ANNUAL REPORT

MIDDLE EAST NUCLEAR ENERGY MONITOR: COUNTRY PERSPECTIVES 2018

Joy Nasr and Ali Ahmad

AUB POLICY INSTITUTE

Issam Fares Institute for Public Policy and International Affairs

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The Energy Policy and Security Program is an interdisciplinary platform that seeks to examine, inform, and impact regional and global energy sectors as well as security policies within the Middle East. Moreover, it closely monitors the challenges and opportunities of the shift towards alternative energy sources. With a seed grant support from the John D. and Catherine T. MacArthur Foundation, the program investigates the prospects of nuclear power in the Middle East and its potential to promote regional cooperation to address security concerns associated with the spread of nuclear power.

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EXECUTIVE SUMMARY

This report is the first edition of a yearly publication that examines the development and challenges of nuclear power projects in the Middle East. Nuclear power has become a reality in the region. The six nuclear power aspirants in the Middle East (Egypt, Iran, Jordan, Saudi Arabia, Turkey and the United Arab Emirates) are at different levels of commitment and progress towards establishing their civilian nuclear power programs (see Exhibit 1). The content of this report is largely based on interviews conducted by the authors with various stakeholders including government officials, industry insiders and experts. It provides detailed and up-to-date accounts on the status of the ongoing six nuclear power programs in the region.

In this inaugural report, the focus is on the bidding processes, the financing and stakeholder agreements, and the technology and fuel providers. As for fuel cycle activities, this report provides, when available, the status of activities for uranium exploration, mining, milling, conversion, fuel fabrication, reprocessing, and waste storage plans.

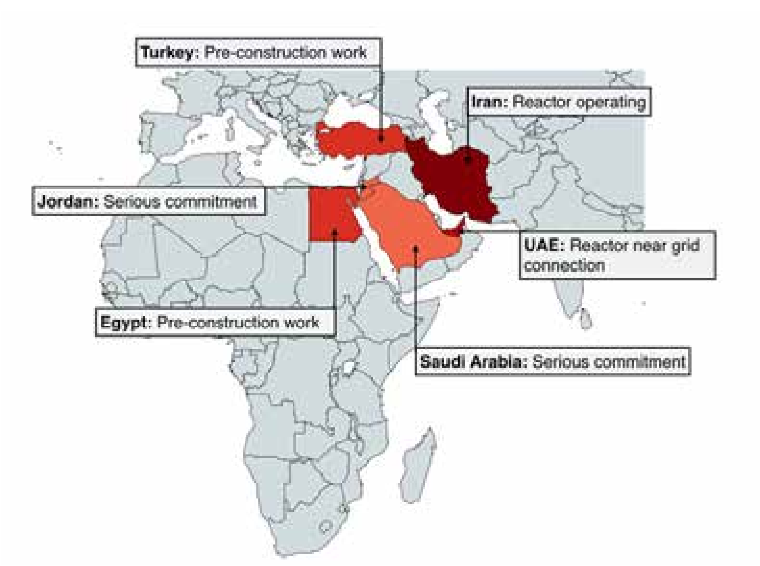

Exhibit 1: Status of national nuclear programs in the Middle East

Nuclear power capacity in the region can be divided into three categories: operational capacity where nuclear reactors are already generating power, committed capacity where plans to build nuclear power plants (NPP) are finalized, and planned capacity where plans to build NPPs exist but are not yet finalized. Exhibit 2 shows the distribution of these three categories across the region. Iran is the only country with an operational nuclear capacity of 1 GWe, committed capacity is currently at 15.2 GWe distributed between the UAE (5.6), Egypt (4.8) and Turkey (4.8). Jordan, Saudi Arabia and Turkey have ambitious plans to build NPPs but these plans are not confirmed yet.

A summary of the level of progress of nuclear power plans by country is provided below:

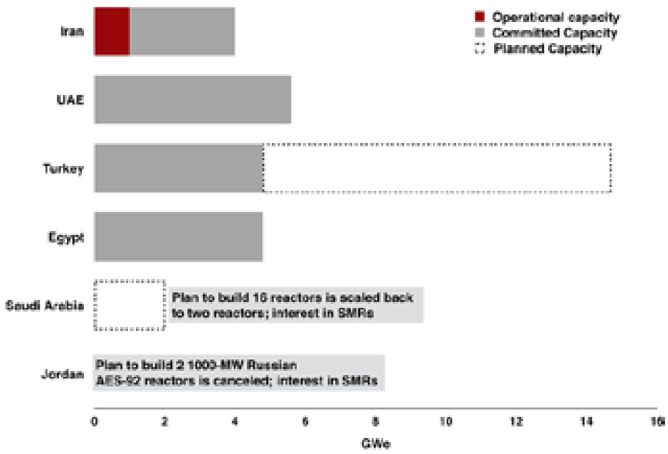

Exhibit 2: Nuclear power capacity in the Middle East

Iran

Iran has the most advanced nuclear energy and fuel cycle capabilities among the nuclear power aspirants in the Middle East, and its Bushehr I reactor is the only operational nuclear power unit in the region. Before the US withdrawal from the Iran nuclear deal (also known as the JCPOA), Iran seemed to be moving seriously with proposals for new NPPs other than units II and III planned to be added in Bushehr. For example, in July 2015, Iranian officials announced that China's CNNC agreed to build and finance two 100 MWe reactors of China's ACP100 design on the Makran coast, near the Gulf of Oman. However, there has been no progress on this proposal since then. It is unclear how Iran's deteriorating economic situation and the compounding impact of re-imposing US sanctions would influence these plans. While economic pressure may deter Iran from venturing into an expensive expansion of its nuclear power program, political pressure could backfire by pushing Iran to build more nuclear reactors as a response.

United Arab Emirates

The operation of the first unit of the Barakah nuclear power plant in Abu Dhabi is now expected to start by 2020, 12 years after the inception of the project. When all units are operational, the Al-Barakah plant will provide a total of 5600 MWe of power to the national grid. While construction appears to be on time, FANR, the UAE's nuclear regulator, did not issue the operating license to the project company until 2018, due to delays in the construction of the same reactor technology in

South Korea and which was supposed to be completed by 2016 so as to provide the needed operational track record before Al-Barakah unit I is completed. Reactor operation was further postponed as the delays in Korea further delayed the training schedule of the Emiratis, who were to use the Korean experience as guidance and training. The new start date has been pushed to 2020 to allow operators to complete further trainings and seek the necessary regulatory approvals.

Egypt

The Egyptian government is committed to adding nuclear power to its energy mix under the pretext of enhancing the country's energy security. The construction of Egypt's first nuclear power plant at the Dabaa site was supposed to start in 2016 but was delayed due to disagreements in the financing negotiations with Russians investors and due to emerging site suitability and compliance issues reported by Rosatom. The new start date is expected in 2019, now that the deal with Rosatom has been finalized. The total capacity of the Dabaa site will be 4800 MWe. Due to the nature of the deal with Rosatom and its fuel supply and take-back components, Egypt will have no need to develop uranium enrichment, fuel manufacturing and reprocessing activities. Moreover, Egypt's uranium mining activities are unlikely to progress because the claims of vast and profitable uranium reserves are not entirely substantiated. If the reserves prove not to be commercially viable, the current weakness of the global uranium market is enough to deter investors and companies from rushing to mine resources.

Turkey

The pre-construction works of Turkey's first nuclear power plant at Akkuyu started in April 2018. The Akkuyu project, if completed, will add 4800 MWe of nuclear electricity to the grid by late 2020's. Despite a recent withdrawal of Turkish investors, Russia's Rosatom seems committed to developing the project. This may be motivated by Russian geopolitical interests, as well as economic considerations – the Akkuyu project is

		Vendor	Vendor Country	MoUs / Short-listed	Active Agreements
Reactor Technology Suppliers	Large Reactor Suppliers	Rosatom	Russia	Saudi Arabia	Iran, Turkey, Egypt
		Westinghouse-SNPTC	United States-China	Turkey	
		Westinghouse	United States	Saudi Arabia	
		Areva-Mitsubishi	France-Japan	Saudi Arabia, Turkey	
		KEPCO	South Korea	Saudi Arabia	
	SMR Suppliers	CNNC	China	Jordan, Saudi Arabia, Turkey, Iran	
		CNEC	China	Saudi Arabia	
		INVAP	Argentina	Saudi Arabia	
		NuScale	United States	Jordan	
		Rolls Royce	United Kingdom	Jordan	
		X-Energy	United States	Jordan	
		KAERI - KEPCO	South Korea	Saudi Arabia	
Nuclear Fuel Services' Suppliers	Mining	WestWater	United States	Turkey	
		Rio Tino	United Kingdom		
		Uranium One	Canada		UAE
	Conversion & Enrichment	Areva	France		UAE
		URENCO	International		UAE
		Converdyn	United States		UAE
		Tenex	Russia		UAE

Exhibit 3: Nuclear fuel cycle suppliers in the Middle East

seen by the Russians as their own gateway to Middle East nuclear power projects. Turkey's other nuclear power projects, in Sinop and Igneada, are less certain and facing serious financing issues.

Saudi Arabia

Saudi Arabia's 2011 plan to build 16 large reactors of total capacity of 17 GWe has been shelved; instead, the kingdom is now interested in building two large reactors and two small modular reactors. In September 2018, Saudi Arabia short-listed Westinghouse USA, Russia's Rosatom, South Korea's KEPCO, and China's CNNC for its two large-scale reactors. However, there is no financing, contractual or technical model envisioned yet. On the SMR's front, the kingdom is in advanced stage with Korea's KAERI to perform feasibility studies on at least two SMART reactors of 100 MWe generation capacity for desalination.

Jordan

In June 2018, Jordan cancelled its first nuclear power plant joint venture with Russia, citing vast disagreements over the financing model and difficulty finding investors. Instead, the government is now pursuing MOUs with a variety of Small Modular Reactor (SMR) suppliers, as their financing is more likely and their lower power capacity is more suitable to the small Jordanian electricity grid. Feasibility studies are being conducted to build two Korean SMART SMRs with a total 220 MWe capacity at a cost around $800 million. Aqaba, on the Red Sea, is being re-considered as the site of Jordan's SMR plant, due to its proximity to industrial and transportation infrastructure. It is unlikely that any SMR deal will ultimately proceed without great support from the vending party.

IRAN

The Islamic Republic of Iran has the most advanced nuclear energy and fuel cycle capabilities in the region, having established its civilian nuclear program in the 1950's. Upon the signature of the Joint Comprehensive Plan of Action (JCPOA) between Iran and world powers in 2015, Iran's nuclear activities were throttled by the agreed restrictions (Samore, 2015). Despite the recent unilateral withdrawal of the United States from the JCPOA, and reinstating nuclear and economic sanctions on Iran, the agreement is still accepted by the International Atomic Energy Agency (IAEA), Iran and the remaining parties to the agreement.[1]

Iran has one operating reactor unit at Bushehr NPP, with plans to construct two more units on the same site. The Bushehr I unit was completed by Rosatom and connected to the grid in 2013. Iran has also signed agreements with China's CNNC for two more NPPs, at Darkhovain and on the Makran coast. While construction on unit I at Makran was originally expected in 2018, the project has not gone according to schedule and will likely be delayed, given the current political environment.

Bushehr Nuclear Power Plant

The Bushehr I unit was completed in September 2011 then loaded with fuel and commissioned in September 2013. The project experienced consecutive delays since it was restarted in 1995, and was almost cancelled entirely in 2007. This was largely due to Western concerns that Iran is operating a clandestine nuclear weapons program, later leading to disagreements with Russia over fuel supply and takeback (BBC, 2005).

After two years delay because Iran would not agree to return used fuel without being paid for it, an agreement was finally signed in 2005 for fuel supply and takeback.[2] AtomStroyExport (ASE) delivered the fuel assemblies on January 2008 and began loading them into the core of unit I in December 2010. Due to a technical problem with an old pump supplied in the 1970s, the fuel later needed unloading, and the reactor did not begin operation until September 2013 (Reuters, 2011).

The original agreement between Russia and Iran stipulated that the Bushehr NPP would be operated by a joint venture between ASE and the Atomic Energy Organization of Iran (AEOI). In 2010, it was agreed that this joint venture would perform the operator duties for three years, as ASE gradually withdrew from operation services. However, in September 2011, after grid connection, Rosatom announced it was handing over operation to Iran, as only a national company can be a nuclear plant operator under Iranian legislation (IAEA, 2015). As a result, in 2013, over 270 Russian employees were instead "invited" to come work as contractors in Iran for three years under the Nuclear Power Production and Development Company of Iran (NPPD). Those employees provided essentially all reactor equipment control and operation services, while training Iranians to take over operations. The agreement also included training in Russia for Iranian plant operators; Bushehr unit I today is run mostly by Iranians, with a continuous presence of Russian support staff (WNA, 2018; IAEA, 2018).

In November 2014, an agreement between Rosatom and AEOI was signed for the construction of four more VVER-1000 reactor units at Bushehr on a turnkey basis. While this agreement stipulates that most components and services are to be supplied by Iranian products, Rosatom will still supply the fuel and take it back to Russia for the lifetime of the reactors. Nonetheless, the agreement stipulates that both parties "work on necessary arrangements for the fabrication in Iran of the nuclear fuel or its elements to be used in Russian design units" (World Nuclear News, 2014). This will ultimately have to fall within the JCPOA restrictions until 2030, after which

1 The EU, China, and Russia have affirmed their intent on keeping to the terms of the JCPOA. The IAEA has continued to verify nuclear energy and fuel cycle activities in Iran, certifying that it is still in full compliance with the agreement's provisions. World Nuclear News, "Europe and Iran reiterate commitment to JCPOA," May 21, 2018, http://world-nuclear-news.org/Articles/Europe-and-Iran-reiterate-commitment-to-JCPOA

2 Iran's agreement to this has secured its fuel supply for the lifetime of the Bushehr 1 reactor unit, and a similar agreement will be expected for the remaining units, when they are commissioned. The United States insists that this takeback agreement is proof that Iran does not need to enrich its own uranium and can suffice from buying fuel on the market; Iran sees enrichment and fuel fabrication essential in the future when it expands its nuclear fleet. For more, see: Washington Post, "Russia to Provide Fuel for Iranian Reactor," Mar. 1, 2005, http://www.washingtonpost.com/wp-dyn/articles/A58619-2005Feb27.html??noredirect=on&noredirect=on; Council on Foreign Relations, "Russia's Nuclear Deal with Iran," Feb. 28, 2006, https://www.cfr.org/backgrounder/russias-nuclear-deal-iran

Iran can more freely develop its own enriched fuel.[3]

Also in November 2014, the NPPD and ASE signed a construction contract for units II and III at Bushehr, with two desalination plants part of the project (Rosatom Europe, Press Release, 2017). The units will be financed by Rosatom, as was unit I, while Iran gradually repays Russia the debt. The first stone for Unit II was symbolically set in September 2016, the initial excavation followed in October 2017. ASE successfully submitted a detailed contract of the reactor designs to NPPD in August 2018, and in September 2018, Iran and Russia announced at the IAEA that construction work on Units II & III had officially begun, and will be completed in 2024 and 2026 for units II and III respectively (NEI Magazine, 2018; Mehr News Agency, 2018; NuclearStreet, 2018).

It should be noted that with the recent decline in the strength of Iran's economy, devaluation of the Iranian rial, and the challenges of re-imposed sanctions, Iran might find it difficult to finance or commit to a large expansion of its nuclear program. However, the Iranians may have also pushed forward faster on Bushehr considering the US behavior as a symbolic measure signaling that Iran will not be economically or politically intimidated from pursuing its planned nuclear power projects.

Before the US withdrawal from the JCPOA, Iran was said to be moving seriously with proposals for new NPPs and nuclear desalination plants across the country. In 2011, the AEOI announced that a 360 MWe light water reactor is planned for Darkhovain, using almost only indigenous technology and design, adapted from Chinese technology (World Nuclear News, 2007). This project was originally taken up by China, who was pressured by the US to drop the deal at the height of the international sanctions campaign against Iranian nuclear activities. Increasing the project's controversy at the time was that the IAEA had requested design and construction information from Iran in 2007 and never received them, and Iran later submitted them after significant delays following a second request in 2009 (US Congressional Research Service, 2018, 7-8; IAEA, 2016, 17-18; IAEA, 2009; NTI; 2016). In May 2014, the AEOI reiterated its progress and commitment to this project (WNA, 2018). Similarly, the AEOI announced in July 2015 that China's CNNC agreed to build and finance two 100 MWe reactors of China's ACP100 design on the Makran coast, near the Gulf of Oman (Tasnim News, 2016). However, there has been no progress on this NPP proposal since then, aside from ceremonial MOUs and announcements; it is unclear how Iran's economic situation and the re-imposition of US sanctions will influence these plans.

Fuel Cycle Activities in Iran

Mining and Milling Infrastructure

Iran has modest uranium resources, and the resources that it does possess are not economically viable. Nonetheless, with difficulty securing uranium on the global market, Iran resorted in 2009 to mining the scarce uranium that it does possess, though the quantities produced were modest (WNA, 2018). What has fed Iran's centrifuges since their development has been the 450 tons of uranium that Iran purchased from South Africa in the 1980s (WSJ, 2011). Of which, about 366 tons have been converted into UF6 at the Isfahan Nuclear Technology Center since 2004 (Belfer Center, The Iran Deal, 2015).

Enrichment Capabilities

In 2000, Iran began building the Pilot Fuel Enrichment Plant (PFEP) aboveground at Natanz, but did not declare it to the IAEA until a dissident group identified the facility in 2002 (WNA, 2018). Also at Natanz is the underground Fuel Enrichment Plant (FEP). At the PFEP, two cascades produced low enriched uranium (LEU) up to 20 percent of U-235 for the Tehran Research Reactor (TRR). One cascade enriches from 3.5 to up to 20 percent U-235, while the second takes the tails from the first and enriches it to 10 percent LEU (Author interviews; WNA, 2018).

In August 2011, the AEOI confirmed that it had far more 20 percent LEU than it needed for the TRR, and, as a result, the IAEA required a full revision of the previous safeguards placed on Natanz (IAEA, 2011). In total, Iran had fed 1631 kg of 3.5 percent LEU to produce about 202 kg of 19.75 percent uranium at the PFEP from the beginning of operations in 2010 up until the JCPOA was signed in 2015 (Samore, 2015).

By 2006, Iran had 164 IR-1 centrifuges, locally developed from the Pakistani P1 centrifuge design. By 2009, Iran had developed and installed far more advanced centrifuge designs, such as the IR-2, IR-3, and IR-4. By November 2013, there were 164 IR-2m[4] centrifuges installed at the PFEP, with 178 IR-4, one IR-5, 13 IR-6, and one IR-6S.[5] The JCPOA forbids the use of these more advanced centrifuges for ten years

3 For a detailed primer on the limitations set by the JCPOA and their expiration timeline, see the Belfer Center for Science and International Affairs, "The Iran Deal: A Definitive Guide," Aug. 3, 2015, https://www.belfercenter.org/publication/iran-nuclear-deal-definitive-guide

4 For reference, the IR-2 is said to be about eight times more efficient than the IR-1, and the IR-8 about twenty times more efficient. Source: WNA Iran (2018).

5 For helpful infographics on Iranian fuel cycle capabilities and infrastructure pre- and post-JCPOA, see the Belfer Center for Science and International Affairs, "The Iran Deal: A Definitive Guide," Aug. 3, 2015, https://www.belfercenter.org/publication/iran-nuclear-deal-definitive-guide following implementation, except for minimal feeding into its newest IR-8 centrifuges as research for the TRR, fully within the restrictions of the JCPOA and under maximum monitoring.

Also in 2006, Iran was expanding the FEP at the underground level of the Natanz facility, installing up to 15,420 IR-1 by the time the JCPOA was signed in 2015. A total of 8271 kg of 3.5 percent LEU had been produced at the Natanz FEP by 2015, from which about 1557 kg were converted into 19.75 percent LEU.[6] Iran notified the IAEA in 2013 that it had installed 1000 of the new IR-2m centrifuges at the Natanz FEP, but they were never operational by the time the JCPOA was signed.

The Fordow enrichment facility was also developed in 2006, which, by October 2015, had 696 IR-1 centrifuges operating and enriching to 3.5 percent, at a rate of 10.6 kg per month. The Fordow FEP facility also allowed Iran to produce a further 246 kg of 19.75 percent LEU from the output and 1806 kg of 3.5 percent LEU. In total, until the JCPOA entered implementation, Iran had produced a total of 16,142 kg of 3.5 percent LEU, of which 3,437 kg were used to produce 448 kg of 19.75 percent LEU at the Natanz PFEP, Natanz FEP, and Fordow FEP.

Conversion & Fuel Fabrication

Isfahan is the site of Iran's uranium oxide production plant, converting UF6 to UO2. By November 2015, the facility had produced 2.3 tons of enriched UO2. The Isfahan center consists of a fuel fabrication plant, which produces the fuel plate assemblies for the Tehran Research Reactor.

6 The main concern for the international community was that this level of enrichment was 90% of the way to producing weapons-grade HEU, and, therefore, only a small clandestine facility would be needed to achieve the necessary weapons-grade enrichment level.

THE UNITED ARAB EMIRATES

The United Arab Emirates (UAE) began in 2008 a nuclear power project that is today heralded by the IAEA as the "golden standard" for nuclear newcomers. The UAE completely disavowed domestic enrichment and reprocessing capabilities to secure the South Korean reactor design with the support of the United States (UAE Government, "Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy," 2010). Under this arrangement, the UAE receives fabricated fuel-plates from KEPCO in South Korea, and all used fuel is returned to the vendor.

The project is a joint venture between the Emirates Nuclear Energy Company (ENEC) and KEPCO, with ENEC holding an 82 percent share in the project company (ENEC, Press Release, 2018). Korean operators will service the Al-Barakah NPP until 2030, when trained Emirati perthe sonnel are expected to take over (World Nuclear News, 2017). By September 2018, the UAE had finished construction of its first two of 4 Korean APR1400 reactors at the Al-Barakah site and has since begun safety and security testing. Unit I is scheduled for operation in early 2020, with the remaining units expected to go online in 2021, barring any delays in the testing processes.

Al-Barakah Nuclear Power Plants

After the creation of the Emirate Nuclear Energy Corporation (ENEC) as the nuclear promoter and the Federal Authority for Nuclear Regulation (FANR) as the regulator, the UAE conferred greatly to the IAEA and the US Nuclear Regulatory Commission in its site selection (World Nuclear News, 2018). Ultimately, Al-Barakah, between Abu Dhabi and Ruwais, was selected in 2009 due its distance from large population centers, proximity to existing electrical grids, industrial infrastructure, and large supplies of water (Nawah Company Website).

In July of 2012, the Al-Barakah site received final approvals from ENEC and FANR, and construction on Unit I began almost immediately. This was largely because the regulatory and legal framework was implemented in the early pre-project phase, so that by the time the contractual details with KEPCO were decided, the site and construction licenses were issued. Construction on Unit II shortly followed in May 2013 (NEI Magazine, 2013).

Construction on unit I was completed by June 2017. While construction was on schedule, and while the fuel plates had also made it to Al-Barakah on time, the FANR did not issue the operating license until 2018 to Nawah, the joint venture project company between KEPCO and ENEC. When KEPCO sold the APR1400 to the UAE in 2009, its newest reactor version had only existed as a design, and the first reactor of the new type was projected to go online in Korea in 2013. The plan was that this would give the UAE a few years to monitor the reactor in Korea and learn from its operators before it is commissioned at Al-Barakah. However, the Korean reactor was delayed and did not finish until 2016, and the FANR refused to issue the operating license regardless of the Al-Barakah construction timeline (Forbes, 2017). As a result, the project company, Nawah, had to wait until March 2018 to receive an operating license, and until May 2018 to begin fuel loading.

Reactor operation was further postponed as the delays in South Korea further delayed the training schedule of the Emiratis, who were to use the Korean experience as guidance and training (Reuters, 2017). The new start date was pushed to 2020 to allow operators to complete further trainings and seek the necessary regulatory approvals. Unit II will finish construction shortly afterwards and is expected to go online by 2021. The licenses for units III and IV were issued in September 2014, with construction starting a week later on unit III. Construction on unit IV began a year later in September 2014. As of the latest data from March 2018, unit III was about 80 percent complete, and unit IV was 67 percent complete.

Furthermore, a largely expatriate workforce is running the Al-Barakah NPP; it is common to have over ten languages being spoken on an operating floor, and, even though English is the official language on site, not all workers are fluent (Author interviews). As a result, communication and training between Western experts, Koreans, and Emirati labor, which includes vast amounts of immigrant labor from South Asia, has been slow (Author interviews). Managers familiar with the situation have complained that consolidating training across all languages spoken has been the most challenging aspect of these last safety tests and protocols in advance of commissioning (Author interviews).[7]

It should be noted that even under the "gold standard" and financial readiness of the Emiratis, the Al-Barakah NPP still took 12 years to be completed, from inception in 2008 to the expected grid connection of the first reactor in 2020. Additionally, it will have taken the Emiratis 22 years, until 2030, to be ready to operate the plant on their own.

7 *The authors conducted off-record interviews with a consultant from ENEC as well as with US policy experts in Washington, DC, familiar with the internal issues behind the delays experienced in the Al-Barakah NPP.*

The Bidding Process

Three companies were initially asked to submit a proposal: Areva with Suez and Total proposing the third-generation European Pressurized Water Reactor (EPR) which has since been plagued by cost overruns and construction delays (Bloomberg, 2017); General Electric and Hitachi proposing the third-generation Advanced Boiling Water Reactor; and a large South Korean consortium led by KEPCO proposing the APR1400 pressurized water reactor (WNA, 2018). The Korean consortium included Samsung, Hyundai, Doosan, and Westinghouse, whose operational design, the System-80, was adapted into the APR1400 by KEPCO. As a result, a US nuclear cooperation agreement needed to be signed with the UAE under Section 123 of the US Atomic Energy Act (1954).

On schedule, ENEC announced in December 2009 that the Korean consortium had been selected to construct four APR 1400 MWe units, citing the technology's demonstrated capacity, lowest construction costs, and shortest construction time among the bidders as main reasons for selection (The National, 2009). A variety of KEPCO subsidiaries would be involved: Korea Hydro and Nuclear Power Co. Ltd. is the engineering, procurement, and construction (EPC) contractor and operator until 2030, when the Emirati Nawah staff are expected to take over. Korea Power Engineering Co. Inc. will provide the plant design and engineering services; Korea Nuclear Fuel Ltd. will provide the fuel and manage its takeback; and Korea Plant Service and Engineering Co. Ltd. will handle maintenance.

The discount on the project was another competitive advantage cited as the reason for choosing KEPCO as the supplier. The bidding price, USD 24.4 billion, was in fact 20 percent below the industry average. However, it emerged in January 2018 that the former Korean President at the time of the deal's signing, Lee Myung-bak, who was sentenced to jail on October 8th, 2018, for corruption, had actually provided the Emiratis with a secret weapon and military protection deal in order to secure the Al-Barakah NPP deal (Korea Times, 2018), which was seen as a gateway for other nuclear newbuild projects emerging in the region.

The Emirati experience shows that even under the gold standard, transparency is quite difficult to achieve in nuclear power projects, simply due to the inherent political questions that they are tied to. It will not be uncommon for other countries in the region to seek out similar behind-the-scenes deals from vendors like Russia, South Korea, and the United States as vendors begin to reinvigorate their nuclear industry by signing nuclear newbuild deals with particularly large markets like Turkey and Saudi Arabia.

Nawah, The Al-Barakah Project Company

The Nawah Energy Company was set up in May 2016 to operate and maintain the four units at Al-Barakah, with 18 percent equity from KEPCO and 82 percent from ENEC (ENEC, 2018). As the initial proposal included Korea Hydro and Nuclear Power Co. Ltd. as the operator and contractor, the company signed a USD 880 million 'operating support services agreement' to provide ENEC with 400 qualified staff members to train Nawah employees up until 2030. Afterwards, Nawah is expected to take over operations. The same agreement included fuel supply for three four-year cycles of the four units (World Nuclear News, 2017).

The Barakah One Public Joint Stock Company (Barakah One) was set up in October. The company independently took over management of the USD 24.4 billion in project finances and will work as a long-term partner of Nawah, who oversees operation. Its mandate lists its priority as representing "the commercial and financial interests" of the project company, Nawah, and ensuring profitability and stakeholder interests. Under this arrangement, the Barakah One company sought to secure direct commercial loans worth USD 19.6 billion and managed equity funding for the remaining USD 4.7 billion between ENEC and KEPCO.

Financing was not an issue as most of the lenders are affiliated with the Emirati and Korean governments. The project company received USD 2.5 billion from the Export-Import Bank of Korea, and a maximum loan credit of USD 16.2 billion from the Department of Finance of Abu Dhabi (ENEC, 2016; WNA, 2018). Abu Dhabi is essentially lending itself the money for the project. Since the project was lauded as a 'gold standard,' and since most of the capital required for construction is guaranteed and available from the Abu Dhabi government, Barakah One was also able to secure USD 250 million in private commercial loans from a consortium of the National Bank of Abu Dhabi, the First Gulf Bank, HSBC, and Standard Chartered. This small amount was unnecessary, since either the Korean Import-Export Bank or the Abu Dhabi Finance Department could have easily added that amount to their billions in loans. However, this set of international banks was likely pursued for a symbolic capital contribution only to further the impression that the project is bankable, profitable, and well managed.

The electricity price and payback arrangements are still being finalized. However, this will not likely change the financing arrangement discussed above, as most of the financing is secured by a mix of debt and equity from the Abu Dhabi and Korean governments, and the contract stipulates a fixed-price arrangement for most of the debt repayment.

Fuel Cycle Activities in the UAE

As the UAE abandoned enrichment and reprocessing plans when it signed the US 123 agreement, it will have to be dependent on a variety of fuel supply contracts to secure fuel procurement and takeback. KEPCO Nuclear Fuels is currently in charge of delivering and taking back the fuel; however, the UAE seems interested in developing a regional nuclear waste disposal site in the future (ENEC; The National, 2014). So far, the UAE's intentions for front-end of the fuel cycle are much clearer than those for the back-end.

Right after the construction licenses were issued for units I and II of Barakah in July 2012, ENEC awarded six different kinds of contracts to secure its nuclear fuel supply chain, starting with a mix of enriched uranium product and separate supplies of natural uranium concentrates, in addition to their conversion and enrichment services.

The supply of uranium concentrates will be supplied by Canada-based Uranium One, UK-based Rio Tinto, France's Areva, and Russia's Techsnabexport (Tenex); conversion services will be performed by USA's Converdyn, Tenex, and Areva; and, enrichment will be through Urenco, Areva, and Tenex. Details on the differences between these offers are unclear; Areva claims its contract is worth around $500 million in enriched uranium supply, while Tenex claims to have secured half of the Barakah NPP's supply. Either way, the enriched uranium will be delivered to KEPCO Nuclear Fuels to manufacture, deliver, and install the fuel assemblies.

One reason for this diversified approach could be that it is more financially sound for the project company to diversify its supply, both in terms of risk aversion as well as taking advantage of a collection of offers available. Another could be because the UAE has already signed nuclear cooperation agreements with all these countries and is giving the other bidders a piece of the cake to maintain strong relations with all different providers.

As for nuclear waste, the UAE's short-term plan is to store its irradiated fuel in spent fuel ponds for 20 to 30 years. The UAE is still working on a long-term waste disposal strategy, but it still maintains the intention to develop an in-country regional nuclear waste disposal site by the time the spent fuel is cooled, or likely in the future when regional demand exists. (ENEC; author interviews). Under the current agreement, the ownership of and responsibility for the used fuel will be transferred to a newly formed state entity after around 20 years. This is envisioned as part of a "dual track" nuclear waste management strategy that involves developing a national storage system in parallel with exploring regional cooperative options along the lines of European precedents (The National, 2015).

The UAE faces three main options in developing a long-term nuclear waste strategy. First and most preferred by the UAE is a GCC regional nuclear waste storage and management facility, which the UAE hopes can serve its Arab neighbors, given the interest in nuclear power in the region. The Arab Atomic Energy Agency is already discussing such an option with a diverse group of MENA countries (Rosner et al., 2015), and given that the UAE has been the most serious and dependable in its nuclear commitments, it is a safe assumption that the UAE be considered a leading partner in this initiative, if it is ever realized. Second, the UAE is considering shipping the cooled fuel to Sweden's SKB permanent storage facilities (WNA, 2018). Sweden, in fact, possesses one of the only permanent solutions to nuclear waste, a 500-meter underground depository that is available for use by other countries (International Energy Organization). Third, the UAE has the option to sell its used fuel for reprocessing by Areva or Rosatom. This is unlikely as the global uranium and nuclear fuel market is already over-saturated, meaning large-scale enrichers like France, Russia, and China are looking to get rid of their stocks rather than enlarge them (Melissa Mann and Andrea Jannetta, May 15, 2018, conversations with authors).

EGYPT

Egypt's plan to build a nuclear power plant at El-Dabaa site was initiated in 1984. However, the project was suspended twice, the first time as a reaction to the 1986 Chernobyl accident, and the second time due to the Egyptian revolution in 2011 (NTI, 2014).

Today, the new Egyptian government has restarted the El Dabaa NPP project of four 1200 MWe reactors and, in December 2017, signed an agreement with Russia to officially launch work on the first two AES-2006 units (World Nuclear News, 2017). Construction is set to begin in 2020 for the first unit, with commercial operation expected in 2026.

The El-Dabaa Nuclear Power Plant

As of now, the Dabaa NPP will be built and mostly funded by Rosatom, the Russian state-owned nuclear reactor supplier. The NPP will consist of four AES-2006 units, producing a total 4800 MWe in electrical output. Egypt also intends to also use the units for seawater desalination (EgyptToday, 2017). However, information obtained from sources close to Rosatom speak of site suitability and compliance issues that may delay the project further.

Egypt did not have an open bidding process and opted to talk directly with Rosatom, who effectively was the only technology provider ready to invest in the Egyptian project, due to Egypt's inability to pay and dependence on the vendor bankrolling the project. Such demands seemed to fit in with Rosatom's business model (according to authors' interviews with Washington energy policy experts and staff at the Egyptian Nuclear Power Plants Authority).

The first memorandum of understanding (MoU) between Egypt and Russia was signed in November 2015 and included fuel supply, fuel takeback, training, and development of a regulatory infrastructure (World Nuclear News, 2015). At that point, the parties had hoped construction would begin in late 2016, but disagreements over financing emerged (WNA, 2018). A financing agreement for a Russian state export loan was first signed; it covered 85% of the total construction costs and set repayment to commence at commissioning of the last reactor for 22 years and at an annual interest rate of 3% (Ahram Online, 2017). However, Russia was unwilling to wait until the project completion and pushed for payments to begin when the first reactor is expected to go online (according to authors' interviews with staff in the Egypt Nuclear Power Plants Authority).

The Russian argument is that the Dabaa reactors are expected to have already generated $17 billion in sovereign revenues for the Egyptian government by the time the project is complete (Ahram Online, 2017), and that those profits should be used to begin payback. Moreover, a power purchasing agreement has also not yet been finalized. It is most likely, however, that Egypt will sell the electricity at a fixed-price arrangement as it repays the debt to Rosatom, as is standard in this financing and contractual model.

Fuel Cycle Activities in Egypt

In 2013, Egypt's Nuclear Materials Authority (NMA) stated the government's long-held claims that the country is home to vast uranium ore deposits around the Red Sea and Sinai region (UNECE, 2015). In 2015, the government opened an international bidding process for exploration and mining companies to explore at least three of the most promising uranium deposits; no news has developed from this process since. This could be due to Egypt's reserves being less economically viable than marketed by the government. If the reserves prove not be commercially viable, the current weakness of the global uranium market is enough to deter investors and companies from rushing to mine resources.

Additionally, it is not clear how would Egypt use its uranium resources domestically, especially with no intention to enrich uranium and in light with the fuel supply agreement with Rosatom for the lifetime of the Dabaa NPP. Supplying fuel services and taking it back is an integral part of Rosatom's business model.

The Egyptian government signed a cooperation agreement with Saudi Arabia on uranium exploration with the hope of one day establishing a regional mining and milling facility (Ahram Online, 2017). Egypt does not have any conversion or enrichment capabilities, though it once operated a reprocessing and fuel fabrication lab for a now-deactivated Russian research reactor built in 1961.

TURKEY

Turkey started the pre-construction phase of its first nuclear power plant in April 2018 (IAEA, 2018). Russia's Rosatom will be building the Akkuyu power plant, around 500 kilometers from Ankara on the Mediterranean Sea. The other two NPPs at Sinop and Igneada, however, remain as memoranda of understanding, with no financial or contractual models secured yet.

The Akkuyu Nuclear Power Plant

The Akkuyu plant consists of 4 units of the Russian VVER pressurized water reactor technology, the AES-2006, for a total of 4800 MWe (IAEA, 2018). The project company, Akkuyu Nuclear Joint Stock Company, is owned entirely by Russian equity under a Build-Own-Operate (BOO) model that includes fuel take-back and envisions a fifteen-year payback period to investors, after which the electricity will be sold on the open market, with Turkey receiving 20 percent of the profits (Karaduman, 2015).

The two sides, however, have been having trouble finding strategic investors. Recently, a Turkish consortium of investors expected to purchase 49 percent of Rosatom's stock in the Akkuyu project company pulled out citing various financial disagreements with the Russians (Karaduman, 2015). It is unclear this early on whether the Akkuyu NPP will finish on schedule. The Turkish economy was already weak and stretched too thin at the inception of the project in 2006; in fact, financing difficulties led to the failure of the first two attempts to build nuclear power plants in Turkey (Ayden, 2018). Nonetheless, one distinct characteristic of the Akkuyu NPP is the seriousness of the Russian support it is receiving, both financially and politically. This seems to be motivated by both Russian geopolitical and economic interests – the Akkuyu NPP is seen by the Russians as their own gateway to Middle East nuclear power projects[9].

The Bidding Process

While the project did not commence construction until mid-2018, the bidding process for the current Akkuyu NPP goes back to a failed 2006 plan for a similar plant at Sinop,[8] to be built by Atomic Energy of Canada Ltd (AECL) (Ayden, 2018). The Turkish Atomic Energy Authority (TAEK) envisioned the 4800 MWe plant to be online by 2015 and under joint public-private ownership. Discussions had already been underway with AECL to build a 1500 MWe CANDU plant as an initial investment in the project. That project was then moved to Akkuyu as the site already had a license from 1976.[9] The project was scrapped altogether afterwards as TAEK could not find suitable Turkish and foreign investors in the project (Ayden, 2018).

As a result, the Turkish Electricity Trade & Contract Corporation (TETAS) launched a tender process in March 2008 for an NPP at Akkuyu, calling for bids for Pressurized Water Reactors (PWR), Boiling Water Reactors (BWR), and Pressurized Heavy Water Reactors (PHWR) types with at least 600 MWe generation output and a 40-year lifetime. A main requirement in the tender was for foreign vendors to take back used fuel (WNA, 2018). While 14 parties submitted expressions of interest in the Akkuyu NPP, only Russia's state-owned AtomStroyExport (ASE) was prepared to offer a fuel take-back proposal (World Nuclear News, 2010). Therefore, the only bid received on Akkuyu was from Rosatom; the bidding process was moot.

After some delay in the decision process due to disagreements on electricity prices in ASE's bid, TAEK and Rosatom finally signed two agreements in August 2009, a nuclear cooperation agreement and an agreement on the exchange of information on nuclear facilities and nuclear accidents. The Turkish government hoped to secure 25 percent equity to take less debt at high interest rates, thus offsetting the high electricity prices (WNA, 2018). Under this plan, the first unit was to come into service in 2016, with the remaining three consecutively until 2019. In November 2009, the Turkish high court issued an order citing that the TAEK-Rosatom contract was unconstitutional as TAEK did not receive the necessary approval from the population living in proximity to the plant, Rosatom had not yet submitted an environmental impact assessment, and identified problems with the electricity pricing scheme (Reuters, 2011). As a result, TAEK cancelled the contract without providing justification, stating that a new bid process would be launched soon. However, TAEK bypassed the tender process altogether and proceeded directly into another agreement with Rosatom (WNA, 2018). In May 2010, the Russian and Turkish heads of state signed a $20 billion intergovernmental agreement for Rosatom to build, own, and operate four 1200 MWe reactor units of the AES-2006 technology (NYT, 2010).

Financing of the Akkuyu Project Company

Under a BOO model for the Akkuyu NPP, Rosatom will

8 Early in 2006, various site characterization and feasibility studies confirmed that Sinop is a more efficient location for a NPP, as its cooling water temperature is on average 5 C lower than that at Akkuyu, allowing for a 1% increase in electric efficiency. As a result, in 2009, after the new bidding process for the first NPP at Akkuyu was complete, Turkey already had a site selected and feasibility studies concluded for its second proposed NPP at Sinop.

9 This goes back to Turkey's first nuclear power plans in 1970. Later in 1976, the Akkuyu site was licensed for a nuclear power plant without much due diligence in the site selection. In 1989, plans were cancelled as the government could not find a financial guarantee for the project.

finance the plant with 100 percent equity in the project company, with Rosatom Overseas owning a 65 percent stake and its subsidiaries sharing the remaining (WNA, 2018). In the long-term after the plant has been repaid, Russian subsidiaries intend to retain 51 percent of the project company and sell the remaining shares to strategic investors.

While the Akkuyu Nuclear JSC was registered with full Russian equity, up until construction, Rosatom was still looking for a non-Russian investor to take up 49 percent of shares (WNA, 2018). In June 2017, a consortium of three Turkish companies signed an agreement with Rusatom to purchase the shares: Cengiz Holding, Kolin Construction, and Kalyon Construction would each receive a 16.33 percent stake. However, in February 2018, the consortium pulled out of the contract, citing a failure to reach a final deal with Rosatom (AA Energy, 2018). As a result, the project company remains under full Russian equity, while investors are still sought.

The Power Purchasing Agreement & Fuel Supply

In the current BOO contract, TETAS will purchase 70 percent of the electricity generated by units I & II and 30 percent of that by units III & IV for the first fifteen years of service, the period through which each unit is expected to be repaid. The remaining electricity will be sold by the Akkuyu Nuclear JSC on the open market, with full profits returning to the Russian shareholders until the fifteen-year debt repayment is complete. Afterwards, the Turkish government will receive 20 percent of the profits of the project company, and shareholders will divide the remainder (Daily Sabah, 2018). Rosatom will supply the fabricated fuel plates and take-back used fuel, thereby securing the fuel supply chain for the sixty-year lifetime of the reactor.

The Sinop Nuclear Power Plant

Plans to set up an NPP at Sinop, on the Black Sea, go back to the early days of Turkey's nuclear program (Ayden, 2018). However, it was not until 2008 that preparatory work began on the site, in addition to a project for a EUR 1.7 billion nuclear technology center. In May 2013, by the time the feasibility studies, site permits, and licensing were complete, Turkey had signed an informal agreement with a Mitsubishi-Areva consortium for the construction of four Atmea1 reactors, totaling a capacity of 4600 MWe (World Nuclear News, 2017). These would be the first of their kind to be built. The bid was officially accepted in April 2015 (Engie, Press Release, 2015). The Japanese-led public-private consortium, however, is reported to be set to abandon the Sinop project because the delayed project's construction costs have ballooned to around $44 billion, nearly double the original estimate, making it difficult for lead builder Mitsubishi Heavy Industries and its partners to continue with the plans. Most likely reason that Turkey chose the expensive and untested Atmea1 reactors over Rosatom's is Turkey's need to diversify its suppliers in a continued effort to promote energy security as part of the country's future energy strategy (according to the website of the Turkish Ministry of Energy & Mineral Resources: Turkey's Energy Strategy). A second possibility is that after securing the low-hanging fruit – the Rosatom reactor – Turkey may have been interested in more prestigious options from Western suppliers, in line with one of its rivals, the UAE's Korean reactors. In all cases, it is still unclear how the Sinop project will proceed, if at all.

The Bidding Process

Turkey's plans at Sinop started on a rough track, with various withdrawals driven by uncertainty in the global nuclear and financial market of 2008. The first provider interested in Sinop was the Korea Electric Power Corporation (KEPCO), which signed an agreement with Turkey to submit a tender for four APR-1400 reactors. KEPCO was to take 40 percent equity in the plant company and would help with financing the remainder However, the process fell through on KEPCO's insistence on receiving electricity sale guarantees from the government and ministry directly, rather than from the Turkish Electricity Trade & Contract Corporation, TETAS, as was being done at Akkuyu. The Turkish government was unable to offer such guarantees at the time due to its own difficult economic circumstances (WNA, 2018).

In 2010, Japan prepared to submit a proposal for a 5600 MWe NPP using four 1350 MWe Advanced Pressurized Water Reactors (APWR). The proposal was expected in March 2011. When the Fukushima Daiichi accident occurred that month, Japan pulled the plug on the entire project. In March 2012, as Japan was again working on signing a nuclear cooperation agreement with Turkey, Mitsubishi took the opportunity to submit an expression of interest for its Atmea1 reactors, a product of its joint venture with Areva. Canada's Candu Energy also was interested in the process, but after conducting a six-month feasibility study, it withdrew its interest without providing detail (WNA, 2018).

The Mitsubishi-Areva Agreement

With only the Mitsubishi-Areva offer still standing (the Japanese withdrawal is still unconfirmed), in March 2015, Turkey, Canada, and France reached a final agreement on the Sinop NPP at the prime ministerial level, and Turkish parliament later ratified the agreement. The four first-of-their-kind Atmea1 reactors will be built on Areva's third-generation pressurized water reactors and was expected to cost around $22 billion. The 2015 agreement allows for 70 percent loan financing and 30 percent equity (NTI, 2018).

The state generation company EUAS planned to take 35 percent stake in the Sinop Nuclear Power Company, with the remaining shared among Mitsubishi (15 percent), Itochu (15 percent), and Engie (21 percent), with a search ongoing for another strategic investor (Reuters, 2018). The costs since signing the agreement have ballooned to $46.2 billion, which has cast doubt over the project's fate. The cost increases were largely due to much stricter safety and security procedures in Japan, the reactor's manufacturer, after the Fukushima accident (Nikkei Asian Review, 2018). As the Atmea1 reactor will be the first of its kind, the Japanese nuclear regulator added many more safety and regulatory hoops to jump through to ensure the reactor is not another embarrassment to the Japanese nuclear industry. Ultimately, this has raised costs far beyond expectation, over double the original projected price.

Japan is likely to ask Turkey to increase its financial burden, which Turkey is likely to protest. Moreover, the main Japanese investor, trading giant Itochu, withdrew from the project in April 2018 as a result of the ever-increasing financial hurdles, casting doubt on the project's success. The company "deemed it too difficult" to complete construction by 2023 as originally planned (Japan Times, 2018). In reaction, EUAS now intends to buy 49 percent equity in the project company, with the French Engie company as the operator, due to its experience operating 7 NPPs in Belgium (Turkish Minute, 2018).

As of the most recent available data, there is no certain financial arrangement for Sinop considering the costs; even the EUAS purchase is not set in stone. Furthermore, it is still unclear what the power purchasing agreement or contractual model will look like. Engie has described the project as under a Build-Own-Operate contractual model, while the Turkish government and EUAS have described it as a Build-Own-Transfer model (WNA, 2018). Third, in May 2018, the feasibility study due for completion in mid-2017 was still "several months from completion" and the 2017 construction start date had been missed with no clear start date in sight. The operational target of 2023 has been officially dropped.

The Igneada Nuclear Power Plant

While Turkey's NPPs have not gone as smoothly as expected, this has not stopped the country from signing further international agreements for a third NPP. As part of Turkey's goal to install an extra 100GWe of capacity by 2030, it announced in late 2015 a plan for a third NPP at Igneada on the Black Sea, 12 kilometers from the Bulgarian border (Sofia News Agency, 2011). The Turkish PM stated that the project would be mostly indigenous and dependent on national capacities developed in the Akkuyu and Sinop projects. Construction was to start in 2019 (WNA, 2018).

One year before the site was selected, in November 2014, the Turkish state generation company TETAS signed an agreement with Westinghouse and the Chinese State Nuclear Power Technology Corporation (SNPTC) for four reactors and all their lifecycle activities, including operations, fuel, maintenance, engineering, and plant services up until decommissioning (WNA, 2018). The expectation from the agreement is that SNPTC would support the development of a Turkish indigenous capability in lifecycle services. There have so far been no suggestions on a possible contractual model or power purchasing agreement. What is likely, however, is that the plant will consist of two of Westinghouse's AP1000 reactors and two of SNPTC's CAP1400 technology, which SNPTC developed from the American AP1000's.[10]

Fuel Cycle Activities in Turkey

Fuel cycle activities in Turkey are confined to a possible uranium mining site and to the development of a fuel fabrication facility under the Rosatom-Akkuyu agreement (Turkish Ministry of Energy and Natural Resources). Both these plans have not yet commenced with details and prospects for execution remain unclear.

A deposit of uranium was discovered in the 1980s in Temrezli, Anatolia. An Australian-Turkish holding company, Anatolia Energy, already had 18 exploration licenses throughout Turkey, including the Temrezli site. However, the US-based WestWater Resources, formerly known as Uranium Resources Inc., was set on penetrating the Turkish uranium market, in part because it wanted to move its Texas facilities off shore for reductions in cost, and because it saw the Middle East as a lucrative nuclear market in the future. With no room for new companies in Turkey's uranium exploration projects, in June 2015, WestWater Resources bought out Anatolia Energy in order to put all Turkish projects under its auspices (WNA, 2018).

10 The CAP1400 is built from the technology of the AP1000, which SNPTC introduced to China for its own NPPs, later developing it with slight variations that make the reactor more marketable to developing countries. In doing so, it increased its efficiency, electrical output, lifetime, and further minimized human input in certain operational areas. There are currently six AP1000 units under construction in the USA and China, and the first CAP1400 reactor is due to start construction this year at Shidaowan, China. See: NTI, "CAP1400 reactor vessel passes pressure tests" http://www.world-nuclear-news.org/NN-CAP1400-reactor-vessel-passes-pressure-tests-2203174.html; and Zheng et al., "The General Design and Technology Innovations of CAP1400," https://www.sciencedirect.com/science/article/pii/S2095809916301539.

WestWater conducted a preliminary economic feasibility study on the site, and it was found to be "comfortably" profitable and in line with the industry's costs benchmark. The Turkish Ministry of Energy & Natural Resources awarded a production license to WestWater and completed the pre-feasibility study in February 2015. A development decision was expected shortly afterward, however, due to globally low uranium prices and a weak global nuclear market, the project was put on standby in 2016 pending market enhancement. WestWater's plan to move its Rosita uranium treatment plant from Texas to Temrezli was also delayed (WNA, 2018). Ultimately, the Turkish government revoked all the company's mining and exploration licenses in June 2018 without sufficient justification (WestWater Resources, Press Release, 2018). It is likely that political tensions between Turkey and the United States played a role.

While the Rosatom's 2015 agreement includes a fuel supply and take-back section, it also stipulates support from Russia on the development of a fuel fabrication plant in Turkey – a parallel module of Turkey's plans with China to localize the fuel supply chain and fuel its future nuclear fleet (WNA, 2018). This plan has not proceeded on course due to the unforeseen legal and financial developments that have plagued the Akkuyu NPP since 2010 (according to authors' interviews with a Turkish renewables and nuclear energy expert). As with China, Russia and Turkey have not abandoned the idea yet and will likely re-explore their options after steady progress on the first reactor unit at Akkuyu. Still, any possible implementation of this a fuel fabrication project in Turkey is highly unlikely in the near future.

SAUDI ARABIA

The Kingdom of Saudi Arabia (KSA) has been seeking a national nuclear power program since 2006, when it commissioned a study with the Gulf Cooperation Council (GCC) for a Saudi Arabian NPP that could sell power to the region, as well as provide much needed desalination capacity (WNA, 2018). In June 2011, Saudi Arabia's newly established King Abdullah City for Atomic and Renewable Energy (KACARE) declared that the kingdom is planning to build 16 reactors (World Nuclear News, 2011; Reuters, 2011). Today, plans for 16 nation-wide reactors have been shelved; instead KSA is pursuing two large reactors along with two SMRs for desalination, in collaboration with KEPCO (SMART Power Co. official website).

In mid-2017, the government approved the Saudi National Atomic Energy Project (SNAEP) to implement a civilian nuclear energy program with three modules: a fleet of large nuclear reactors, a set of SMRs, and fuel cycle activities (KACARE official website). It has already identified two sites for the first project, at Khor Duweihin and Umm Huwayd, on both sides of Qatar on the Persian Gulf (US Energy Information Administration, 2018). While political motivations are suspected in the location's proximity to Saudi Arabia's rival, Qatar, the kingdom maintains that the sites were selected due to their proximity to the industrial grid and the UAE's Al-Barakah NPP (according to conversations with US policy staffers and experts familiar with the details of the Saudi nuclear program).

Saudi Arabia's Short-list of Nuclear Technology Suppliers

In September 2018, KSA short-listed Westinghouse USA, Russia's Rosatom, South Korea's KEPCO, and China's CNNC for its two large-scale reactors (WSJ, 2018). There is no financing or contractual or technical model envisioned yet (according to authors' interviews with Washington energy policy experts familiar with the internal proceedings of the Saudi program).[11]

Saudi Arabia is so far determined to maintain its right to enrich uranium, also signaling a nuclear hedging strategy in the event Iran ever pursues a nuclear weapon (CBS, 2018). The United States has maintained that Saudi Arabia must follow the gold standard, forego enrichment, and sign a 123 nuclear cooperation agreement in order to receive the Westinghouse or KEPCO reactors, as the latter incorporates the Westinghouse System-80 design in its operational software (WSJ, 2018). Under Section 123 of the US Atomic Energy Act (1954), a nuclear cooperation agreement, known as the 123 agreement, is required between the United States and recipients of US nuclear technology. The United States has almost always requested that this agreement include foregoing the right to enrich,[12] and this rule has been applied uniformly in the Middle East.

There have been various media reports stating that President Trump has mentioned in closed meetings that if the United States does not provide the Saudis with nuclear technology, then China or Russia will, and, the United States is better off allowing the Kingdom to enrich under US supervision (WSJ, 2018; Times of Israel, 2018). The negotiations are still at an absolute stalemate over Saudi Arabia's refusal to forego the right to enrich, and at the very least, sign the Additional Protocol to the Nuclear Nonproliferation Treaty, the minimum US demand (according to conversations between the authors and experts and diplomatic staff closely familiar with these internal conversations).

Bidders for Small Modular Reactors

In January 2018, KEPCO and KACARE began economic feasibility studies on the reactor technology's application to Saudi Arabia (SMART Nuclear Co. official website). However, the earliest considerations for SMRs in Saudi Arabia were in 2013, when a nuclear cooperation agreement with Argentina was signed for its CAREM small reactor technologies. The plans were intended for desalination, and an April 2013 timeline from KACARE showed construction suggested to start in 2016 (WNA, 2018).

By 2015, Saudi Arabia's plans for large-scale reactors had stalled, and due to economic constraints on the Kingdom's budgets, caused by the record low prices of oil, more weight was placed on the strategy of pursuing small modular reactors in the short-term for desalination purposes (according to authors' interviews

11 Private conversations between the authors and US government personnel closely familiar with the internal proceedings of the Saudi nuclear project have dismissed these reports as empty talk. Various experts do not believe that a Saudi nuclear program will materialize, regardless of what is reported. The Saudis have no institutional capacity pursuing a nuclear project, and as such, everything is still ink on paper at high levels of the Saudi government and whatever government it is negotiating with. US State Department personnel stated that communicating with KACARE and the government is very difficult, responses are often sent back very late and vaguely, and when high-level meetings are scheduled between the Department and the relevant authorities in KSA, no communication, preparation, or points of contact are available until arrival to Saudi Arabia.

12 The United States made an exception for India in 2005 for geopolitical reasons to counter Pakistan and China. According to authors' interviews with US Congressional staffers familiar with nuclear issues on Capitol Hill and involved in the US-India nuclear cooperation agreement's Congressional debate in 2005, that agreement was sold to Congress on the basis of huge economic benefit for US businesses, which have not materialized. Congress was lobbied to allow India the right to enrich, given the massive potential profits for the American economy and nuclear industry. The same arguments are reemerging today about the Saudi deal, with even President Trump suggesting that the US allowing Saudi Arabia to enrich would be very beneficial to the dying US nuclear industry.

with US Middle East energy policy experts). In March of that year, KSA signed another agreement with Korea's KAERI to perform feasibility studies on at least two SMART reactors of 100 MWe generation capacity for desalination. KAERI claims that it has pioneered the integration of SMR technology into desalination plants capable of producing 40,000 m3/day of water at less than the cost of generating an equal capacity from gas turbines (SMART Nuclear Co. official website).

The total cost of building one SMART unit in Saudi Arabia is expected at $1 billion (WNA, 2018). This project seems to be on track and currently in the final stages of its pre-project engineering study. Later in September 2015, further agreements were signed between the two parties to develop SMART reactor infrastructure, expertise, and training programs. The contract for pre-project planning and feasibility studies for KAERI is worth $130 million. KAERI's affiliate, KEPCO Engineering & Construction, is conducting the study, and SMART Power Co Ltd., established in 2014 to export Korea's SMART reactors, is listed as the prime EPC contractor. In late 2016, KACARE stated that plans for construction start by end of 2018 were on schedule; however, there has been little up-to-date information or news available on the progress of this study and whether construction will be delayed further (WNA, 2018; according to authors' interviews with US Middle East energy policy experts). No financing agreement has been worked out for the construction and operation of the plant.

That has not stopped the Kingdom from exploring its other SMR options, necessitating the involvement of various technologies and providers. At the same time of signing the feasibility studies with KAERI in March 2015, KACARE also signed an agreement with the Argentinian state-owned Investigacion Aplicada (INVAP) and a Saudi tech start-up Taqnia, creating the joint-venture company 'Invania' with the mandate of adapting INVAP's small reactor technologies to Saudi desalination and electric supply needs (INVAP, Press Release, 2015). Particularly, the new company is looking at modifying the Argentinian CAREM that can produce 100 MWt energy for desalination and 27 MWe in electrical generation. The parties are still exploring technical options more suited for the later stages of KSA's nuclear maturity, and no information is publicly available on a project timeline yet (INVAP).

China's Nuclear Engineering Corporation (CNEC) is the latest to sign an agreement in August 2017 with KACARE on SMRs. Saudi Arabia is interested in the small 200 MWe high temperature reactor that China completed in Shandong in November 2017 (Power Magazine, 2017). The Saudis expect to monitor and assess the reactor in Shandong and decide on its applicability to the Saudi system (World Nuclear News, 2016; 2017). In March 2017, another agreement was signed with China for the localization of the construction and fuel supply chain, including a feasibility study that began in August 2017.

Fuel Cycle Activities in Saudi Arabia

Fuel cycle activities in KSA are currently limited to an exploratory study and feasibility assessment of uranium and thorium resources in the Kingdom, conducted by the China National Nuclear Corporation and the Saudi Geological Survey (Reuters, 2017). The project is due in 2022 and explores nine areas across the Kingdom, in addition to ongoing feasibility studies regarding fuel chain localization (NEI Magazine, 2016). Even if Saudi Arabia extracts its uranium resources, it does not have the infrastructure to enrich uranium to fuel its reactors. China is working with Jordan and KSA on uranium exploration and potential mining in the two countries. Saudi Arabia also signed a separate agreement with Jordan for uranium exploration and yellowcake production in central Jordan (World Nuclear News, 2017).

As the central issue around the Saudi nuclear program remains the question of Saudi enrichment, it is worth noting that the G8 pledged not to export enrichment technology in 2008 (Herner, 2009). The only countries with the capability of providing enrichment technology are the United States, Russia, Canada, France, Germany, the UK, and China. This G8 pledge means all these providers except China will not export their enrichment technology to Saudi Arabia. Additionally, the agreement on localization of the fuel chain with China is far from materializing itself as investment in Saudi enrichment technology, and experts have provided a plethora of reasons for why China will likely not share its technology for both, political and economic reasons (according to authors' interviews with Melissa Mann, CEO of URENCO, and Andrea Jannetta, Editor-in-Chief of Fuel Cycle Weekly). Saudi Arabia has no viable commercial option for enrichment, as no technology providers have the economic or political incentive to provide it.

JORDAN

The Hashemite Kingdom of Jordan's nuclear program has experienced various setbacks and challenges since its inception. In 2013, Jordan signed a $10 billion contract with Russia's Rosatom for two 1000 MWe AES-92 reactor units at Qasr Amra. However, Jordan announced in June 2018 that it is cancelling the deal because Rosatom asked for 50 percent private equity in commercial loans to fund the project, a deal breaker for Jordan as it would substantially raise interests and costs. Instead, the government is now pursuing MOUs with a variety of small modular reactor (SMR) suppliers, as their financing is more likely and their lower power capacity is more suitable to the small Jordanian electricity grid (NeutronBytes, 2018; NEI Magazine, 2018).

While its commercial nuclear power plans have faltered, Jordan has achieved significant advances in research and development activities. In December 2016, Jordan commissioned its first research reactor, a 5 MWt unit that can be upgraded to 10 MWt. It is located at the Jordan University for Science and Technology and uses 19 percent enriched uranium fuel. The reactor was provided by the Korean Atomic Energy Research Institute (KAERI) and Daewoo and financed by a $70 million Korean soft loan with 0.2 percent interest, to be repaid over 30 years. The fuel is provided and will be taken back by KAERI (WNA, 2018).

The Bidding Process

The plans for nuclear new build in Jordan go back to 2008, when the country was considering building Atomic Energy of Canada Ltd.'s (AECL) 740 MWe Enhanced Candu-6 reactor, which uses natural uranium fuel for power and desalination. With reports of Jordan looking for bidders, Areva approached Jordan to market its 1100 MWe Atmea1 reactor, the joint venture with Mitsubishi. JAEC also signed an MOU with KEPCO to carry out a site selection and feasibility study on its first nuclear power and desalination project (WNA, 2018).

By end of 2009, JAEC had received seven offers from four reactor vendors, ultimately shortlisting three designs in May 2010: the Areva-Mitsubishi Atmea1 reactor; a newer version of Canada's Candu reactors, the EC6; and, the Rosatom AES-92. By 2012, the finalists were Atmea1 and AES-92, deemed more suitable for Jordan's financial and electrical supply situation. The final decision rested largely on "the financing and organizational support that the vendor will be providing for the future operation of the plant." Between 2008 and 2014, the site changed from near the coast of Al-Aqaba on the Red Sea in 2008, to Qasr-Amra in 2014, 70 kilometers southeast of Amman, an inland site with no direct access to cooling water (WNA, 2018).

The Rosatom-JAEC Agreement

In October 2013, JAEC announced that Rosatom was the preferred bidder, and, in March 2015, JAEC and Rosatom signed a final agreement for two AES-92 units with a capacity of 1100 MWe (total 2200 MWe) and a total cost of $10 billion (Reuters, 2015). It was expected at the time of agreement that the newly formed Jordan Nuclear Power Company (JNPC) would be responsible for obtaining financing for about 50 percent of the total required funds (Reuters, 2015).

In terms of financing, JAEC hoped for a limited recourse-financing contract, with a debt-equity ratio of at least 70-30. On the other hand, Rosatom insisted on at least 50 percent commercial equity funding. The disagreement was insurmountable: in June 2018, after much difficulty finding strategic investors, JAEC withdrew from the agreement. It stated that Rosatom's requirement of commercial loans for half the project financing made it far too expensive for investors and Jordan's financial circumstances, as it would have likely increased the prices of generated electricity (Energy Central Magazine, 2018). JAEC is now looking at proposals for small modular reactors (SMR) to build instead.

Prospects for Small Modular Reactors

After having sought all feasible options and failed to secure its share of the Qasr Amra NPP, Jordan now turns to Small Modular Reactors (SMRs), which are more fundable and likely more suitable for Jordan's electrical situation (according to authors' interviews with energy policy experts). Of most interest to JAEC among SMR providers is the Korean 110 MWe SMART reactor.

Feasibility studies are already ongoing between JAEC, the Saudi King Abdullah City for Atomic and Renewable Energy (KACARE), and KAERI to build two nuclear reactors in Jordan with a total 220 MWe capacity (World Nuclear News, 2017). JEAC Chairman, Khaled Toukan noted that the two reactors will cost around $800 million each, stating that the project will be financed by the three parties involved and that Jordan has received pledges of support for the reactors from the governments of Saudi Arabia and South Korea (WNA, 2018). Still, any deal with KEPCO will still require a US 123 agreement, as in the case of large-scale NPPs, as the SMART reactor also uses significant US technology and software in its design.

There are two other SMR options that JAEC is considering, in addition to KEPCO's SMART reactors. First is the US NuScale Power's SMR, which is the United States' first small modular reactor to apply for licensing. This option will likely be far above Jordan's budget, and will require significant time for production and testing before it can be sold to and constructed in Jordan. Second, JAEC is also considering China's

High-Temperature Gas-Cooled Reactor (HTGR), which is currently being built in Shandong and being considered by Saudi Arabia (according to authors' interviews with JAEC staff). Chairman Toukan previously noted that no contract would be signed with CNNC before the actual commissioning, startup, and operation of the Shandong reactor for at least two years (NEI Magazine, 2018). China's reactor will likely not be available for sale and construction before 2025.

Previously, JAEC had been considering the UK's Rolls Royce for a to-be-determined light water reactor-type of SMR. In November 2017, an MOU was signed between JAEC and Rolls Royce for a technical feasibility study for Rolls Royce's SMR in Jordan (World Nuclear News, 2017). A similar agreement was signed with US's X-Energy for a new generation of South Africa's pebble bed HTGR as an SMR, with water desalination and other thermal applications; however, talks with X-Energy are in their preliminary phases with no sign of moving forward, at least compared to NuScale's design. Both these technologies have not yet been tested.

As for Russia's Rosatom, following Jordan's withdrawal announcement, the company offered collaboration on its own version of an unannounced SMR (Rusatom, Press Release, 2018). The company's president has already stated that "SMR technologies will certainly become one of [the company's] priorities" in the evolving global energy market, yet no details are yet available on a Russian SMR design.

While it has not finalized any SMR deal yet, JAEC is currently conducting an SMR feasibility study; Aqaba, on the Red Sea, is being considered as the site of Jordan's SMR plant, due to its proximity to industrial and transportation infrastructure.[13] It is unlikely that any SMR deal will ultimately proceed without great support from the vending party. Jordan's economy has always struggled and been highly dependent on foreign aid.

The Qasr Amra project was never bankable. Though SMRs are only 10 percent of the cost, Jordan cannot afford the elevated electricity price, per kWh, compared to other available options and all the hidden costs that accompany nuclear power, such as the necessary grid upgrades, personnel training, and security and energy infrastructure.

Fuel Cycle Activities in Jordan

According to the IAEA's 'Red Book' of uranium resources, Jordan is inferred to possess 59,600 tU amenable to open pit mining. Another 100,000 tU is estimated as phosphate byproduct as well. JAEC has long claimed that Jordan has uranium resources capable of supplying its indigenous program as well as exporting to customers abroad (WNA, 2018). However, Rio Tinto and Areva conducted various exploration studies between 2008 and 2012 and found that the deposits were not economically feasible (according to US nuclear energy experts). Nonetheless, Jordan hoped to mine its uranium reserves and even offered to trade uranium at some point for the cost of new nuclear reactors (WNA, 2018). The low commercial viability of the deposits, as well as the record low global price of uranium, made the plan unworkable.

In March 2017, JAEC and Saudi Arabia's KA-CARE signed an agreement covering uranium exploration and mining in central Jordan. Jordan and Saudi Arabia hope to use this uranium to fuel their future NPPs (WNA, 2018). China is supporting both countries independently in other uranium exploration projects (World Nuclear News, 2017). Additionally, Jordan's JAEC Chairman, Toukan, has stated on multiple occasions that Jordan expects to take part in a regional collaborative project for a common nuclear waste disposal site with the UAE, Saudi Arabia, and Egypt. Jordan has held off on signing the US 123 Agreement to maintain its option of contributing to a regional uranium enrichment facility with Saudi Arabia and Egypt.

13 Aqaba is a disqualified large-scale NPP site, due to its seismic activity. SMRs are not as vulnerable to seismic destruction as are large-scale NPPs, and, therefore, Aqaba was a first-choice site in this case due to its industrial proximity. Source: Private author conversations with JAEC officials.

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