Considerations for and Barriers to Saudi Arabia's Development of Uranium Enrichment: A Commercial Perspective

April 12, 2018

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Intent is difficult to gauge and the purpose of this brief is not to speculate on the motivations for the Kingdom of Saudi Arabia's desire to retain its right to enrichment technology in nonproliferation agreements.[i]

Instead, we examine the commercial challenges the KSA will face should it decide to build enough enrichment capacity to supply its own fleet of reactors and/or supply enrichment services to the global commercial nuclear industry.

Currently, there is a widespread misconception that a U.S.-Saudi 123 Agreement that does not contain a "Gold Standard" provision--forswearing of enrichment and reprocessing by the Saudis--will somehow result in the immediate transfer of enrichment technology to KSA or the development of a Saudi enrichment capability overnight. This is hardly the case.

Commercial and Technical Barriers to Entry

The global enrichment market is indeed depressed, leading some observers to conclude that the development of any enrichment capacity, as it would supposedly be uneconomic for the foreseeable future, is an indication of nefarious purposes.

The flip side of the coin is that the depressed market outlook for uranium enrichment is also a powerful disincentive for current holders of enrichment technology to license or transfer such technologies to potential entrants, which would only create more competition in an oversupplied market.

There are many other barriers. In addition to the costs of construction, workforce training, supply chains, and infrastructure, challenges in the development of a conversion capability, a prerequisite to enrichment, have been virtually disregarded in this discussion.

The working assumption is that Saudi Arabia uses proven centrifuge enrichment technology owned and licensed by a globally recognized supplier that has passed nonproliferation, export control and Nuclear Suppliers Group muster for its domestic enrichment program.[ii]

It is unlikely that any company that owns centrifuge enrichment technology would be persuaded to license it under a technology transfer agreement to a competitor under any circumstances, let alone the depressed state of today's SWU[iii] market.

Since the Fukushima accident eight years ago, excess enrichment capacity and an accumulation of SWU and enrichment uranium product inventories have outstripped SWU demand, as reactors were permanently closed or idled for extended time periods and new build programs cancelled, ultimately leading to a collapse in SWU price, a dynamic that is forecast by experts to last until the late 2020s.

In 2010, the average long-term enrichment price was $156/SWU. By 2017, that price had plummeted by 73% to $42.92/SWU.[iv]

The cost of starting up an enrichment facility presents a formidable barrier. The price tag for enrichment plants rivals that of new nuclear build. The 4.8 million SWU/year URENCO USA plant in New Mexico cost $5 billion to construct, roughly $1,100/SWU, in a country where the commercial nuclear industry is mature.[v]

The figure does not factor in the cost of educating, training and recruiting personnel, establishing regulatory requirements, complying with international nonproliferation regimes and best practices, licensing, establishing supply chains and building infrastructure.

Significantly, it does not incorporate the billions in liabilities for managing depleted tailings and decommissioning/decontamination of old plants.

Nor does it provide for construction of conversion capacity, the most overlooked, underappreciated step in the nuclear fuel production process. Overcapacity and a low price environment in conversion has been a feature of the global front end market for decades.

But since 2011 the sector has been decimated, particularly for companies that sell conversion services separately from enrichment, and existing plants have slashed capacity or shut down indefinitely.

The 2010 long term conversion price in North America was $9.04/kgU and $9.75/kgU in Europe. Those numbers dropped to $5.30/kgU and $5.96/kgU, respectively, in 2017.[vi]

Here, too, it is hard to envision a future scenario under which a convertor would be willing to transfer the technology to a competitor.

<u>Current State of Competition</u>
Today, three enrichment companies dominate the global SWU market, URENCO, Orano (AREVA) and Rosatom.

Both Rosatom and URENCO deploy proprietary centrifuge technology. In 2003, URENCO restructured its centrifuge engineering, design and fabrication capabilities into a new company, Enrichment Technology Corporation.

In 2006, ETC became a joint venture between URENCO and Orano and currently operates as an independent company. It designs enrichment plants, provides project management for their construction, and manufacture, supplies and installs ultra gas centrifuges and pipework.

The firm is responsible for supplying technology to the world's two newest commercial enrichment plants, the 7.5 million SWU/year George Besse II located in France and owned by Orano, and the aforementioned URENCO USA plant owned by URENCO.[vii]

Three other countries have plans to deploy or expand indigenous enrichment capabilities. Fuel cycle companies in Japan and Brazil are continuing to develop modest domestic supply capability.

China, by contrast, is aggressively expanding all sectors of its nuclear power program, including enrichment. Current capacity is estimated at 5-6 million SWU/year which includes 1.5 million SWU of capacity using Russian supplied centrifuges. The remaining 4.1 million SWU capacity has been built using indigenous centrifuge technology.[viii]

China's latest five-year plan calls for a total domestic enrichment capacity of 9.0 million SWU/year by 2020, to keep pace with planned growth in nuclear generation.

In March it completed a large-scale demonstration project for a new generation of centrifuges. The new centrifuges have now been put into production at the Hanzhun fuel facility in Shaanxi province.[ix]

As China moves closer toward realization of its domestic nuclear ambitions it is turning its attention to overseas markets.

On the generation side, utility China General Nuclear owns 33% of the Hinkley Point C project, a two-unit EPR plant under construction in England. CGN is seeking certification for China's HPR1000 design for deployment in the United Kingdom, where the utility could build reactors at Bradwell.

On the supply side, CGN owns the massive Husab uranium mine in Namibia, which is working to ramp up to an annual production rate of 15 million pounds U3O8. China Nuclear Energy Industry Corporation, the marketing agent for China's enrichment operator, has sold small quantities of SWU into the U.S. market for several years.[x]

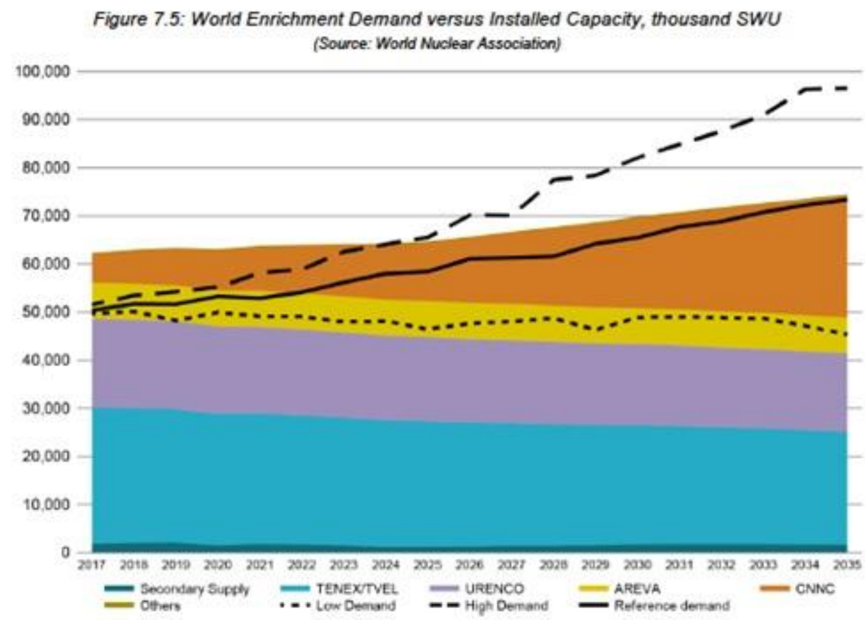
Market Forecast for Enrichment

At the end of 2016, estimated global SWU capacity totaled 60 million SWU, a figure projected to rise modestly to 63.4 million SWU by 2025. Most of that growth will be driven by China's current five year plan.[xi]

But global SWU requirements will continue to trail excess capacity. For 2017 the World Nuclear Association estimated demand of 50.3 million SWU. That figure is forecast to increase to 53.3 million SWU in 2020 and 58.4 million SWU in 2025, leaving 5 million SWU in excess capacity.[xii]

Utilities in member Euratom Supply Agency countries have nearly 100% of their SWU requirements covered under long term contracts for 2017. By 2021, the coverage rate reaches 109% before declining to 81% in 2025.[xiii]

The WNA has explicitly determined installed capacity until 2025; but if future demand requirements exceed SWU supply, "the supply gap should be readily met with capacity expansions from existing suppliers as needed" through 2035.[xiv]



That confidence is due to the quick modular expansion capability of centrifuge designs versus the long lead timelines for building new nuclear plants.

Given the bleak business outlook for SWU, over the past eight years, Orano cancelled the proposed Eagle Rock project, while URENCO slowed the expansion of the URENCO USA plant and decided not to replace older, less efficient or malfunctioning centrifuge machines at Almelo, Gronau and Capenhurst.

Experts believe that Russia may not be adding new capacity and allowing older centrifuges to die out without being replaced in order to reduce capacity by attrition.[xv]

This market dynamic has led the World Nuclear Association to conclude that any significant expansion of SWU capacity by enrichment companies will be inhibited until perhaps towards the end of the next decade.

As stated above, the exception to this rule is China, where it is assumed that capacity will continue to develop in line with projected domestic reactor SWU demand.

State of the Conversion Market

The global nuclear fuel market is served by five primary converters: Cameco, ConverDyn, Orano, Rosatom and China.

While the five own a combined nameplate capacity of 57,500 tU per year, because the facilities operate below that level, actual operating capacity hovers at 45,750 tU per year.

World requirements sat at 62,008 tU in 2017, moving up to 65,119 tU by 2020, 71,740 tU in 2025, 80,005 tU in 2030 and 89,696 tU in 2035.[xvi]

With demand dropping over the past six years, as reactors shut down or planned units cancelled, oversupply has led to significant inventories of secondary supplies that have been substituted for primary conversion production.

About 8,000 tU of secondary supply is expected to come from underfeeding and tails re-enrichment in 2017, a dynamic the WNA said, "highlights the impact of enrichment overcapacity on the conversion market. Overall, the total of secondary resources is equivalent to a medium sized conversion facility."

Construction of additional primary conversion capacity will be necessary only under the most optimistic demand assumptions through to 2035, or if an existing conversion facility is closed.

That risk is real. Citing the global oversupply of UF6, in November Honeywell idled production at the Metropolis conversion plant in Illinois. The company said it is "maintaining minimal operations to support a future restart should business conditions improve."[xvii] The move was preceded by cutting production capacity by 50% to 7,000 tU/year.

Meanwhile, Orano, which spent €610 million ($754 million) to expand and modernize its conversion facilities in 2014, halted production at the end of 2017 and plans to extend the stoppage until late 2018, despite nameplate capacity of 15,000 tU/year. It has an inventory of three years' worth of sales.

As with enrichment, China is building conversion capacity to meet its domestic needs.

Conclusions

Short of a black swan event or unanticipated disruption in supply, the outlook for the commercial nuclear fuel market over the next 10-15 years is bleak. Against that backdrop, the possibility that Saudi Arabia might receive outside help to develop fuel self-sufficiency in conversion and enrichment is small.

After 2035, however, it is difficult to predict with any certainty or credibility what the global enrichment market will look like. Much is predicated on the number of units that are deployed and whether the pace of construction can overtake the loss of demand that will result as reactors reach the end of their operating lives or are shut down prematurely. Considering this long-term uncertainty and the general length of U.S. bilateral nuclear cooperation agreements, Saudi Arabia's preference to retain rights to enrichment is, from a commercial viewpoint, not entirely untenable as some may claim.

The U.S. Energy Information Administration projects that global nuclear capacity will grow at an average annual rate of 1.6% from 2016 through 2040, led predominantly by countries outside of the Organization for Economic Cooperation and Development. China is expected to continue leading world nuclear growth, followed by India. This growth is expected to offset declines in nuclear capacity in the United States, Japan, and countries in Europe.

Assuming the required nonproliferation agreements are in place, Saudi Arabia's priority, of course, must be to comply with international requirements, meet commercial standards, and safely operate any reactors it builds. Although significant uncertainties remain, Riyadh is currently calling for a 17 GWe fleet.

Should the KSA achieve that plan and remain steadfast in its broader ambitions, the approach adopted by China in building a domestic nuclear industry may serve as a model.

China's self sufficiency across and up and down the nuclear supply chain is easy to justify: it has high projections for its domestic fleet and its conversion and enrichment plants have an assured market for their products. Excess capacity, together with reactor designs, is now being peddled overseas.

Given the longer-term outlook for world nuclear growth and the observed success of China's nuclear energy program, KSA's desire to not entirely close the door on enrichment during the length of a potential 123 Agreement with the U.S. can be regarded as defensible, even though there may be no justification (or credible pathway) to pursuing an enrichment capability in the immediate future.

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[i] However, should Saudi Arabia cite security of supply as its reason for retaining the right, an argument can be made from the facts contained in this brief that ample commercial enrichment capacity is available from a variety of suppliers and countries. It should be noted, too, that the International Atomic Energy Agency has established a Low Enriched Uranium (LEU) Bank as an assurance of supply mechanism of last resort.

[ii] Global Laser Enrichment LLC, a business venture owned by General Electric (51%), Hitachi (25%) and Cameco (24%), received in 2012 a construction and operating license from the U.S. Nuclear Regulatory Commission for a 3 million SWU/year enrichment plant using SILEX laser technology at GE's Wilmington, N.C., facility. A laser enrichment test loop was built there in 2009 and is still being operated as part of a commercialization program. In 2016, the U.S. Department of Energy signed an agreement with GLE that could lead to construction of the first commercial SILEX enrichment plant at Paducah, Ky., for the re-enrichment of DOE's DUF6 inventory.

[iii] The capacity of enrichment plants is measured in terms of separative work units or SWU. The World Nuclear Association describes the SWU as "a complex unit" which indicates the energy input relative to the amount of uranium processed, the degree to which it is enriched to U-235 and the level of depletion of the remainder, called the tails.
[iv] The Nuclear Review, TradeTech LLC, February 2018.
[v] According to URENCO, a 1,300 MWe reactor requires about 120,000 SWU per year and an enrichment plant with an annual capacity of 1 million SWU would be able to enrich the uranium needed to fuel about eight units.
[vi] The Nuclear Review, TradeTech LLC, February 2018.
[vii] URENCO USA has enough capacity to supply roughly 33% of annual U.S. SWU requirements, based on 99 reactors generating 99 GWe of electricity and requiring 15.5 million SWU/year.
[viii] The Nuclear Fuel Report: Global Scenarios for Demand and Supply Availability 2017-2035, World Nuclear Association, September 2017.
[ix] "China launches new uranium enrichment centrifuges," World Nuclear News, March 21, 2018.
[x] 2016 Uranium Marketing Annual Report, U.S. Energy Information Administration, May 2017.
[xi] 2017 WNA Report.
[xii] 2017 WNA Report Reference Case, based on a tails assay of 0.22% and forecast world nuclear capacity growth of 403 GWe by 2025 and 482 GWe by 2035. At mid-2017, world nuclear capacity was 391 GWe, including the idled Japanese reactors.
[xiii] Annual Report 2016, Euratom Supply Agency, June 2017.
[xiv] 2017 WNA Report, Figure 7.5.
[xv] 2017 WNA Report.
[xvi] 2017 WNA Report.
[xvii] Statement from Honeywell, November 20, 2017.

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