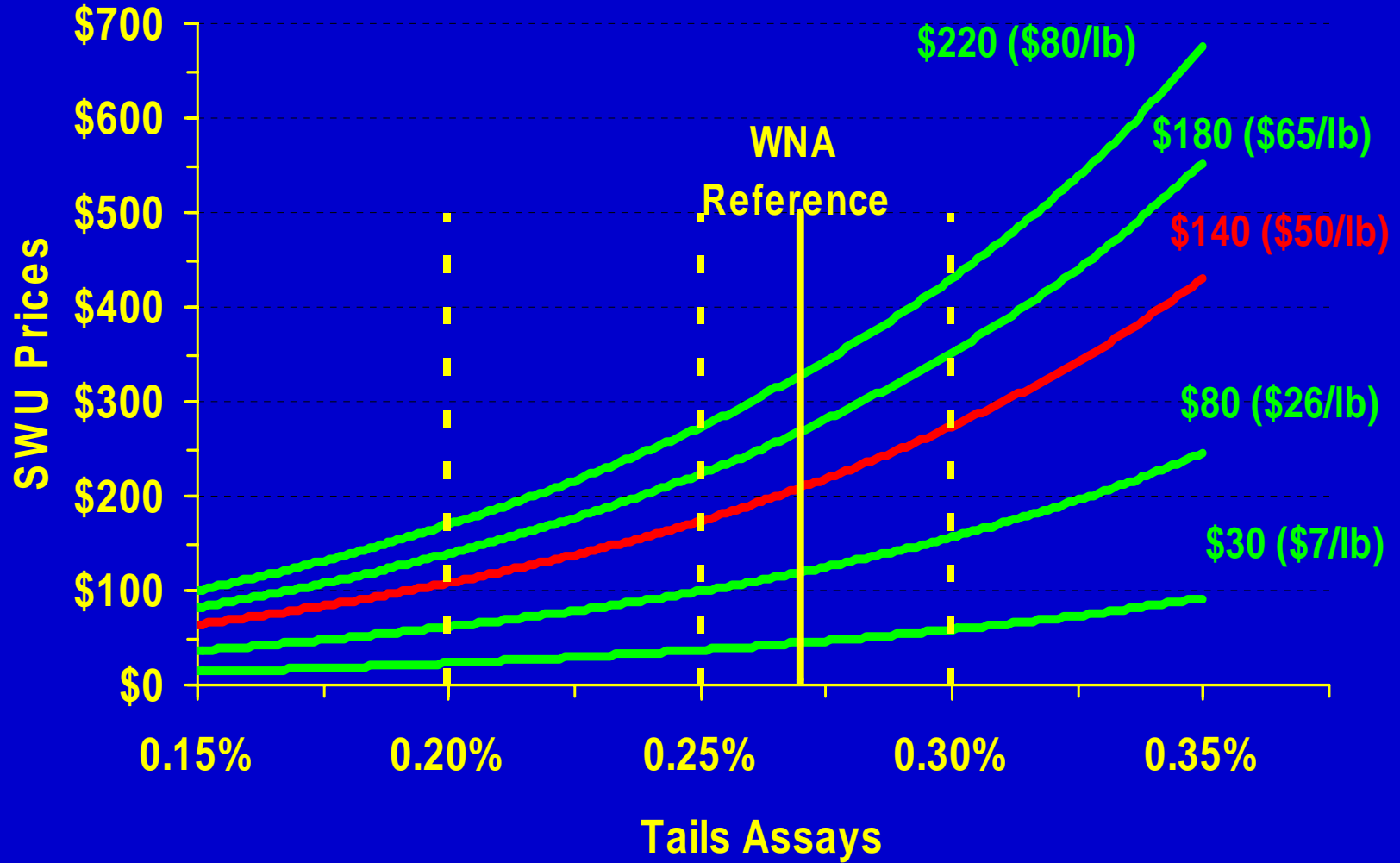
- Limited substitution between uranium and SWU
- Higher price for uranium or SWU results in higher price for the other.
- Market power shifts to suppliers: price and contract terms

□ Look at two cases:

- SWU supply constraints set *minimum* tails assay
- Uranium supply constraints set *maximum* tails assay

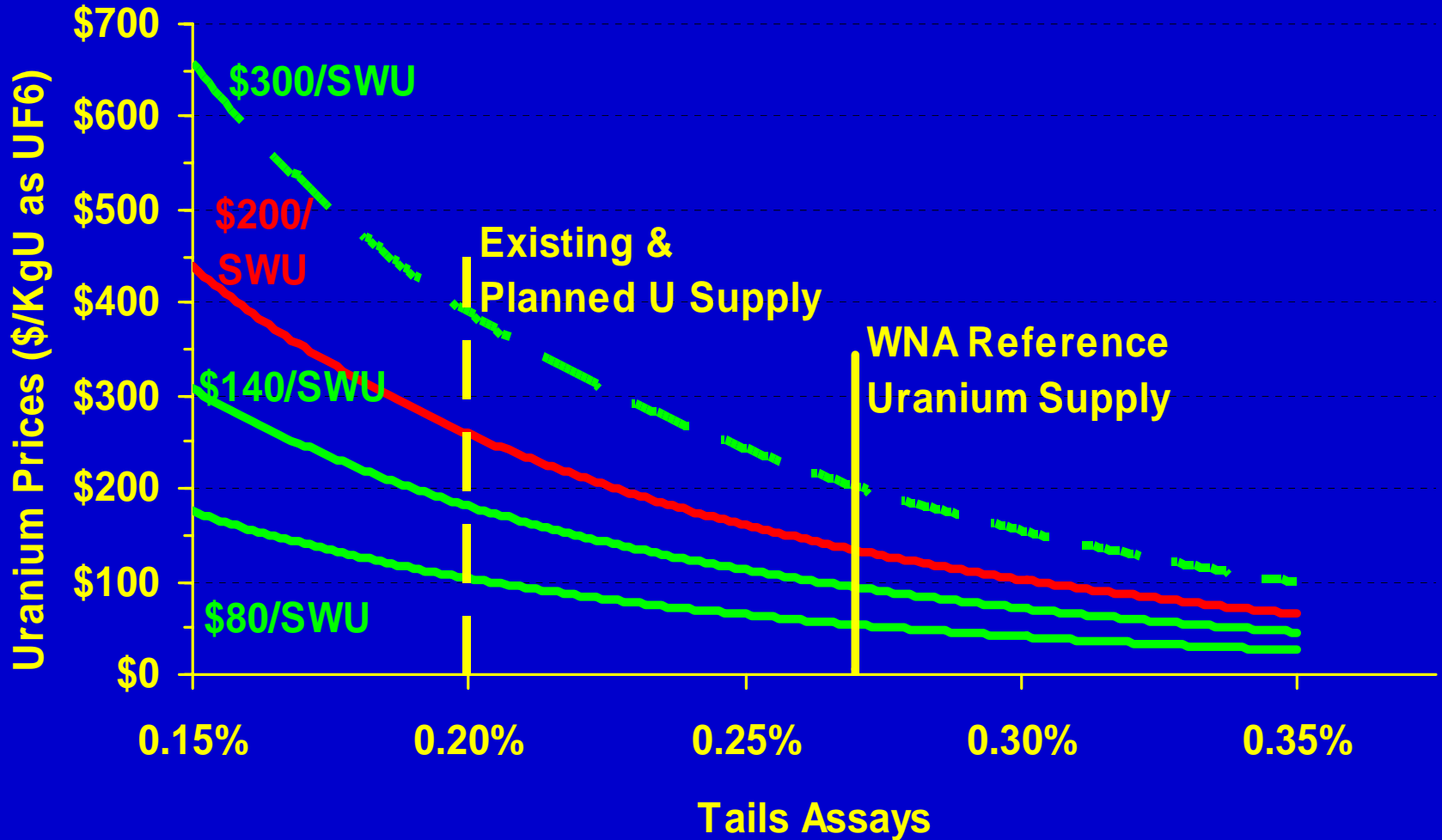
SCARCE ENRICHMENT SETS MINIMUM TAILS

SWU PRICE AS FUNCTION OF URANIUM PRICE



SCARCE URANIUM SETS MAXIMUM TAILS

URANIUM PRICE AS FUNCTION OF SWU PRICE



PRICE DYNAMICS

- **SWU supply sets minimum tails assay:**
 - Given a uranium price, enrichers can raise price to point that utilities seek to substitute more uranium for SWU (by raising tails assay)
- **Uranium supply sets maximum tails assay:**
 - Given a SWU price, uranium suppliers can raise price to point that utilities seek to substitute more SWU for uranium (by lowering tails assay)
- **If both uranium and SWU are scarce:**
 - Suppliers will compete for “scarcity rents” and price of both will rise

AN UNFORTUNATE COMPLICATION: LEGACY CONTRACTS

- ❑ Utilities with legacy enrichment contracts with low prices and tails flexibility will absorb SWU supply, limiting supply for others
- ❑ WNA Reference Case: 42,500 tSWU & 70,000 tU @ 0.27% tails
- ❑ Suppose half of utilities have legacy contracts and go to 0.20% tails – using 24,800 tSWU and 31,200 tU
- ❑ Other half of utilities use remaining 17,700 tSWU but have to enrich at 0.37%, using 43,100 tU
- ❑ But this results in need for 74,300 tU, a shortfall of 4,300 tU – drives up uranium price (and SWU price)