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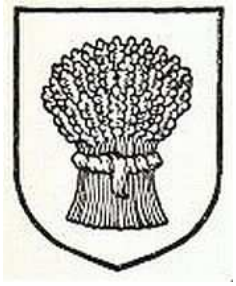

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Thinkpiece

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Nuclear Energy and Uranium in Argentina

The Logic of Vertical Integration

Nuclear & Uranium in Argentina

The Logic of Vertical Integration

+ The country has an aggressive nuclear expansion campaign, from an existing base of several reactors
+ Public opposition to nuclear power is almost non-existent and the country has an energy shortage
+ At least at first glance most U-mining could be done open-pit, which is cheaper but open-pit mining has gleaned opposition in the past in other metals in Argentina
+ Greens are small in number in Argentina and distant from the locations where uranium might be mined
+ The transition to the Macri regime in last year's elections could lower labour and other mining costs from their current high level
+ Argentina has been paying significantly more than the spot price for U supplies from Kazakhstan and Canada
+ Several Canadian Uranium explorers have soldiered on through the grim years of the post-Fukushima downturn and now have credible mining projects in Argentina
× Uranium's spot price remains in the doldrums

The Low-Key Nuclear Powerhouse

When we say Argentina is a nuclear power we are not referring to the club of those armed with bombs but rather the similarly small group of countries that generate electricity from nuclear power. Moreover unlike many of those in retreat from an activity they hate to need, Argentina without any fanfare has added a third reactor to its existing two reactors. Once again Argentina has shown it has the best infrastructure in Latin America. That the legacy of past investment is badly managed and frequently neglected is undoubted but the country has been ahead of the pack since the 1920s, received a mighty overhaul in the 1990s and has spent most of the last fifteen years backsliding (except in nuclear).

Argentina has also been active in nuclear power generation & research and uranium mining since the middle of last century. Some 10% of current electricity needs are met from nuclear power stations in the country. The *Comisión Nacional de Energía Atómica* (CNEA - Atomic Energy Commission) was set up in 1950 to oversee nuclear R&D, including construction of several research reactors. Currently, five research reactors are operated by CNEA and others. Another is planned, similar to the Opal reactor built in Australia by Argentina's INVAP. An example of the country's membership of the front ranks of nuclear technology nations is that Argentina's CAREM small modular reactor design is under consideration for massive desalination projects in Saudi Arabia.

The Power Program

The goal of Argentina's government (irrespective of political colour) is for nuclear power to be part of an expansion in generating capacity to meet rising demand. The government signed co-operation agreements with China and UAE and Argentina received a $240m loan from the development bank of Latin America to extend the life of an existing reactor.

Currently two nuclear reactors generate nearly 10% of the country's electricity and a third reactor has been taken down from operation for refurbishment. The backstory to these is that in 1964, the focus shifted to nuclear power, and following a feasibility study for a 300-500 MW unit for the Buenos Aires region, bids were invited. With the country's policy firmly based on using heavy water reactors fuelled by natural uranium, Canadian and German offers for heavy water designs were most attractive, and the offer from Kraftwerk Union was accepted. The 100% financing that came with the deal was a major attraction for the Argentine authorities.

That plant, known as **Atucha 1** was built at Lima, 115 km northwest of Buenos Aires, and entered commercial operation in 1974. It has a pressure vessel, unlike any other extant heavy water reactor, and it now uses slightly enriched (0.85%) uranium fuel which has doubled the burn-up and consequently reduced operating costs by 40%.

Embalse

In 1967, a second feasibility study was undertaken for a larger plant at Embalse in the Córdoba region, 500 km inland. In this case a CANDU-6 reactor from Atomic Energy of Canada Ltd (AECL) was selected, partly due to the accompanying technology transfer agreement, and was constructed with the Italian company, Italimpianti. The Embalse plant entered commercial operation in 1984, running on natural uranium fuel. In 2010, an agreement was signed to refurbish the plant to extend its operating life by 25 years and increase its power output by around 7%. It was for a long while running at about 80% capacity to limit neutron damage to pressure tubes. It has now been taken down for a refit.

The life of the Embalse CANDU-6 type plant will be extended by 25-30 years in partnership with Candu Energy Inc. This latter firm is a subsidiary of SNC-Lavalin Group which took over Atomic Energy of Canada Ltd reactor division in 2011.

Embalse's power output is being increased by about 35 MW under the latest plan. Contracts for $440 million were signed in August 2011, the main work was originally planned to commence in November 2013, with the reactor is due to be offline for about 20 months then, though the whole project will take five years. Total cost was put at $1.37 billion. The refit was delayed by the delays at Atucha 2's start-up.

Atucha 2

In 1979, a third plant – Atucha 2 – was ordered following a government decision to have four more units coming into operation in the period 1987-97. It was a Siemens design, a larger version of unit 1, and

construction started in 1981 by a joint venture of CNEA and Siemens-KWU. However, work proceeded slowly due to lack of funds and was suspended in 1994 when the plant was 81% complete.

Interestingly this coincided with the years in which the Menem administration was most vigorously privatizing electricity assets. To our memory we cannot remember the nuclear plants ever being proposed for sale. Certainly mothballing the new nuclear plant would have been good news for the newly minted owners of the thermal generators that the government had just sold.

In 1994, Nucleoeléctrica Argentina SA (NA-SA) was set up to take over the nuclear power plants from CNEA and oversee construction of Atucha 2.

In 2003, plans for completing the 692 MW Atucha 2 reactor (745 MW gross) were presented to the government. The Siemens design of the Atucha PHWR units is unique to Argentina, and NASA was seeking expertise from Germany, Spain and Brazil to complete the unit. In 2003, plans for completing the 692 MW Atucha 2 reactor (745 MW gross) were presented to the government. Completing Atucha 2 by 2010 was expected to cost US$ 600 million, including $400 million for heavy water.

The Neuquen heavy water plant completed production of 600 tonnes of heavy water in June 2012, and this was expected to be loaded around April 2013, after loading the 9.76 metre-long fuel assemblies, which commenced in December 2012.

Effective completion of Atucha 2 construction was in September 2011. On June 3, 2014 reached its first criticality, and on June 27, 2014 began to produce energy. On 19 February 2015, the plant reached 100% power production for the first time, increasing the percentage of nuclear power in Argentina's energy mix from 7% to 10%.

It is important to note that Argentina’s nuclear program currently sources its uranium supplies from Kazakhstan and Canada which is a strange situation considering that it has its own supplies in the shuttered CNEA mines and the prospects of potential uranium miners (principally Canadian) in Argentina.

Further Expansion

As mentioned earlier, in August 2006, the government announced a US$3.5 billion strategic plan for the country's nuclear power sector. This involved completing Atucha 2 and extending the operating lifetimes of Atucha 1 and Embalse.

A feasibility study on a fourth reactor has been undertaken, originally planned to start construction after 2010 with a US$2bn capex projected. In July 2007, NASA signed an agreement with AECL to establish contract and project terms for construction of a 740 MWe gross Enhanced CANDU 6 reactor, as well as completing Atucha 2. A further 740 MWe Enhanced CANDU 6 unit was proposed. The government began talks with reactor vendors from France, Russia, Japan, South Korea, China and the USA, indicating that its fourth and fifth reactors were more likely to be LWR type, with Atucha the most likely location.

Russia was offering two AES-2006 units, and China is offering 1000 MWe units. Areva claimed that its Atmea1 reactor was pre-qualified by NASA. A final decision on Atucha 3 & 4 was pending Atucha-2 completion and the refurbishing process of Embalse. In October 2012 the government said that Areva, China National Nuclear Corporation (CNNC), Kepco, Rosatom and Westinghouse were pre-qualified for tendering in 2013. In September 2014, the government signed an agreement with CNNC to conduct pre-project, design, construction, commissioning and operation of the new 800 MWe Candu 6 unit. Meanwhile, CNNC was to provide technical support, services, equipment and instrumentation under a $2bn long-term financing arrangement. In addition, China will also supply materials needed by Argentina to locally produce components for the unit.

CNNC operates two Candu 6 units at its Qinshan plant in China's Zhejiang province, which will be the reference plant for the new Atucha unit.

Scientific Development and Cooperation

In February 2010, the government signed an agreement with Russia's Rosatom to share technical information related to the construction of nuclear power plants and look at possibly using Russian technology in the country. In April 2010, a nuclear cooperation agreement was signed with Russia, and in September 2010, another was signed with South Korea. In May 2011 Rosatom and the Argentine planning & investments minister said they were discussing the possibility of joint development and construction of a 640 MWe reactor of unspecified type. In June 2012 the government signed a nuclear cooperation agreement with China, involving studies for a fourth nuclear power plant, financed by China, and a transfer of fuel fabrication and other technology.

Mention should be made of the CAREM-25 nuclear reactor, which has been developed by CNEA with INVAP and others, since 1984. It is a modular 100 MWt simplified pressurised water reactor with integral steam generators, designed to be used for electricity generation (27 MWe gross, 25 MWe net) or as a research reactor or for water desalination. As mentioned earlier, a CAREM plant is under consideration for desalination in Saudi Arabia.

CAREM has its entire primary coolant system within the reactor pressure vessel, self-pressurised and relying entirely on convection. Fuel is standard 3.4% enriched PWR fuel, with burnable poison (a neutron absorber that is incorporated in the fuel or fuel cladding of a nuclear reactor and gradually burns), and it is refuelled annually. The prototype will be followed by a larger version, possibly 200 MWe, in the northwestern province of Formosa by 2021. Recent studies have explored scaling it up to 300 MWe.

Another aspect of the 2006 plan was to build a 27 MWe prototype of the CAREM reactor, and this is still under construction, next to Atucha. Civil works next to the Atucha site were to start in 2012, the electromechanical installation was due in the first half of 2013 and fuel loading then grid connection in 2016 (now pushed out to the end of 2018). Some 70% of components were slated to be of local manufacture. A second CAREM plant is planned for the province of Formosa.

INVAP has built several research reactors for CNEA and international customers in Egypt (ETRR-2), Algeria (NUR), Peru (RP-0 & RP-10) and Australia (OPAL). Its first was RA-6, a 0.5 MWt open-pool multi-purpose research reactor designed by CNEA and inaugurated in 1982. It is located in San Carlos de Bariloche, Rio Negro, on the premises of the Centro Atómico Bariloche (CAB) belonging to CNEA. It is principally for training, and uses 20%-enriched fuel. RA-8 followed it and operated 1997-2001 in Pilcaniyeu, Río Negro, testing fuel enriched up to 3.4% and control rods for CAREM. It was an open-pool zero power unit.

All this goes to show that Argentina is not just a technology taker in this very sophisticated area but an innovator as well. Indeed the club of those with nuclear industrial capacity is very small indeed. The glaring absence at this point is primary mines within the country to source material.

Legal Framework

In 1994, the Nuclear Regulatory Authority (Autoridad Regulatoria Nuclear, ARN) was formed and took over all regulatory functions from the National Board on Nuclear Regulation (Ente Nacional Regulador Nuclear, ENREN) and CNEA. As well as radiation protection, it is responsible for safety, licensing and safeguards. It reports to the President.

It is useful we feel to go over what types of regulations cover this industry in Argentina.

Art. 205. – The nuclear minerals are regulated for this law as first and second class mines. The Atomic Energy Commission (CNEA) is in charge of the supervision and the provision of advice to provinces about uranium exploration and production.

Art. 206. – Uranium and Thorium are nuclear minerals

Art. 207. – The companies that exploit nuclear mines need to elaborate an EIA before any action. It is forbidden to sell or export nuclear product without CNEA and Government authorization.

Art. 208. – The owners of mines with nuclear minerals are required to inform the CNEA of reserves and production of these facilities

Art. 209. – CNEA will have the first option to sell the nuclear minerals

Art. 210. – The export of nuclear minerals and derivatives needs the CNEA approval, which shall guarantee the internal provision and final destination of the exported minerals

Art. 211. – CNEA may prospect, explore and produce concentrates of nuclear materials in accord with this law. CNEA will exploit or maintain in reserve of following mines: Doctor Baulies/Los Reyunos (in Mendoza Province) and Cerro Solo (in Chubut Province).

The Rest of the Argentine Nuclear/Industrial Complex

Having a domestic nuclear energy industry has also brought Argentina industrial spin-offs in the creation of various plants and technologies that otherwise the country would have no need for. In reviewing these ancillary services, it is glaringly apparent that the missing component is an actual mine capability. Amongst the industrial facilities is a 150 tpa mill complex and refinery producing uranium dioxide powder operated by Dioxitek, a CNEA subsidiary, which is located at Córdoba.

CNEA has a small enrichment plant at Pilcaniyeu, near Bariloche, Rio Negro province, with 60 t/yr capacity. Over 1983-89, INVAP operated a small (20,000 SWU/yr) diffusion enrichment plant for CNEA at Pilcaniyeu but this proved to be unreliable and produced very little low-enriched uranium. After this plant was mothballed enrichment services were imported from the USA.

In August 2006, the CNEA announced that it wanted to recommission the enrichment plant, using its own Sigma advanced diffusion enrichment technology which it claimed to be competitive. The principal reason given was to keep Argentina within the circle of countries recognised as having the right to operate enrichment plants, and thereby support INVAP's commercial prospects internationally. It was proposed to restart enrichment on a pilot scale in 2007 and work up to 3 million SWU per annum in three years. In 2010 the Argentine President inaugurated the recommissioning of the plant.

Production of fuel cladding is undertaken by CNEA subsidiaries. Fuel assemblies are supplied by CONAUR SA, also a CNEA subsidiary, located at the Ezeiza Centre near Buenos Aires. The fuel fabrication plant has a capacity of 150 tpa for Atucha-type fuel and Candu fuel bundles.

Heavy water is produced by ENSI SE (Empresa Neuquina de Servicios de Ingeniería), which is jointly owned by CNEA and the Province of Neuquén where the 200 tpa plant is located (at Arroyito). It is operated by Neuquen Engineering services, majority owned by the provincial government. This was rebuilt and scaled to produce enough for Atucha 2 and the three following reactors at a cost of about $1 billion, and so now has capacity for export.

There are no plans currently for reprocessing used fuel, though an experimental facility was operated in the early 1970s at Ezeiza.

Radioactive waste management

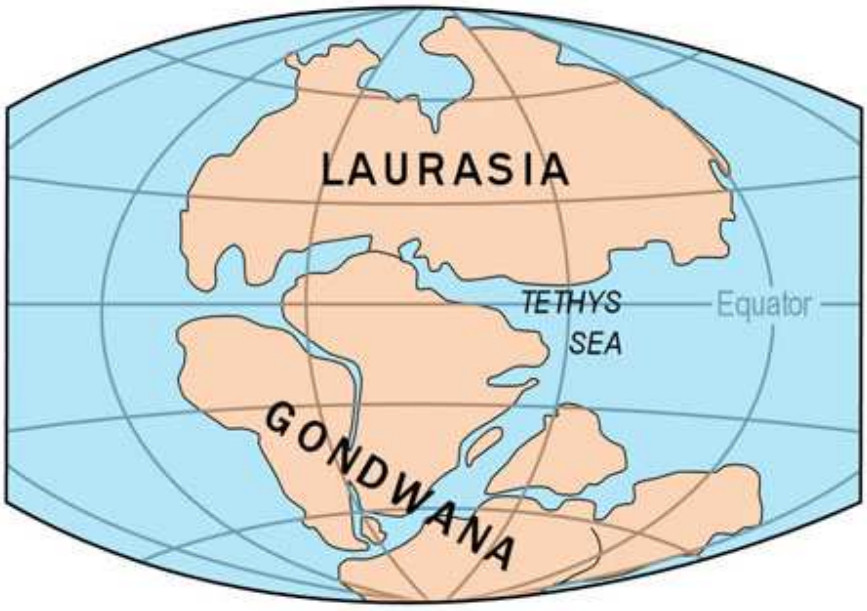
Under the guiding legislation for the sector, the National Law of Nuclear Activity passed into law in April 1997 the law assigns responsibility to CNEA for radioactive waste management, and creates a special fund for the purpose. The operating plants pay into this fund, even though they, like the CNEA, are owned by the government anyway.

Those wastes of low and intermediate-levels, including used fuel from research reactors, are handled at CNEA's Ezeiza facility. Used fuel is stored at each power plant. There is some dry storage at Embalse.

The CNEA is also responsible for plant decommissioning, which must be funded progressively by each operating plant, though as yet no plant has been decommissioned and one wonders how much money would really have been squirrelled away for this purpose in light of the past and present Argentine governments' propensity to raid the piggybank for ongoing budgetary needs (not to mention the regular wipe-outs for currency value from inflationary outbursts).

The Geological Perspective

The attractiveness of Argentina for uranium exploration has much to do with the historical background. By historical we are not talking recently but rather across the eons, in fact back to the break-up of Gondwanaland. In this process of continental drift the current continents of South America and Africa parted company, with Argentina being sheared off from Namibia. The state of Gondwanaland some 200 million years ago is shown in the map below.



Namibia was long famous for its diamonds but is now better known for its uranium deposits and it is with this geological history as a foundation that experts have posited that Argentina, particularly Patagonia, might share the uranium wealth that Namibia does.

Uranium Deposits

Argentine uranium resources listed in the International Atomic Energy Agencies' Red Book total only about 15,000 tonnes of U_3O_8, though the CNEA estimates that there is some 55,000 tonnes as "exploration targets" in several different geological environments. Uranium exploration and limited mining was carried out from the mid-1950s, but the last mine closed in 1997 for economic reasons.

Cumulative national production until then from open pit and heap leaching at seven mines was 2,509 tonnes of Uranium.

However, talk has circulated in recent years about reopening the CNEA's Sierra Pintada mine (also known as the San Rafael mine and mill) in Mendoza in the central west, which closed in 1997. Reserves there and at Cerro Solo in the south total less than 8,000 tonnes of Uranium. A resumption of uranium mining was part of the 2006 plan, in order to make the country self-sufficient.

The San Rafael Mine and mill is shown in the photograph above. The complex consists of:

- Open pit with 0.025%U cut off.
- 6,500 tU reserves.
- Stripping ratio 10/1.
- Average uranium grade: 0.076%.
- Bench height: 2.5m.
- 13.4 million m^3 of tailings
- 376,000 tonnes marginal mineral
- 2,500,000 tonnes of mill feed

There is also the unmined Cerro Solo deposit, likewise owned by the CNEA and located 15 km south of Bororo Nuevo and is reported to contain a historical resource estimate of 15.4 million pounds of U_3O_8.

Both Sierra Pintada and Cerro Solo projects face difficulties related to obtaining permits. Waste remediation is being carried out, or is under study, at former mining/milling sites. The efficient completion of remediation will be very important for obtaining social licenses for new production, as the social perspective on nuclear and mining activities is as controversial in Argentina as in other countries.

The Don Otto uranium mine is located in Salta in the far north of the country, and was the largest mine operated to date in that area, reportedly (Romano, 1999) produced approximately 479,000 t of 0.084% uranium between 1963 and 1981, although this total may include production from the nearby Los

Berthos Mine and possibly the Emmy Mine. Published government resource figures for the Tonco district (Romano, 1999) total 15.9 million tonnes at 0.035% U containing 5,630 t of uranium (0.01% U cutoff). In 2007, CNEA reached agreement with the provincial government of Salta to reopen the Don Otto uranium mine. At that time block leaching was envisaged as the extraction method.

Argentine Politics – the State of Play

The major event in the last year has been the change of government in Argentina. After nearly a decade and a half of irregular iconoclastic governments in Argentina ruled most recently by the dynasts of the Kirchner family, and before that the Duhalde regime, the country has returned to a certain orthodoxy with the election of Mauricio Macri as President in the last quarter of 2016. While not reinserting Argentine directly into the good books of mining investors it has certainly made thinking about the possibilities not being grounds for insanity. Amongst the measures taken so far that have enhanced the perspective for miners are:

- Lifted currency controls – devalued Peso may result in lower costs for project development
- Eliminated export taxes on concentrates and gold/silver doré
- Some import restrictions lifted – may allow better sourcing of equipment

These changes have removed the major bugbears of foreign miners operating in the country. This reopening has coincided with the Lithium boom which has placed Argentina at the centre of the action because of its ample supply of *salares* in its northwestern provinces. Hopefully a uranium resurgence will follow in its wake.

Farther Afield

Beyond Argentina there are regional possibilities, but these do not have the internal logic that Argentine uranium for uranium plants have. Brazil's nuclear power generation capacity consists of two pressurized water reactors, Angra I, with a net output of 637 MWe, first connected to the power grid in 1985 and Angra II, with a net output of 1,350 MWe, connected in 2000. Work on a third reactor, Angra III, with a projected output of 1,405 MWe, began in 1984 but was halted in 1986. Work started again in June 2010 for entry into service in 2015.

We learnt recently that Brazil's own uranium mine isn't sufficient to supply its newest reactor and thus the country will start importing uranium, which opens another ready market in South America for Argentine output. We would note though that Brazil has the sixth largest uranium reserves in the world and in light of the traditional Brazilian self-sufficiency policies, buying uranium from Argentina would at best be only a stop-gap measure.

Risks

Argentina now has a regime that is both pro-mining and pro-nuclear, a rare combination. Despite those positives we would note the following risks:

- Uranium prices remain mired in despondency with one camp feeling this is a cycle that shall not be broken
- Uranium production, even when conducted by the government, has attracted some opposition in Argentina in the past
- Financing remains a problem
- Some provincial governments are against open pit mining and maybe against mining of radio-active materials as well.

Much depends on the level of national sanction given to any given project by the national government. Mining by state interests in Argentina has been traditionally very poorly managed and massively loss-making. It also frequently involved pursuing low-grade deposits (e.g. coal and iron) for nationalist considerations. Thus it is no surprise that despite the resurgent nuclear power program the government has done little to reactivate the mines that CNEA has either exploited in the past or mooted as attractive for future exploitation. This means that the government, if it truly wants a vertically integrated industry, shall have to give its blessing to one of more of the foreign operators and that blessing (in light of the various carrots and sticks at its disposal) should cow (or should we say convince?) provincial governments into cooperation. This would mitigate then most of the potential internal opposition.

Conclusion

The followers of the uranium market are often likened to the Boy Who Cried "Wolf" because they have so often called the turn in the market in recent years and yet that has never manifested itself in higher prices or a return to the golden days per-2008/pre-Fukushima. But like the Boy they may eventually find they are right but no-one will have listened. Certainly the Russian program of converting weapons to energy fuels is nearing its end and certainly the number of nuclear plants, particularly in emerging economies is burgeoning. Certainly the Japanese are backtracking on their step away from nuclear power and yet the Germans are stubbornly sticking to lignite-fired generation over nuclear. All of these factors give enhanced strength to the arguments of the uranium bulls. Moreover the strongest argument bears currently have is "why isn't the price going up?"

Clearly Argentina is a natural market with an existing nuclear power plant fleet that is currently under expansion and yet no indigenous mine production of Uranium. What should be an ideal investing environment is clouded by the generalized negativism towards Argentina. This ongoing bad vibe, perversely, is justified by political and financial events but NOT by mining events because the government in Argentina remains pro-mining. It has long been the case that some provincial governments have followed a more erratic attitude to mining in their bailiwicks. So the ideal uranium development story in Argentina is one in a pro-mining province and at some distance from any substantial settlement (a good example being Rio Negro province). Few miners dabbling in the Argentine space though appear to have cottoned on to the possibilities presented by making themselves an integral part of the revived nuclear power program in Argentina.

Negotiating concessions and even obtaining funding (helped by giving the Federal government some

participation) could go some way towards mitigating the current hostility from capital markets towards funding uranium exploration ventures. A key factor though must be credibility, for as we have noted many uranium companies are as prone as Rare Earth companies were towards pursuing solely the concept of proving up a resource and not developing it, and that in no way moves the Argentine nuclear energy industry towards vertical integration. ONLY those intent upon development and production in the short term can hope to create a real dialogue.

The goal of this note is not to point out winners and losers but rather to illuminate to investors that in Argentina there is a real prospect of a self-supporting uranium industry evolving. There would appear to be a compelling logic for a coherent mine to generator vertical integration in the Argentine nuclear industry with the only thing lacking is a project advanced enough to capture the government (and CNEA's) imagination to make this happen.

Important disclosures

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