Saudi Arabia’s Nuclear Ambitions and Proliferation Risks

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By Sarah Burkhard, Erica Wenig[1], David Albright, and Andrea Stricker

Executive Summary and Recommendations

The Kingdom of Saudi Arabia has an uneasy relationship with Iran. The Iran nuclear deal, or Joint Comprehensive Plan of Action (JCPOA), which went into effect in January 2016, has limited Iran's sensitive nuclear program and subjected it to greater international monitoring. Many hoped that the JCPOA would also ease regional security tensions between Saudi Arabia and Iran, yet they have actually increased despite the deal. The JCPOA has also not eliminated the Kingdom's desire for nuclear weapons capabilities and even nuclear weapons, but rather reduced the pressure on Saudi Arabia to match Iran's nuclear weapons capabilities in the short term. In that sense, the deal has delayed concerns about nuclear proliferation in Saudi Arabia.

However, there is little reason to doubt that Saudi Arabia will more actively seek nuclear weapons capabilities, motivated by its concerns about the ending of the JCPOA's major nuclear limitations starting after year 10 of the deal or sooner if the deal fails. If Iran expands its enrichment capabilities, as it states it will do, Tehran will reduce nuclear breakout times, or the time needed to produce enough weapon-grade uranium for a nuclear weapon, to weeks and then days. With these concerns, the Kingdom is likely to seek nuclear weapons capabilities as a hedge. A priority of the administration of Donald J. Trump is to prevent Saudi Arabia from developing such capabilities, in particular acquiring reprocessing and uranium enrichment facilities. The administration's stated commitment to better enforce and strengthen the JCPOA provides a sounder foundation to achieve that goal.

Saudi Arabia has little nuclear infrastructure today, and acquiring nuclear weapons is a difficult process for any country. At this point in time and at its current pace of nuclear development, Saudi Arabia would require years to create the nuclear infrastructure needed to launch a nuclear weapons effort. Our open source research, which includes translations from Arabic of official Saudi statements, nuclear infrastructure plans, and domestic research, shows that Saudi Arabia is not likely to have launched any domestic covert nuclear programs to create the wherewithal to build nuclear weapons. Instead, like other cases of proliferant states and territories, such as South Africa, Iran, and Taiwan, it appears that Saudi Arabia is concentrating on building up its civilian nuclear infrastructure. It is acquiring nuclear or nuclear-related facilities and committing to placing them under international inspections according to international norms. Saudi Arabia has thus far embarked on a path to seek civil nuclear assistance from several nations, including Russia, South Korea, and China. It is also researching civil nuclear applications and developing a robust nuclear engineering and scientific workforce.

[1] Erica Wenig in particular provided Arabic translations of Saudi statements, press reports, and nuclear research for this report. Former Institute interns Andrew Basham and Stacy Brenner contributed importantly to this report's discussion of security and economic issues with Iran. We also thank Mark Gorwitz, who provided valuable technical references on Saudi Arabia's nuclear and nuclear-relevant research.

Any research on the weaponization of nuclear material would of course be cause for international alarm, as it was in the case of Iran and its secret program to develop a nuclear weapon. However, preventing proliferation in Saudi Arabia should focus first on preventing enrichment and reprocessing capabilities, even in the absence of work on a nuclear weapon. Nuclear suppliers should reach consensus on not exacerbating security concerns in the Middle East by agreeing not to sell Saudi Arabia sensitive fuel cycle capabilities. Moreover, Western governments should enhance their efforts to monitor, detect, and prevent the illicit spread of enrichment and reprocessing capabilities to Saudi Arabia.

A major uncertainty in this analysis is the nuclear relationship between Pakistan and Saudi Arabia. Although reports that Pakistan has promised Saudi Arabia nuclear weapons appear inaccurate, some level of agreement relating to nuclear cooperation appears likely.

Based on other proliferation cases, unresolved, chronic security concerns can foster nuclear weapons development. For many cases, only the resolution of such concerns led to the avoidance of nuclear weapons. Thus, in the long term, diplomatic and other initiatives should be aimed at regional threat reduction efforts to prevent Saudi Arabia and other Middle Eastern nations from seeking nuclear weapons. Perhaps more important, remedying the relatively short-term nature of the Iran deal's nuclear constraints is critical in preventing Saudi Arabia from building a nuclear weapons capability over the next five to 15 years.

Key Findings

· Saudi Arabia is in the early stages of nuclear development. Saudi Arabia does not possess much nuclear material. It has a Comprehensive Safeguards Agreement (CSA) with the International Atomic Energy Agency (IAEA) which entered into force in 2009. That CSA has an old model Small Quantities Protocol (SQP), which holds certain reporting responsibilities in abeyance until nuclear material inventory exceeds one effective kilogram or the Saudis have a nuclear facility such as a reactor.[2] At that time, Saudi Arabia will need to negotiate subsidiary arrangements, including facility attachments, which will specify in more detail the reporting requirements and inspection arrangements. As of early 2017, Saudi Arabia has neither power nor research reactors, nor are any under construction. The general belief in the nonproliferation community is that Saudi Arabia is a nuclear 'newcomer.'

· It is unclear at this point whether Saudi Arabia will sign and ratify the Additional Protocol to its CSA.

[2] The term "one effective kilogram" is used by the IAEA to reflect the mass value of total uranium, e.g. standardizing quantities of natural uranium versus enriched uranium. See IAEA, *Nuclear Material Accounting Handbook,* Services Series 15 (Vienna: May 2008), p. 6, http://www-pub.iaea.org/MTCD/Publications/PDF/svs_015_web.pdf

· As of 2016, there is no evidence of technical research or development of the production of fissile material, namely highly enriched uranium or separated plutonium. However, a European government official confirmed to our Institute in 2014 that the pursuit of scientific and engineering expertise necessary to take command of all aspects of the nuclear fuel cycle is ongoing in Saudi Arabia.

· Saudi Arabia appears genuinely committed to importing many nuclear reactors and has pursued numerous cooperation agreements with other countries. The country's declared nuclear focus is on peaceful applications of nuclear energy, affordable power plants, desalination reactors, and environmental protection. According to recent plans, it intends to install over 16 nuclear reactors during the next few decades. This nuclear development program is expected to remain strictly civilian in nature, focused mainly on deploying nuclear power reactors for generating electricity and desalinating sea water. However, it appears on a trajectory to create domestic appendages that could provide a nuclear weapons capability, even if for some time these capabilities would likely be under international safeguards. The conditions necessary for Saudi Arabia to operate unsafeguarded nuclear facilities or leave the Nuclear Non-Proliferation Treaty (NPT) to build nuclear weapons appear onerous today. The disincentives far outweigh the incentives for such a path. However, this could change depending on the fate of Iran's nuclear program.

· Saudi Arabia has conducted at least one feasibility study on its "involvement in all stages of the nuclear power generation cycle." According to this study's results, using Saudi Arabia's natural uranium deposits to enrich uranium is among the feasible options.[3]

· Although there is no evidence that Saudi Arabia is currently seeking to acquire or build uranium enrichment or reprocessing plants, this could change as its nuclear infrastructure develops and regional tensions fester. Once it establishes its knowledge and industrial base over the next five to 10 years, however, Saudi Arabia will be in a more favorable position to decide on building fuel cycle capabilities, albeit under safeguards. A former IAEA inspector interviewed for this paper judged that Saudi Arabia may seek such technologies in as soon as five years.

· Saudi Arabia's interpretation of the NPT appears to include a view of what some have called a "right to enrich." The country has not taken advantage of nuclear energy assistance from the United States, possibly because U.S. reactor purchases would need a so-called 123 agreement stating that Saudi Arabia would "not pursue sensitive nuclear technologies,"[4] which include enrichment and reprocessing.

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[3] Amena Bakr, "Saudi Arabia May Enrich Uranium for Nuclear Power Plants," *The Daily Star*, June 18, 2010, http://www.dailystar.com.lb/News/Middle-East/2010/Jun-18/85927-saudi-arabia-may-enrich-uranium-for-nuclear-power-plants.ashx

[4] U.S. Department of State, Office of the Spokesman, "U.S. – Saudi Arabia Memorandum of Understanding on Nuclear Energy Cooperation," May 16, 2008, https://2001-2009.state.gov/r/pa/prs/ps/2008/may/104961.htm

· Saudi Arabia has expressed interest in developing an indigenous capability to manufacture nuclear reactors. KA.CARE, the national agency at the forefront of Saudi Arabia's nuclear agenda, has identified several steps within the nuclear fuel cycle as having high potential for local manufacturing, including fuel fabrication, processing, and enrichment. Going beyond the import of technologies, Saudi Arabia appears to have intentions to acquire intellectual property rights and become an exporter of small modular reactors (SMRs).

· Saudi Arabia appears to have a domestic supply of uranium sufficient for a small-scale, clandestine nuclear weapons program. However, Saudi Arabia has not yet mined or processed any uranium from its domestic sources.

· Overlooked by many experts evaluating Saudi Arabia's nuclear future is the fact that the country's nuclear workforce is increasing at a rapid pace in both quality and quantity. The academic nuclear engineering sector is growing substantially, constantly launching new graduate programs and expanding Saudi Arabia's five nuclear research centers. Already in 2014 Saudi Arabia considered it had a "high" comparative advantage in "operations and maintenance" of nuclear reactors and a "medium" advantage in other relevant steps.[5]

· The bulk of its published nuclear research is of a theoretical, rather than experimental nature, and it does not involve significant quantities of uranium or other nuclear material. Nevertheless, Saudi Arabia is pursuing front-end nuclear fuel cycle research, such as studies on the extraction of uranium from ore.

· The growth of its academic nuclear energy sector in past years emphasizes the Saudi ambition to modernize and equip the future generation with technical nuclear capabilities.

· Saudi Arabia is highly invested in medical applications of nuclear science, such as gaining hands-on experience with nuclear reactions and housing at least five hot cells of unknown size. Hot cells over a certain size are of concern because they could be used in small-scale plutonium separation or irradiated fuel reprocessing experiments. In the case of Iran, hot cells exceeding six cubic meters are banned unless expressly allowed by the executive body of the JCPOA, and allowed ones are subject to IAEA monitoring. Regardless of the size of the Kingdom's hot cells, Saudi Arabia does not currently have any irradiated fuel (or targets) it could use in such experiments. Nonetheless, learning more about these hot cells and limiting the size of any future ones makes sense. In addition, the IAEA should report to member states on its knowledge of these hot cells.

· Official statements by Saudi Arabian officials suggest a commitment to acquire nuclear weapons, or at least advanced nuclear fuel cycle capabilities, in the event that Iran's nuclear program is not adequately constrained by the nuclear deal. Recent statements indicate that

[5] Maher Al Odan, Head of Research & Development & Innovation, KA.CARE, "KACARE's Sustainable Energy Initiatives," *PowerPoint Presentation at an IAEA 59th General Conference Side Event,* Vienna, September 16, 2015, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2015/2015-09-16-NPTDS/6_SAUDI_Odan_SMR_GC_SE_16Sept.pdf

officials are for now content with the temporary restrictions on Iran's nuclear capabilities brought by the JCPOA. The opinions of society and prominent Saudi analysts are mixed.

· Under the JCPOA, restrictions on Iran's enrichment program start to conclude from year 10 to 15 of the deal's implementation (or in the period 2026-2031), and Saudi Arabia may again come to fear a renewed Iranian nuclear threat. This threat could be viewed as greater than prior to the agreement due to the international legitimization of Iran's nuclear weapons capabilities under the JCPOA, in particular. If the JCPOA ends prematurely, Iran's actions and those of the United States and UN Security Council to constrain Iran will likely dictate whether the nuclear program is seen as a threat that Saudi Arabia must match.

· It is likely that Saudi Arabia did not pursue nuclear weapons capabilities following the IAEA's discovery of Iran's covert nuclear programs in 2003. The exact reasons why are uncertain, but part of the rationale appears to be that the international community refused to legitimize Iran's enrichment program and instead enacted United Nations Security Council and other unilateral and regional sanctions against Iran. Those actions may have discouraged Saudi Arabia from seeking uranium enrichment technologies out of concern of being stigmatized and possibly subjected to international pressure and sanctions. However, Saudi Arabia's concerns over the Iranian program likely contributed to its decision to pursue nuclear energy projects on a large scale as part of a hedging strategy.

· Unfortunately, the ability of the international community to detect potentially small-scale proliferation-relevant research and development by any nation is questionable, including today in Saudi Arabia. As Saudi Arabia has no major nuclear facilities, the IAEA's familiarity with its research and procurement efforts is limited.

· An on-going concern is that Saudi Arabia may plan to receive nuclear assistance from Pakistan. The Institute uncovered evidence that the assistance would not involve Pakistan supplying Saudi Arabia with a full nuclear weapon or weapons; however, Pakistan may assist in other important ways, such as supplying sensitive equipment, materials, and know-how used in enrichment or reprocessing. An unanswered question is whether Pakistan and Saudi Arabia may be cooperating on sensitive nuclear technologies in Pakistan. In an extreme case, Saudi Arabia may be financing, or will finance, an unsafeguarded uranium enrichment facility in Pakistan for later use, either in a civil or military program.

· Saudi Arabia secretly purchased a controversial set of ballistic missiles from China in the 1980s, the DF-3 missiles, which can carry nuclear weapons. The United States detected the purchase after the fact. They appear to remain operational.

Recommendations

· When Saudi Arabia brings into full application its CSA with the IAEA, it should also sign and ratify the Additional Protocol.

· Western national intelligence capabilities should focus on the detection of proliferation-relevant Saudi research and development, as well as procurements which could signify covert, or even overt, nuclear fuel cycle development or interest in nuclear weaponization.

· The United States should reaffirm that it is a staunch ally of Saudi Arabia, even while expressing concern about troubling regional and domestic actions, such as its intervention in Yemen and violations of human rights. Doubts about the United States' commitment to assisting the Kingdom's security should nevertheless be removed as part of this policy.

· The United States should make clear to Saudi Arabia in private conversations that its pursuit of uranium enrichment or reprocessing, whether in Saudi Arabia or abroad, would threaten the U.S. defense commitment to Saudi Arabia and destroy it if the Kingdom seeks nuclear weapons. This U.S. policy should happen in parallel with efforts to strengthen and extend, or make permanent, the nuclear limitations of the JCPOA.

· All nuclear suppliers should condition the sale of reactors to Saudi Arabia on a prohibition of domestic reprocessing and enrichment, despite the difficulties of doing so at such a late date.

· The United States and its partners should work diplomatically to discourage the sale of advanced fuel cycle capabilities to Saudi Arabia and its neighbors. As part of that effort, the United States should initiate an effort to guarantee enriched uranium fuel supplies to Saudi nuclear reactors. Although a private U.S. initiative to do so has not succeeded so far, the U.S. government should initiate an effort among reactor suppliers to create an ensured international fuel supply for Saudi and other Middle Eastern countries' reactors. This effort should focus on providing enriched uranium fuel and avoiding mixed (plutonium/uranium) oxide (MOX) fuel.

· Equally, discussions need to be held with countries that are not members of the NSG, such as Pakistan and India, to discourage them from selling advanced nuclear technology and capabilities to Saudi Arabia. Pakistan should be pressed not to conduct any nuclear activities for Saudi Arabia, in Pakistan or abroad.

· A priority is the strengthening of the JCPOA, particularly by better enforcing the deal and extending the duration of the major nuclear limitations. This would prevent a renewed crisis in which Saudi Arabia would be expected to pursue advanced fuel cycle capabilities. A strengthening of the JCPOA would need to mitigate the impact of renewed Iranian enrichment on Saudi threat assessments.

· In the absence of the JCPOA, UN Security Council resolutions against Iran's nuclear program would ostensibly fall back into place. The United States and the international community would need to ensure that Iran's nuclear program does not present a renewed threat to Saudi Arabia by enacting additional sanctions against Iran and instituting containment and deterrence measures, among other actions.

· Regional Middle East tensions must be addressed and threat reduction efforts developed more broadly.

Part I: Review of the Kingdom's Views on Nuclear Proliferation

Official Statements about Nuclear Proliferation in the Context of the JCPOA

In the weeks prior to the signing of the JCPOA, a little noticed interview with *The London Telegraph* by Saudi ambassador to the United Kingdom, Prince Mohammed bin Nawwaf bin Abdulaziz al-Saud, brought to light a potentially increased proliferation risk with regard to Saudi Arabia. While Prince Mohammad stated that Saudi Arabia had always supported the resolution of the Iranian nuclear threat by means of diplomacy and negotiation, support of any deal with Iran would only come, he said, after assurances that the JCPOA was "watertight." He stated, "We hope we receive the assurances that guarantee Iran will not pursue this kind of weapon...If this does not happen," Prince Mohammed went on to explain, "then all options will be on the table for Saudi Arabia."[6] His statement suggests a commitment to acquire nuclear weapons, or at least advanced nuclear fuel cycle capabilities, in the event that Iran's nuclear program is not adequately constrained by the nuclear deal.

Tensions were temporarily reduced during King Salman bin Abdulaziz Al Saud's visit to the White House in early September 2015. Saudi Foreign Minister Adel al-Jubeir stated that the King had been reassured by the verification regime to be implemented under the JCPOA and "under those conditions, Saudi Arabia supported the deal."[7] Near the start of the deal's implementation, however, Saudi Arabia started to raise new concerns about Iran's use of newly available money from lifted sanctions to fund regional proxy efforts. Foreign Minister al-Jubeir stated that if Iran were able to obtain a nuclear weapon despite the JCPOA, Saudi Arabia "would do whatever we need to do in order to protect our people." He admitted that he did not think it would be "logical to expect us to discuss any such issue in public." The foreign minister also stated, "If an American decline were to happen or an American withdrawal were to happen, the concern that everybody has is that it would leave a void, and whenever you have a void, or a vacuum, evil forces flow."[8]

The election of Donald Trump is expected to lead to stricter enforcement of the deal, efforts to strengthen it, and negotiations for a follow-on deal that extends the nuclear restrictions, limits ballistic missiles, and tightens monitoring. Despite initial fears that the Trump administration would abrogate the deal, most do not expect that to happen. Nonetheless, Iran may decide that the enhanced enforcement and calls to strengthen the deal warrant violating or leaving it entirely. Thus, for planning purposes, one must ask whether the JCPOA will survive its intended duration.

One Saudi official made a key statement indicative of official thinking on what the new president should do. Prince Turki al-Faisal, the former head of intelligence for the Kingdom,

[6] Con Coughlin, "The Saudis Are Ready to Go Nuclear," *The Telegraph*, June 8, 2015.
[7] Yeganeh Torbati and Julia Edwards, "Saudi Arabia Satisfied with Obama's Assurances on Iran Deal," Reuters. September 4, 2015, http://www.reuters.com/article/us-usa-saudi-jubeir-idUSKCN0R42D420150904
[8] Angus McDowall, "Exclusive: Saudi Arabia Warns against 'Nefarious Activities' by Iran," Reuters. January 21, 2016, http://www.reuters.com/article/us-saudi-nuclear-idUSKCN0UX2HK

said President Trump should not discard the JCPOA, despite general concern inside the government of the agreement's ability to reign in Iran's malign regional activities and capacity to develop nuclear weapons. As reported by Reuters, Prince Turki stated, "I don't think he should scrap it. It's been worked on for many years and the general consensus in the world, not just the United States, is that it has achieved an objective, which is a 15-year hiatus in the program that Iran embarked on to develop nuclear weapons." This statement indicates that the Kingdom appreciates the delay created by the JCPOA on Iran's ability to make a nuclear weapon.[9]

Nonetheless, Saudi Arabia may choose to quietly build its nuclear capabilities while the JCPOA is in force so that it is prepared to match a resurgent and growing Iranian nuclear program when the deal ends. Maintaining vigilance over the Kingdom's statements and nuclear research and development related activities will be important as the nuclear deal is implemented and particularly as the key enrichment related restrictions start to lift.

If the deal does not survive, the United States or its allies are likely to invoke under the JCPOA the snapback of UN Security Council sanctions. However, much more would be needed to ensure that Iran's nuclear capabilities do not present a renewed threat.

Security Incentives and Disincentives to Pursue Advanced Nuclear Capabilities

Incentives. Saudi Arabia has strategic and geopolitical incentives to acquire nuclear weapons and counterbalance Iran. Iran and Saudi Arabia have been engaged in the equivalent of a regional cold war for dominance since at least 1979, in addition to being in a centuries-long disagreement over their respective interpretations of Islam.[10] Moreover, many major Saudi Arabian cities and oil facilities are located precariously along the Persian Gulf and the Red Sea, making them more vulnerable to air or seaborne attack.[11] With both states competing to become the regional hegemon, unchecked growth in Iran's nuclear program could tilt the Saudis' thinking on building up their own nuclear capabilities now or in the future. Based on Iran's planned growth in its enrichment program, Iran would be only a few months away from producing enough weapon-grade uranium for a nuclear weapon, i.e. nuclear breakout, in year 15 of the JCPOA, and within days a few years later. Coupled with a decrease in confidence about the United States' willingness to ensure regional security, Saudi Arabia could be spurred to future "impulsive" actions, as stated in a German intelligence memo seen by Reuters. This may include competing with Iran in the nuclear arena.[12]

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[9] Yara Bayoumy, "Senior Saudi Prince Says Trump Shouldn't Scrap Iran Deal," Reuters. November 11, 2016, http://www.reuters.com/article/us-usa-election-saudi-iran-idUSKBN1361SS

[10] Kim Ghattas, "The Saudi Cold War with Iran Heats Up," *Foreign Policy*, July 15, 2015, http://foreignpolicy.com/2015/07/15/the-saudi-cold-war-with-iran-heats-up/

[11] Thomas W. Lippman, "Policy Brief No. 5: Nuclear Weapons and Saudi Strategy" (Washington, D.C.: The Middle East Institute, January 2008), https://www.mei.edu/sites/default/files/publications/Lippman.pdf

[12] "German Spy Agency Warns of Saudi Shift to 'Impulsive' Policies," Reuters. December 2, 2015, http://www.reuters.com/article/us-saudi-germany-warning-idUSKBN0TL1O020151202#8hJjrlwIzOttjIVX.97

In addition to the tension between Iran and Saudi Arabia, an expanding Iranian nuclear program after the JCPOA nuclear restrictions end would increase tensions between Iran and Israel, possibly resulting in calls for Israel to drop its policy of nuclear opacity. Israeli decisions will then further impact Saudi Arabia's decisions.

Saudi Arabia may seek advanced nuclear capabilities not only as a way to deter Iran militarily and provide a check on its regional activities, but also with an eye toward safeguarding its internal affairs from interference. Saudi Arabia's security-based incentives to obtain a nuclear deterrent against Iran stem mainly from its perceived military weakness relative to Iran and their history of uneasy and rivalry based relations. The two have engaged in a struggle for Middle Eastern hegemony since the Iranian Revolution of 1979 challenged Saudi hegemony.[13] These incentives include fears of an Iranian-backed Shiite domestic rebellion.

The rise of the Iranian theocratic leadership created challenges for Saudi Arabia in 1979 when the domestic uprisings of Shiites inspired by the Iranian Revolution began to occur.[14] The first of these uprisings took place on November 11, 1979 in Qatif, located in Saudi Arabia's oil rich Eastern Province. The local Shiite population, who were "very receptive to Khomeini and his attacks on the Saudi royal family," staged protests, strikes, and other demonstrations against the Saudi monarchy that later devolved into armed conflict with Saudi and U.S. security forces.[15] After thousands of arrests, hundreds of injuries, and 24 deaths, the security forces reestablished control of Qatif and the oil fields on November 30, 1979.[16]

More recently, in 2011, Qatif saw a reinvigorated Shia movement as the Arab Spring swept across North Africa and the Middle East. The demonstrations aimed to protest against decades of Shia repression, and with multiple regime changes occurring during the Arab Spring, the Saudi government felt threatened by the unrest.[17] Between 2011 and 2015, twenty protesters were killed and hundreds of others were injured in the suppression of these demonstrations.[18]

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[13] F. Gregory Gause, "Beyond Sectarianism: The New Middle East Cold War" (Qatar: Brookings Doha Center, July 2014), No. 11, http://www.brookings.edu/~/media/research/files/papers/2014/07/22-beyond-sectarianism-cold-war-gause/english-pdf.pdf

[14] Michel Nehme, "Saudi Arabia 1950–80: Between Nationalism and Religion," *Middle Eastern Studies,* October 1994, Vol. 30, No. 4, pp. 930-943.

[15] Ibid.

[16] Frederic Wehrey, "The Forgotten Uprising in Eastern Saudi Arabia" (Washington, D.C.: Carnegie Endowment for International Peace, June 14, 2013), http://carnegieendowment.org/2013/06/14/forgotten-uprising-in-eastern-saudi-arabia; Toby Craig Jones, "Rebellion on the Saudi Periphery: Modernity, Marginalization, and the Shia Uprising of 1979," *International Journal of Middle East Studies*, May 2006, Vol. 38, No. 2, p. 223.

[17] Orlando Crowcroft, "Saudi Arabia's Shia and Riyadh's Other War - 'The Language of Hatred is Getting Worse,'" *International Business Times*, April 8, 2015, http://www.ibtimes.co.uk/saudi-arabias-shia-riyadhs-other-war-language-hatred-getting-worse-1495364

[18] "Reporting Saudi Arabia's Hidden Uprising," BBC, May 30, 2014, http://www.bbc.com/news/world-middle-east-27619309

Tensions grew further in the fall of 2015 when nearly 800 participants in the annual Muslim pilgrimage (Hajj) to Mecca were killed in a stampede.[19] Over half of the victims were Iranian. Following the incident, Saudi Arabia executed a top Shiite cleric for terrorism in January 2016. In response, protesters stormed the Saudi embassy in Tehran, leading the Kingdom to severe ties with Iran.[20] In an interview with *The Economist* shortly thereafter, the Saudi Minister of Defense, Prince Mohammad Bin Salman Al-Saud, blamed Iran for the escalation, downplaying the effect of the execution on bilateral relations. The high-profile minister emphasized that "direct conflict is something that we do not foresee at all, and whoever is pushing towards that is somebody who is not in their right mind. Because a war between Saudi Arabia and Iran is the beginning of a major catastrophe in the region, and it will reflect very strongly on the rest of the world. For sure we will not allow any such thing."[21]

In 2012, Saudi Arabia accused Iran of being behind cyber attacks targeting the Saudi state oil producer, Aramco. The attack, known as Shamoon, damaged three quarters of the company's computers and required five months to recover at "an extreme cost." In 2016 and 2017, media reports and a U.S. State Department security report indicated that "Shamoon 2" had resurfaced in attacks against fifteen Saudi governmental and non-governmental organizations; however, it was less destructive.[22] Iran's willingness to use cyber attacks to cause destruction to Saudi national interests will likely serve as a new form of exacerbating tensions between the two countries.

The Saudi press also continues to publish incendiary rhetoric about Iran, as evidenced by Saudi officials accusing Iranian religious leaders of seeking to politicize the Hajj. One article in the Saudi daily *Okaz* accused Iran's mullahs of targeting the safety and stability of the Kingdom. It also claimed Supreme Leader Ayatollah Ali Khamenei incited spies to execute terror acts in the Kingdom.[23] In May 2016, Iran announced that its pilgrims would not participate in the upcoming Hajj after claiming Saudi Arabia could not ensure its citizens' safety.[24]

Saudi leaders believe that as Iran becomes increasingly emboldened as a result of the nuclear deal and further acts with impunity in its destabilizing activities in the region, it may have domestic repercussions like the uprisings seen in Qatif.[25] The sudden influx of frozen assets and

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[19] Monica Sarkar, "Iran to Saudis: Our Pilgrims Will Not Take Part in Hajj," CNN, May 30, 2016, http://www.cnn.com/2016/05/30/middleeast/iran-saudi-hajj/

[20] Ben Brumfield, Yousuf Basil, and Catherine E. Schoichet, "Saudi Arabia Severs Ties with Iran as Mideast Protests Rage," CNN, January 4, 2016, http://www.cnn.com/2016/01/03/middleeast/saudi-arabia-executes-dozens-terror/

[21] "Transcript: Interview with Muhammed bin Salman," *The Economist*, January 6, 2016, http://www.economist.com/saudi_interview

[22] Bill Gertz, "Iran Renews Destructive Cyber Attacks on Saudi Arabia," *Washington Free Beacon,* February 22, 2017, http://freebeacon.com/national-security/iran-renews-destructive-cyber-attacks-saudi-arabia/

[23] [Translated] "Speeches Reveal Iran's Involvement in Politicizing Hajj," *Okaz*, May 18, 2016, http://www.okaz.com.sa/new/Issues/20160518/Con20160518840054.htm

[24] "Iran to Saudis: Our Pilgrims Will Not Take Part in Hajj."

[25] Loveday Morris and Hugh Naylor, "Arab States Fear Nuclear Deal Will Give Iran a Bigger Regional Role," *The Washington Post*, July 14, 2015, https://www.washingtonpost.com/world/middle_east/arab-states-fear-dangerous-iranian-nuclear-deal-will-shake-up-region/2015/07/14/96d68ff3-7fce-4bf5-9170-6bcc9dfe46aa_story.html

funds provided by the lifting of sanctions have, from the Saudis' view, facilitated additional Iranian or client group aggression and activities in the region. The fear that Iran would misuse the additional money for '"nefarious activities"' is pointed out by Foreign Minister Adel al-Jubeir in his January 2016 interview along with the statement that Saudi Arabia "would do 'whatever we need to do in order to protect our people.'"[26]

According to U.S. State Department cables obtained by WikiLeaks, the late King Abdullah privately warned U.S. officials in 2008 that if Iran acquired nuclear weapons, "everyone in the region would do the same, including Saudi Arabia."[27] In an interview with *The Daily Telegraph* in June 2015, Saudi Arabia's ambassador to London said knowledge of Iran's pursuit of a nuclear weapon "changed the whole outlook in the region."[28] As stated above, Prince Mohammed bin Nawwaf bin Abdulaziz al-Saud said that if negotiations between Iran and the P5+1 (or the countries that negotiated the JCPOA – the United States, Britain, France, China, Russia, and Germany) fail to ensure a commitment to refrain from obtaining a nuclear weapon, "then all options will be on the table for Saudi Arabia."

Sadqa bin Yehia Fadel, a member of Saudi Arabia's Consultative Council, published an article in *Okaz* in August 2015, saying the Kingdom had completely excluded the military nuclear option; however, the insistence of countries like Israel and Iran to retain this option might force the Kingdom to reconsider its decision.[29]

Shortly after the JCPOA was signed, as discussed above, King Salman met with President Obama at the White House during a visit to Washington D.C. in September 2015. Following the meeting, Saudi Foreign Minister al-Jubeir said the Kingdom was satisfied with reassurances from the Obama administration regarding the nuclear deal with Iran.[30] "We believe this agreement will contribute to security and stability in the region," al-Jubeir said. Despite satisfaction with the deal, Saudi Arabia appears to remain concerned with regional players' nuclear ambitions.

Opinion poll results published in October 2015, shortly after the Iran deal was signed, showed that the Saudi public was split over the agreement, with approximately 42 percent describing it in negative terms and 39 percent believing it to be "fairly good."[31]

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[26] "Exclusive: Saudi Arabia Warns against 'Nefarious Activities' by Iran."
[27] Jason Burke, "Riyadh Will Build Nuclear Weapons if Iran Gets Them, Saudi Prince Warns," *The Guardian,* June 29, 2011, https://www.theguardian.com/world/2011/jun/29/saudi-build-nuclear-weapons-iran
[28] "The Saudis Are Ready to Go Nuclear."
[29] Sadqa bin Yehia Fadel, "Saudi Nuclear Politics," *Okaz*, August 2, 2015, http://www.okaz.com.sa/new/Issues/20150802/Con20150802786966.htm
[30] Doina Chiacu, "Saudi Arabia Welcomes Iran Nuclear Deal After Obama Meeting- Foreign Minister," Reuters. September 4, 2015, http://af.reuters.com/article/worldNews/idAFKCN0R42CU20150904
[31] David Pollock, "New Saudi Poll Shows Iran, Russia, United States, and ISIS Are All Unpopular; Mixed Views on Others" (Washington, D.C.: The Washington Institute for Near East Policy, October 22, 2015), http://www.washingtoninstitute.org/policy-analysis/view/new-saudi-poll-shows-iran-russia-united-states-and-isis-are-all-unpopular-m

Since the discovery of Iran's enrichment program, heated debates between the United States and Iran have occurred over whether or not Iran has the "right to enrich" under the NPT. Article IV of the NPT states: "Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination."[32] This is interpreted by Iranian officials to mean that they have the right to research and maintain internal control of all aspects of the nuclear fuel cycle, including uranium enrichment. The United States has taken the view that the NPT does not give Iran the unqualified right to enrich, emphasizing that the right to enrich is conditional on demonstrating a peaceful nuclear program, a step Iran has yet to accomplish under the JCPOA. In that sense, the JCPOA allowed Iran to operate a limited uranium enrichment program under heightened IAEA monitoring while it demonstrates to the IAEA that its program is peaceful.

However, the JCPOA created the precedent that a country in violation of its safeguards agreement could maintain a uranium enrichment program, albeit with additional restrictions. Despite that caveat, Iran has continued to advance that it has an absolute right to enrich under the NPT. Iran's view has gained regional support. Former Minister of Foreign Affairs for the Egyptian government, Nabil Fahmy, proposed a four-point plan for nuclear security in the Middle East whereby the third point proclaims: "Arab countries- all members to the NPT-should preserve their right to enrich and reprocess nuclear material under International Atomic Energy Agency safeguards, even if they do not all have the intention to exercise that right in the near future."[33] This opinion was also expressed by a member of the Kingdom's intelligence community at the Munich Security Conference, where he stated that "we should insist on having equal rights for everybody, this is part of the [Nuclear Nonproliferation Treaty] arrangement."[34]

On balance, the Iran nuclear deal has created a precedent that may create complications for stemming nuclear proliferation. By leaving Iran's enrichment infrastructure intact and allowing it to continue enriching uranium, it may be difficult for the United States or others in the international community to argue in the future against another state's enrichment plans.

In a lengthy 2016 interview with the *Bulletin of the Atomic Scientists*, Prince Turki al Faisal re-emphasized Saudi Arabia's public position to be "absolutely" in favor of a nuclear weapons free zone in the Middle East. Al-Faisal previously announced the kingdom's position in his 2013 paper: "A Political Plan for a Weapons of Mass Destruction-Free Zone (WMDFZ) in the Middle East."[35] In the paper, al Faisal stated, "It is the right of all nations - including Israel and Iran - to

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[32] *Treaty on the Non-Proliferation of Nuclear Weapons,* 729 UNTS 161, July 1, 1968.

[33] Nabil Fahmy, "Egyptian Concerns on the P5+1/Iran Joint Comprehensive Plan of Action" (Oslo: Norwegian Institute of International Affairs, September 28, 2015), http://www.nupi.no/en/News/Egyptian-Concerns-on-the-P5-1-Iran-Joint-Comprehensive-Plan-of-Action#

[34] Nuclear Threat Initiative, "Report: Saudi Arabia Wants Uranium-Enrichment Capacity," February 14, 2014, http://www.nti.org/gsn/article/saudi-arabia-reportedly-wants-develop-full-nuclear-fuel-cycle/

[35] Prince Turki al-Faisal, "A Political Plan for a Weapons of Mass Destruction-Free Zone (WMDFZ) in the Middle East" (Cambridge: Harvard University Belfer Center, July 9, 2013),

have nuclear programs for peaceful uses if they are transparent and under the supervision of the IAEA." Al-Faisal noted that the Kingdom is pursuing nuclear energy to decrease its dependence on fossil fuels. It seeks to pursue $50 billion in contracts with multiple countries to build nuclear reactors over the next two decades. He emphasized that although every country has the right to pursue a civilian nuclear energy program, Iran should not "parlay" that into pursuing a nuclear weapon. Failing to create a nuclear weapons-free zone in the Middle East "will incentivize all countries in the area to undertake what may prove to be a fateful decision that will expand nuclear proliferation rather than confirm security and peace," al-Faisal wrote.

In a mid-2016 column in *al-Riyadh*, military and strategic analyst Ibrahim al-Marie wrote that the P5+1 are allowing Iran to expand in the region at the expense of Arab national security. Al-Marie argued the United States sees that Iran having a nuclear weapon would threaten Israel; however, allowing Iran to expand at the expense of Arab countries perpetuates the Persian-Arab conflict and diverts attention from focus on tensions with Israel.[36]

In May 2016, Abdullah Ibrahim al-Askar, a member of the Saudi Consultative Council, published an article in *al-Riyadh* titled, "Iran Will Not Change."[37] Al-Askar wrote that those who are optimistic about the nuclear deal forget that the Iranian constitution stipulates that the Iranian revolution will be exported. This means "Iran will not stop exporting sectarian expansion always coupled with terrorism." Al-Askar pointed out that Iran creates and supports terror groups like Hezbollah in Lebanon and the Houthis in Yemen, in addition to spreading sectarianism in African countries. He stated that the world has watched Iran's behavior during and after the deal, and serious observers say the deal will not last long despite the international community's hopes.

In September 2016, an op-ed in *Okaz* addressed the concern of many Saudi youth – that Iran may be in a better position than the Kingdom due to its nuclear program and success at controlling Arab capitals like Baghdad, Beirut, and Sanaa. The article argued against this belief by saying that Iran is weakened due to high poverty levels and unemployment.[38]

Disincentives. Saudi Arabia is expected to continually weigh these incentives to acquire advanced nuclear capabilities (which possibly include the ability to weaponize fissile material and deliver a nuclear weapon) against a considerable list of disincentives. For starters, Saudi Arabia would jeopardize its good standing in the international community, which it has

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http://belfercenter.hks.harvard.edu/publication/23220/political_plan_for_a_weapons_of_mass_destructionfree_zone_wmdfz_in_the_middle_east.html?breadcrumb=%2Fexperts%2F2837%2Fprince_turki_al_faisal;
D. Drollette, "View from the Inside: Prince Turki Al-Faisal on Saudi Arabia, Nuclear Energy and Weapons, and Middle East Politics," *Bulletin of the Atomic Scientists,* Vol. 72, Issue 1, January 2, 2016, http://thebulletin.org/2016/january/view-inside-prince-turki-al-faisal-saudi-arabia-nuclear-energy-and-weapons-and-middle-east-politics9074

[36] [Translated] Ibrahim al-Marie, "The Equation which the United States seeks in the Middle East," *Al-Riyadh*, June 5, 2016, http://www.alriyadh.com/1508975

[37] [Translated] Abdullah Ibrahim al-Askar, "Iran will not change," *Al-Riyadh*, May 18, 2016, http://www.alriyadh.com/1503857

[38] [Translated] Khalaf al-Harbi, "Is Iran Better Than Us?" *Okaz*, September 4, 2016, http://bit.ly/2dKkjiE

established through signing several treaties and joining nonproliferation regimes. These include the NPT, IAEA, Convention for the Suppression of Acts of Nuclear Terrorism, Proliferation Security Initiative (PSI), Convention on the Physical Protection of Nuclear Material (CPPNM), and 2005 amendment of the CPPNM.

Following the discovery of a covert program, Saudi Arabia would risk severe United Nations and other countries' sanctions. While economic in nature, the sanctions take on a security dimension because Saudi Arabia's economy is predominantly reliant on its oil exports. They accounted for nearly 50 percent of gross domestic product and about 85 percent of export earnings in 2015.[39] Its imported reactors would also likely remain dependent on the supply of low enriched uranium fuel. Therefore, a targeted sanctions regime focused on Saudi oil exports and imported nuclear fuel could cripple its economy and hurt its security. On the other hand, the countries and organizations applying sanctions would have to weigh their own significant energy and security demands against concerns that Saudi Arabia could get advanced nuclear capabilities. Saudi Arabia's contribution to the global oil market (which is roughly three times greater than that of Iran) grants it substantial leverage in determining global oil prices.[40] As such, establishing a credible sanctions regime targeting Saudi oil would pose a difficult choice for the oil-dependent West. This will be particularly true if some in the international community become sympathetic to a Saudi desire to obtain a nuclear deterrent to balance Iran.

The threat of potential sanctions would also carry great weight in Saudi Arabia's nuclear weapons calculus as the government is facing its largest budget deficit in history. It is currently seeking to diversify its energy usage in order to sell more oil abroad rather than use it domestically at an expensive loss.[41] If there is a decrease in revenue, the Saudis would be unable to spend as much money balancing Iranian influence in neighboring countries as they are now.

Moving to a sanctions regime would likely depend on the detection of a covert program. Due to its limited use of nuclear material, Saudi Arabia signed a CSA with an old model SQP in 2005, and the agreement went into force in 2009. There has been controversy within the IAEA about the Saudis' desire to use the old model SQP, which is less robust than newer ones. IAEA inspections are limited under the current arrangement since the Saudi nuclear material inventory does not exceed one effective kilogram and it has no nuclear facilities such as a reactor in place.[42] Certain reporting requirements are also held in abeyance. Once nuclear material exceeds one effective kilogram and it has a nuclear facility, Saudi Arabia will need to conclude subsidiary arrangements including detailed facility attachments, inspection

[39] "Saudi Arabia Facts and Figures" (Austria: Organization of Petroleum Exporting Countries, last modified 2015), http://www.opec.org/opec_web/en/about_us/169.htm

[40] Colin H. Kahl, Melissa G. Dalton, and Mathew Irvine, "Atomic Kingdom: If Iran Builds the Bomb, Will Saudi Arabia Be Next?" (Washington, D.C.: Center for a New American Security, February 2013), pp. 19-20.

[41] Fredric Wehrey, "Saudi Arabia's Anxious Autocrats," *Journal of Democracy*, Vol. 26, No. 2, p. 82.

[42] The term "one effective kilogram" is used by the IAEA to reflect the mass value of total uranium, e.g. standardizing quantities of natural uranium versus enriched uranium. See IAEA, *Nuclear Material Accounting Handbook,* Services Series 15 (Vienna: May 2008), p. 6, http://www-pub.iaea.org/MTCD/Publications/PDF/svs_015_web.pdf

arrangements, and reporting requirements. As of December 2015, the IAEA had not conducted any inspections in the Kingdom.[43] This is why the IAEA's 2015 conclusion about Saudi Arabia confirms peaceful use of *declared* nuclear material, but it cannot make a definitive statement on whether there is potentially *undeclared* material, leaving Saudi Arabia with a "conclusion" instead of the desired "broader conclusion."[44] As stated, Saudi Arabia has not ratified the Additional Protocol (AP).[45]

Iran, by comparison, also had a CSA in place in the early 2000s and no Additional Protocol, but was subject to frequent inspections. Yet, Iran was still conducting a range of undeclared nuclear activities which escaped the IAEA's detection. The IAEA's limited familiarity with Saudi Arabia, including its sites, institutions, and scientists, may make the detection of a covert program especially difficult. Under its SQP, facilities have to be declared six months before they start to operate. This means Saudi Arabia could start the construction of nuclear facilities without notifying the IAEA.

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[43] Olli Heinonen and Simon Henderson, "Nuclear Kingdom: Saudi Arabia's Atomic Ambitions" (Washington, D.C.: Washington Institute for Near East Policy, March 27, 2014), http://www.washingtoninstitute.org/policy-analysis/view/nuclear-kingdom-saudi-arabias-atomic-ambitions

[44] IAEA, "The Safeguards Implementation Report for 2015," May 3, 2016, https://armscontrollaw.files.wordpress.com/2016/10/iaea-2015-sir.pdf

[45] Nuclear Threat Initiative, "Country Profiles: Saudi Arabia - Treaties," last modified April 2015, http://www.nti.org/country-profiles/saudi-arabia/treaties/

Part II: Nuclear Infrastructure

Ambitious Nuclear Plans

Saudi Arabia is staunchly committed to developing nuclear energy. In October 2016, the Saudi Council of Ministers reaffirmed the Kingdom's right to a peaceful nuclear energy program.[46]

Saudi Arabia has impressive nuclear goals and has made agreements with numerous international partners. However, progress in building nuclear reactors has been very slow. Saudi Arabian scientists have conducted a myriad of feasibility studies regarding the development of nuclear power plants that date back to the 1970s, although most of these plans have never been realized.[47] Still, the Kingdom's goal is to have nuclear power plants produce 20 percent of Saudi Arabia's electricity capacity by 2020.[48] Whether this goal is achievable is highly doubtful.

Saudi Arabia appears interested in the complete fuel cycle. In a presentation at an IAEA conference side event in 2015, the head of research, development, and innovation at KA.CARE, the national agency at the forefront of Saudi Arabia's nuclear agenda, identified steps and specific components of the nuclear power cycle that have "high localization potential." They are identified through their combination of economic attractiveness and comparative advantage. Listed loosely from high comparative advantage to medium comparative advantage, these steps and components include: operation and maintenance, valves, mining and milling, engineering, pipes, pumps, radioactive waste, fuel fabrication, construction, spent fuel, and processing and enrichment.[49]

In 2010, Saudi Arabia's KA.CARE contracted Poyry, a Finland-based global engineering consulting firm, to draft an economic and technical feasibility study for its nuclear program. In working with KA.CARE, it became clear that "Saudi Arabia would want to play a role in as many of the stages of generating nuclear power as possible eventually."[50] In addition, as the study came to a close, Poyry's president for energy at the UK branch reported that enrichment and

[46] [Translated] "Saudi Renews its Confirmation of the Right of the Program to Use Peaceful Nuclear Energy," Kuwait News Agency, October 10, 2016, http://www.kuna.net.kw/ArticleDetails.aspx?id=2537502&language=ar
[47] Mark Fitzpatrick, *Nuclear Programmes in the Middle East: In the Shadow of Iran* (London: International Institute for Strategic Studies, 2008), p. 41.
[48] [Translated] Naif al-Waeil, "Nuclear Saudi...Dream Project for the Future of Energy is Brighter and Safer," *al-Riyadh,* June 22, 2015, http://www.alriyadh.com/1058888
[49] Maher Al Odan, Head of Research & Development & Innovation, KA.CARE, "KACARE's Sustainable Energy Initiatives," *PowerPoint Presentation at an IAEA 59th General Conference Side Event,* Vienna, September 16, 2015, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2015/2015-09-16-NPTDS/6_SAUDI_Odan_SMR_GC_SE_16Sept.pdf
[50] Amena Bakr, "Saudi Arabia May Enrich Uranium for Nuclear Power Plants," *The Daily Star*, June 18, 2010, http://www.dailystar.com.lb/News/Middle-East/2010/Jun-18/85927-saudi-arabia-may-enrich-uranium-for-nuclear-power-plants.ashx

mining were feasible in Saudi Arabia, though initially they would rely on outsourcing their needs.[51] The results of this study have not been made public.

A European government official knowledgeable about Saudi Arabia stated to our Institute in 2014 that Saudi Arabia's pursuit of the scientific and engineering expertise necessary to take command of all aspects of the nuclear fuel cycle was ongoing.

Despite these ambitious plans, Saudi Arabia has neither power nor research reactors. Its nuclear infrastructure consists of ion accelerators and cyclotrons. Two accelerators, a 3000 kilovolt Tandetron accelerator, and a 350 kilovolt light-ion accelerator, are utilized for experiments in nuclear physics.[52]

A Multitude of Nuclear Cooperation Agreements

In May 2008, the United States and Saudi Arabia signed a MoU on Civil Nuclear Energy Cooperation. According to a Department of State press release:

> *The United States will assist the Kingdom of Saudi Arabia to develop civilian nuclear energy for use in medicine, industry, and power generation and will help in development of both the human and infrastructure resources in accordance with evolving International Atomic Energy Agency guidance and standards. Saudi Arabia has stated its intent to rely on international markets for nuclear fuel and to not pursue sensitive nuclear technologies, which stands in direct contrast to the actions of Iran.*[53]

This understanding has not led to orders for nuclear reactors from the United States. The fact that this memorandum did not evolve into an official 123 agreement forswearing the development of indigenous fuel cycle capabilities suggests that Saudi Arabia seeks to maintain the option of developing such capabilities, possibly including reprocessing and uranium enrichment.

This view is reinforced by a private U.S. initiative that started prior to 2014 that sought to sell Saudi Arabia reactors with a guaranteed supply of enriched uranium fuel, where the low enriched uranium would be produced in a Saudi-funded U.S. gas centrifuge plant. In return, the Kingdom would commit not to reprocess the spent fuel or build an indigenous enrichment plant. The plan was for the spent fuel to be removed to a third party country for storage or disposal. Despite initial hopes, this plan has stalled. According to a person knowledgeable

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[51] Ibid.

[52] Colin H. Kahl, Melissa G. Dalton, and Mathew Irvine, "Atomic Kingdom: If Iran Builds the Bomb, Will Saudi Arabia Be Next?" (Washington, D.C.: Center for a New American Security, February 2013), p. 21; Mark Fitzpatrick, *Nuclear Programmes in the Middle East: In the Shadow of Iran* (London: International Institute for Strategic Studies, 2008), p. 41.

[53] Department of State, Office of the Spokesman, "U.S.-Saudi Arabia Memorandum of Understanding on Nuclear Energy Cooperation," Press Release, May 16, 2008, http://2001-2009.state.gov/r/pa/prs/ps/2008/may/104961.htm

about the discussions, the reasons included turnover in the Royal Family leadership and the price of oil. He added that Saudi Arabia gave the impression they were willing to accept no enrichment or reprocessing, but the JCPOA may have given them second thoughts, further suggesting that Saudi Arabia is keeping its fuel cycle options open.

The Kingdom has pursued cooperation with many other countries, where reprocessing or enrichment is not banned as a condition of the supply of reactors. A wide array of international nuclear agreements have followed, which may dramatically change Saudi Arabia's limited nuclear infrastructure.

In 2014, Saudi Arabia announced its plan to build 16 or more reactors over the next 20 years. A 2013 study proposed three sites: "Jubail on the Persian Gulf and Rabuk and Jizan on the Red Sea," as nuclear reactor sites that would total about 18 gigawatts of electrical power.[54] A 2016 study proposed ten further sites for nuclear reactors. According to the Saudi magazine *al-Muhandis*, a nuclear power plant would be established along each of several small canals in the vast desert region in the south in order to produce up to 50 gigawatts of electricity.[55] For these plans, Saudi Arabia solicited aid from or signed agreements with a variety of countries, including Russia, France, China, Argentina, Hungary, Finland, Jordan, and South Korea. The scope and scale of these agreements are quite extensive.

A 2015 agreement signed with Russia appeared to envision the largest number of power reactors provided by a single country, in addition to research reactors and fuel cycle services. At an international forum in Moscow in 2016, Rosatom confirmed plans to build up to 16 reactors in Saudi Arabia.[56] The project is scheduled until 2030 and estimated to cost $100 billion.[57] As reported by the World Nuclear Association:

> *A June 2015 agreement with Rosatom provided for cooperation in the field of nuclear energy, including: the design, construction, operation and decommissioning of nuclear power and research reactors, including desalination plants and particle accelerators; the provision of nuclear fuel cycle services, including nuclear power plants and research reactors; the management of used nuclear fuel and radioactive waste management; the production of radioisotopes and their application in industry, medicine and agriculture; and the education and training of specialists in the field of nuclear energy.*[58]

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[54] "Saudis update ambitious nuclear energy plans," *Neutron Bytes,* September 2, 2014, https://neutronbytes.com/2014/09/02/saudis-update-ambitious-nuclear-energy-plans/

[55] Miteb Al-Awad, "KSA Plans Largest Artificial Oil Canal," *Saudi Gazette*, April 20, 2016, http://saudigazette.com.sa/saudi-arabia/ksa-plans-largest-artificial-oil-canal/

[56] Nasser Al-Haqbani, "Moscow Highlights Strategic Partnership with Riyadh, Readiness to Contribute to the Construction of 16 NPP in KSA," VIII International Forum, ATOMEXPO 2016, Moscow, June 29, 2016, http://english.aawsat.com/2016/06/article55353534/moscow-highlights-strategic-partnership-riyadh-readiness-contribute-construction-16-npp-ksa

[57] "Russia offers to build 16 nuke power plants in Kingdom," *Saudi Gazette*, September 6, 2016, http://saudigazette.com.sa/saudi-arabia/russia-offers-build-16-nuke-power-plants-kingdom/

[58] "Nuclear Power in Saudi Arabia," *World Nuclear Association*, updated October 2016, http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Saudi-Arabia/

The agreement seems to assign responsibility for "management of used nuclear fuel"[59] to Russia's Rosatom, which usually means that Saudi Arabia would export its spent fuel to Russia. Because spent fuel from power reactors typically contain a large amount of plutonium, these exports would limit the ability or, at least, the motivation of Saudi Arabia to develop a civilian reprocessing program. No specific reactor type was mentioned in the public announcement, but it is assumed that the discussions would involve large nuclear power reactors. However, as far as could be determined, Saudi Arabia has so far shown general interest in smaller Russian reactors, including the Russian ABV 6-M, a small, pressurized floating light water reactor (LWR).[60] This reactor, with an electrical power of 8.5 megawatts-electrical (MWe) requires fuel with higher levels of enrichment. Fuel for the Russian ABV-6M is enriched to almost 20 percent (19.7 percent).[61] It would have to be re-fueled only once every 10 years. Saudi Arabia has also shown interest in the OBKM KLT-40S, a 70 MWe floating power plant run on near 20 percent enriched uranium.[62,63] From past experience, the "side-deals" of a nuclear reactor export, including potential transfer of sensitive knowledge and technology, could indicate proliferation sensitivity and should be carefully observed.

Saudi Arabia has also signed an agreement with South Korea to build reactors. In 2011, the two countries signed a MoU. In 2015, the Kingdom contracted with the Korea Atomic Energy Research Institute (KAERI) to look at "the feasibility of constructing two reactors in Saudi Arabia." These System-Integrated Modular Advanced Reactors (or SMART reactors) are 330 megawatt-thermal (MWth), pressurized water reactors with integral steam generators, advanced safety features, a 60-year life span, and three-year refueling cycle at a cost of $1 billion each.[64] SMART is designed for generating up to 100 MWe of electricity generation, as well as seawater desalination. In June 2016, the Korea Electric Power Corporation for Engineering and Construction along with KAERI signed a contract to build a SMART nuclear reactor in Saudi Arabia. According to an article published in *Okaz*, the project will last "30 months until November 2018." Because it uses U.S. technology, the Korean company needs a U.S. license to build a nuclear reactor with an advanced integrated system;[65] however, it is

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[59] Ibid.

[60] "Development Of Reactor Safety Concepts And Nuclear Desalination System," Sustainable Energy Center at King Saud University, Web page, Accessed December 2016, https://set.ksu.edu.sa/en/node/332; IAEA, "Status of Small and Medium Sized Reactor Designs," September 2011, https://www.iaea.org/NuclearPower/Downloads/Technology/files/SMR-booklet.pdf

[61] IAEA, *Status of Small and Medium Sized Reactor Designs: A Supplement to the IAEA Advanced Reactors Information System (ARIS),* September 2012, https://www.iaea.org/NuclearPower/Downloadable/SMR/files/smr-status-sep-2012.pdf

[62] Maher Al Odan, Head of Research & Development & Innovation, KA.CARE, "KACARE's Sustainable Energy Initiatives," *PowerPoint Presentation at an IAEA 59th General Conference Side Event,* Vienna, September 16, 2015, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2015/2015-09-16-NPTDS/6_SAUDI_Odan_SMR_GC_SE_16Sept.pdf

[63] IAEA ARIS, "KLT," 2013, https://aris.iaea.org/sites/..%5CPDF%5CKLT-40S.pdf

[64] "Saudi Arabia Teams Up With Korea on SMART," World Nuclear News, March 4, 2015, http://www.world-nuclear-news.org/NN-Saudi-Arabia-teams-up-with-Korea-on-SMART-0403154.html

[65] [Translated] "Saudi-Korean Partnership to Build a SMART Nuclear Reactor," *Okaz,* June 12, 2016, http://www.okaz.com.sa/new/Issues/20160612/Con20160612843679.htm

likely that this license will be granted. According to a U.S. government official, it is certain that the reactor will be built.

The SMART reactor uses fuel made of standard low-enriched uranium dioxide.[66] No public information can be found that states whether the fuel supply or spent fuel management are part of the agreement. The reactor comes with a 60-year on-site spent fuel storage, so its fuel is likely to stay in Saudi Arabia during its lifetime.[67]

Saudi Arabia has expressed interest in developing the ability to manufacture small modular reactors (SMRs), such as SMART. During a presentation at an IAEA General Conference side event in 2015, the head of research, development, and innovation at KA.CARE announced that Saudi Arabia has a "desire for full IP [Intellectual Property] ownership of NSSS technology".[68] NSSS stands for Nuclear Steam Supply System, and it "consists of the reactor core, helically coiled steam generators and a pressurizer integrated in the reactor pressure vessel."[69] This, and other information found in the presentation, may indicate ambitions to develop the ability to make and perhaps export SMRs.

A second memorandum of understanding between Saudi Arabia and South Korea was signed in November 2016, aimed at cooperation over nuclear safety regulations.[70] The MoU was signed at KA.CARE headquarters in Riyadh. KA.CARE released a statement afterward which stated, "The MOU aims at exchanging experiences and practices in the areas of regulating nuclear safety, safeguards and physical protection, radiation protection and relevant research, as well as development in a manner to serve atomic energy programs in the Kingdom of Saudi Arabia." The memorandum was a culmination of five years of discussions.

In 2012, during a visit by Chinese Premier Wen Jiabao to Saudi Arabia, the two countries signed a nuclear agreement to cooperate on "maintenance and development of nuclear power plants and research reactors, and manufacturing and supply of nuclear fuel elements."[71] Four years later, in January 2016, President Xi Jinping and King Salman confirmed a MoU between the two countries signed by the president of KA.CARE Hashim bin Abdullah Yamani and China Nuclear

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[66] Jong-Tae Seo, KEPCO Engineering and Construction Company, "Small and Modular Reactor Development, Safety and Licensing in Korea," *Presentation to the IAEA Technical Working Group on Light Water Reactors,* Vienna, June 18-20, 2013, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-06-18-06-20-TWG-NPTD/35-korea-smr.pdf

[67] Won Jae Lee, Korean Atomic Energy Research Institute, "The SMART Reactor," *Power Point Presentation at the 4th Annual Asian-Pacific Nuclear Energy Forum,* Berkeley, California, June 18-19, 2010, http://www.uxc.com/smr/Library%5CDesign%20Specific/SMART/Presentations/2010%20-%20The%20SMART%20Reactor.pdf

[68] "KACARE's Sustainable Energy Initiatives."

[69] IAEA, "Advances in Small Modular Reactor Technology Developments," 2016 ed., August 2016, https://aris.iaea.org/Publications/SMR-Book_2016.pdf

[70] "Saudi Arabia and South Korea to Cooperate in Nuclear Regulation," World Nuclear News, November 28, 2016, http://www.world-nuclear-news.org/NP-Saudi-Arabia-and-South-Korea-to-cooperate-in-nuclear-regulation-2811165.html

[71] Summer Said, "Saudi Arabia, China Sign Nuclear Cooperation Pact," *The Wall Street Journal,* January 16, 2012, http://www.wsj.com/articles/SB10001424052970204468004577164742025285500

Engineering Corporation (CNEC) chairman Wang Shu Jin. Under the agreement, China will supply Saudi Arabia with a high-temperature gas-cooled reactor (HTR).[72] Neither the timeline nor the cost of the project are known.

A Chinese HTR has a capacity of 500 MWth, or 211 MWe, a fuel cycle of 1057 days, and a reactor lifetime of 40 years. Its fuel contains uranium dioxide, enriched to 8.5 percent uranium-235 (U-235).[73] The contract would be expected to come with a life-time fuel supply.

An agreement with France set in to motion feasibility studies concerning the construction of two European Pressurised Reactors (EPR).[74,75] The EPR is a very powerful reactor, capable of producing 1650 MWe. It has a life-span of 60 years, a refueling cycle of 1-2 years, and can be used with different fuels: low enriched uranium (LEU), mixed oxide (MOX) fuel, or reprocessed uranium.

An article in the Saudi magazine *al-Muhandis* addressed discussions with Areva, the French-operated nuclear company, about cooperation with regard to training, development, and organizing conferences in the field of nuclear energy.[76] Secretary-General of the Saudi Council of Engineers, Dr. Hussein al-Fadhli, met with Areva's manager for business development in the Middle East, Amer Abdulaziz al-Rajiba. Following the meeting, al-Fadhli said the coming period will witness greater cooperation between the council and a number of public and private authorities.

An Argentinian agreement created a joint venture company to develop nuclear technology. Invania was the offspring of Taqnia (Saudi Arabia) and Invap (Argentina), two R&D companies.[77] Argentina may supply a small reactor, such as the CAREM (Central Argentina de Elementos Modulares) mainly for desalination purposes.[78,79] The CAREM is a medium-sized, 25 MWe

[72] "China, Saudi Arabia Agree to Build HRT," World Nuclear News, January 20, 2016, http://www.world-nuclear-news.org/NN-China-Saudi-Arabia-agree-to-build-HTR-2001164.html

[73] IAEA Advanced Reactors Information System, "Status report 96 - High Temperature Gas Cooled Reactor - Pebble-Bed Module (HTR-PM)," 2011, https://aris.iaea.org/sites/..%5CPDF%5CHTR-PM.pdf

[74] "France, Saudi Arabia Announce $12B in Deals," Agence France-Presse. June 24, 2015, http://www.defensenews.com/story/defense/international/mideast-africa/2015/06/24/france-to-study-building-nuclear-reactors-in-saudi-arabia/29213887/

[75] "France to Study Reactor Construction in Saudi Arabia," World Nuclear News, June 26, 2015, http://www.world-nuclear-news.org/NP-France-to-study-reactor-construction-in-Saudi-Arabia-2606154.html ; "Nuclear Power in Saudi Arabia," *World Nuclear Association*, updated October 2016, http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Saudi-Arabia/

[76] Miteb Al-Awad, "KSA Plans Largest Artificial Oil Canal," *Saudi Gazette*, April 20, 2016, http://saudigazette.com.sa/saudi-arabia/ksa-plans-largest-artificial-oil-canal/

[77] "Saudi Arabia and Argentina Form Joint Venture," World Nuclear News, March 9, 2015, http://www.world-nuclear-news.org/NP-Saudi-Arabia-and-Argentina-form-joint-venture-0903158.html

[78] Sustainable Energy Center at King Saud University website, https://set.ksu.edu.sa/en/node/332

[79] Jim Green, "Saudi Arabia's Nuclear Power Program and its Weapons Ambitions," *Nuclear Monitor Online*, September 18, 2014, https://www.wiseinternational.org/book/export/html/4195

pressurized water reactor. It is fueled with LEU (3.1 percent enriched) and has a fuel cycle of 14 months.[80] Argentina may also provide hot cells for this reactor.[81]

A Finnish agreement signed in 2014[82] with Saudi Arabia focuses on setting up advisory and safety infrastructures, and a Hungarian agreement signed in 2015 focuses on safety and research cooperation.[83]

In 2014, an article in *Kyodo News International* reported that Saudi Arabia and Japan were "accelerating" talks for cooperation on civil nuclear energy, including the potential for Japanese manufacturers to export reactors to the Kingdom.[84] No additional talks have occurred.

Jordan and Saudi Arabia signed an agreement for cooperation in the field of nuclear energy for peaceful purposes in January 2014. The agreement was signed by President of KA.CARE, Dr. Yamani, and the president of Jordan's Atomic Energy Commission, Dr. Khaled Toukan. Under the agreement, Saudi Arabia and Jordan will cooperate in various fields of nuclear energy. This includes basic and applied research in the field of nuclear energy science, design, construction, and operation of nuclear power plants or research reactors. The agreement also includes cooperation in the excavation, mining/metallurgy, and treatment of raw materials. Saudi Arabia and Jordan are also set to collaborate in the field of managing radioactive waste and the exploitation of associated minerals. In addition, the agreement includes cooperation in the field of innovative technologies for the new generations of nuclear reactors and their engineering, radioisotope production activities, radiation techniques and their application, nuclear safeguards, observation of nuclear materials and their audit, preparation of legislation, laws, and nuclear regulation guidelines. Finally, they will collaborate in the field of safety, nuclear peace, protection from radiation, environment protection, and the preparation of human resources. In a statement to the press, Dr. Yamani confirmed the importance of the agreement to achieving mutual benefit from information and expertise.[85]

Saudi Arabia has expressed interest in a wide variety of reactors. According to KA.CARE, the "target list" of nuclear reactors includes several SMRs which run on LEU, each with a re-fueling cycle of 24 months. The list includes: the B&W mPower, NuScale, Westinghouse SMR, Holtec

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[80] IAEA, *Status of Small and Medium Sized Reactor Designs: A Supplement to the IAEA Advanced Reactors Information System (ARIS),* September 2012, https://www.iaea.org/NuclearPower/Downloadable/SMR/files/smr-status-sep-2012.pdf

[81] "Saudi Arabia's Nuclear Power Program and its Weapons Ambitions."

[82] [Translated] "Finish-Saudi Cooperation to Implement Unified Nuclear Law," *Al Khaleej Online*, September 6, 2014, http://bit.ly/2hioaXz

[83] "Hungary, Saudi Arabia Agree to Cooperation," World Nuclear News, October 20, 2015, http://www.world-nuclear-news.org/NP-Saudi-Arabia-Hungary-agree-to-cooperation-2010155.html; "Finland to Help Saudi Arabia Set Up Nuclear Regulator," Nuc Net, May 5, 2014, http://www.nucnet.org/all-the-news/2014/05/05/finland-to-help-saudi-arabia-set-up-nuclear-regulator?no_redirect=true

[84] [Translated] "The Kingdom and Japan Agree to Accelerate Talks for a Peaceful Nuclear Agreement," *Ajel*, February 19, 2014, http://www.ajel.sa/local/1243326

[85] [Translated] Prince Maged, "Saudi-Jordan Cooperation Agreement in the Field of Nuclear Energy," *a-Sharq al-Awsat*, January 23, 2014, http://archive.aawsat.com/details.asp?section=6&article=758703&issueno=12840#.V2KwhbsrKUk

SMR-160, KAERI SMART, CNNC ACP-100, SNPTC CAP-150, CNEA CAREM, DCNS Flexblue, Politecnico di Milano (Westinghouse) IRIS, OKBM Afrikantov KLT-40S, and OKBM Afrikantov VBER-300.[86] Of the not previously discussed reactors, the B&W mPower, NuScale, Westinghouse, and Holtec are American SMRs, which run on near five percent LEU with a re-fueling cycle of 24 months. They mostly differ in power output, with the Westinghouse SMR being the most powerful (800 MWth) and NuScale being the least powerful (160 MWth).[87] The thermal power of the Holtec SMR-160 is unknown.[88] The China National Nuclear Corporation (CNNC) ACP-100 and the SNPTC CAP-150 are Chinese SMRs run on LEU (less than five percent). The ACP-100 has a re-fueling cycle of two years and a power output of 310 MWth. The CAP-150 has a re-fueling cycle of three years and a power output of 450 MWth.[89] DCNS Flexblue is a French underwater, 530 MWth pressurized water reactor. It runs on less than five percent enriched uranium. The re-fueling cycle is 40 months. The reactor has to stop electricity production to refuel.[90]

The IRIS (International Reactor Innovative and Secure) is a medium-sized light water reactor run on LEU. Its power output is up to 1000 MWth.[91] The reactor is designed by an international team of engineers and seems unlikely to be built.[92] Neither heavy water nor research reactors of the types most suitable for application in a nuclear weapons program are on KA.CARE's priority list.

Taking Stock. Although the Kingdom's long term nuclear power future remains largely unclear, the most recent agreements with France and South Korea called for feasibility studies projected to last at least three years, after which reactor construction could begin if conditions were favorable.[93] Thus, it is reasonable to project that Saudi Arabia is on a trajectory to build nuclear power reactors.

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[86] "KACARE's Sustainable Energy Initiatives."
[87] "About Generation mPower," Generation mPower, Accessed January 2017, http://www.generationmpower.com/#technology; "How NuScale Technology Works," NuScale Power, accessed January 2017, http://www.nuscalepower.com/our-technology/technology-overview; Small Modular Reactor by Westinghouse, Westinghouse, Accessed January 2017, http://www.westinghousenuclear.com/New-Plants/Small-Modular-Reactor
[88] "SMR-160 Overview," Holtec International, Accessed December 2016, https://smrllc.com/technology/smr-160-overview/
[89] Zhen Mingguang, "Small Reactors R&D in China," *Presentation at the TWG-LWR meeting,* Vienna, June 18 - 20, 2013, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-06-18-06-20-TWG-NPTD/36-snerdi-china-smr.pdf
[90] KnE Energy, "ICoNETS Conference Proceedings International Conference on Nuclear Energy Technologies and Sciences," International Conference on Nuclear Energy Technologies and Sciences (2015), Bali, Indonesia, October 15-16, 2015, http://knepublishing.com/index.php/KnE-Energy/issue/view/39
[91] Mario D. Carelli et al., "IRIS (International Reactor Innovative and Secure) – Design Overview and Deployment Prospects," International Conference on Nuclear Energy for New Europe, Bled, Slovenia, September 5-8, 2005, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/37/104/37104800.pdf
[92] Ux Consulting Company, "SMR Design Profile," August 14, 2012, https://www.uxc.com/smr/uxc_SMRDetail.aspx?key=IRIS.
[93] Ibid.

With all the discussions on obtaining nuclear reactors, which would use significant quantities of nuclear material, Saudi Arabia will need to fully implement its CSA. An article in *Al Hayat* from November 2015 reported, "A Saudi authority revealed yesterday that his country went beyond the stage of limited quantities of enriched uranium to full application which supports Saudi's nuclear program…" referring to statements by Dr. Yamani, president of KA.CARE. Dr. Yamani said that this allowed Saudi Arabia to obtain nuclear technology for peaceful purposes.[94] Despite the use of the past tense, our Institute interprets this direct translation as a sign that Saudi Arabia is preparing to fully implement the CSA. Whether it will also ratify the Additional Protocol is unknown.

Leading Research at Academic Institutions and Publications

Contrary to common belief, Saudi Arabia does not have a complete lack of nuclear knowledge. According to the Center on Contemporary Conflict, "Saudi Arabia started a nuclear weapons program in 1975 under the command of the Saudi Minister of Defense, operated from Al-Kharu nuclear research center."[95] This information could not be confirmed. Nevertheless, Saudi Arabia has accumulated knowledge and expertise, some of which is potentially sensitive, in the nuclear field for decades. While none of the research conducted prior to 1990 can be necessarily claimed to be in response to Iran's nuclear program, or prior to 2015 in response to the nuclear deal, this knowledge is regardless Saudi Arabia's base for current and future research and development. In accordance with its limited CSA, i.e. SQP, nuclear activities at most research centers are theoretical in nature. Several academic and official research interests, activities, and capabilities are discussed below from a proliferation standpoint.

KA.CARE and Other Research Institutions. Saudi Arabia has five nuclear research centers: the King Faisal Research Center in Riyadh (KFSHRC), the Sustainable Energy Center at King Saud University, the Atomic Energy Research Institute in Riyadh, the King Abdul Aziz City for Science and Technology, and the King Abdullah City for Atomic and Renewable Energy or KA.CARE.

KA.CARE is at the forefront of Saudi Arabia's nuclear agenda, overseeing all energy related projects, including funding and implementation of contracts. This nuclear body appears to be under the sole purview of the King and seems to prioritize atomic energy projects over renewable energy. As of 2016, however, there is no evidence of hands-on research on the production of fissile material. Nevertheless, all of the research centers seem to have laboratories with the capacity to perform nuclear experiments on a small scale.

Founded in 2010, KA.CARE is now tasked with analyzing the Kingdom's renewable energy resources and establishing a Nuclear Holding Company (NHC) responsible for building and

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[94] [Translated] "Yamani: Saudi Arabia Moved To 'Full Application' To Enrich Uranium," *Al-Hayat*, November 4, 2015, http://bit.ly/2agc75k

[95] Friedrich Steinhausler, "Infrastructure Security and Nuclear Power" (Monterey: Naval Postgraduate School Center on Contemporary Conflict, *Strategic Insights,* 2009), http://www.dtic.mil/dtic/tr/fulltext/u2/a534515.pdf

operating nuclear power plants."[96] KA.CARE disperses funds and expertise to other universities and research centers. Scientists in KA.CARE's nuclear research program focus on developing technology related to reactors, radioisotopes, and radiation. The center has an independent, annual budget and is responsible "for supervising and controlling all works related to the use of atomic energy." KA.CARE proposed that the Kingdom install 17 gigawatts of nuclear power in 2012, "but it has not yet laid out plans to do so."[97] KA.CARE president, Dr. Hashim Yamani, announced delays to the Kingdom's ambitious plans in 2015. Despite originally aiming to develop 17 gigawatts of nuclear power by 2032, now the Kingdom hopes to achieve this by 2040.[98]

In 2015, changes in leadership of energy policies lead to King Salman being the sole authority over the nuclear program, and to prioritizing nuclear over solar plans.[99]

KA.CARE president, Dr. Hashim Abdullah Yamani, obtained a PhD and a master's degree in physics from Harvard University. In addition, Dr. Yamani holds two degrees from Berkeley. He was a guest professor at the University of Bielefeld in Germany and a postdoctoral fellow at the University of Ontario. He represented Saudi Arabia at the Nuclear Security Summit in Washington in 2012, 2012, 2014, and 2016.[100] Yamani appears capable of transforming Saudi Arabia's nuclear program from novice to advanced, considering his solid educational background and extensive experience in the field.

To prepare the next generation of specialized engineers for its peaceful nuclear program, KA.CARE is sending 40 Saudi engineering students from three different universities to visit companies and specialized reactors, hosted by Electricite de France (EDF) and Areva. Students spent from three to seven months in training at engineering facilities and at nuclear power plants owned by the companies in France and Germany.[101] In addition, KA.CARE, in cooperation with King Abdulaziz University in Jeddah, will send 16 nuclear engineering students to France for a seven-week program and another group to South Korea for an eight-week

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[96] "Climate Change Legislation in Saudi Arabia," an excerpt from *The 2015 Global Climate Legislation Study: A Review of Climate Change Legislation in 99 Countries* (London: London School of Economics, Grantham Institute, 2015), http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/05/SAUDI_ARABIA.pdf

[97] Angus McDowall, "Saudi Arabia Considers Its Own Nuclear Options After Iran Deal," Reuters. July 21, 2015, http://www.reuters.com/article/us-iran-nuclear-saudi-nuclear-idUSKCN0PV1GC20150721

[98] "Saudi Arabia's Nuclear, Renewable Energy Plans Pushed Back," Reuters. January 19, 2015, http://www.reuters.com/article/saudi-nuclear-energy-idUSL6N0UY2LS20150119

[99] "Saudi Arabia: The Supreme Council of the King Abdullah City for Atomic and Renewable Energy (KA-Care) disbanded," Middle East News Agency, April 2, 2015, http://www.eversheds.com/global/en/what/articles/index.page?ArticleID=en/Energy/saudi-arabia-ka-care-disbanded-150204

[100] Simon Henderson, "Saudi Snub at the Nuclear Summit" (Washington, D.C.: The Washington Institute for Near East Policy, March 30, 2016), http://www.washingtoninstitute.org/policy-analysis/view/saudi-snub-at-the-nuclear-summit

[101] [Translated] Naif al-Waeil, "Nuclear Saudi...Dream Project for the Future of Energy is Brighter and Safer," *al-Riyadh*, June 22, 2015, http://www.alriyadh.com/1058888

program in the summer of 2016.[102] Not all training is short-term, however. Saudi Arabia's National Transformation Program 2020 includes a program in partnership with the Korean Atomic Energy Research Institute (KAERI) to train 30 Saudi engineers for three years, participating in the design of SMART reactors.[103]

Under the umbrella of KA.CARE, KACST operates the Nuclear Science Research Institute. This institute is divided into five centers, including the National Center for Irradiation Technology, National Center for Applied Radiation Technology, National Center for Accelerators Technology, National Center for Nuclear Technology, and the Nuclear Regulatory Unit.[104] The website for KACST's National Center for Nuclear Technology promotes nuclear technology as important to establish an advanced society, using nuclear energy to produce electricity and desalinate water.[105] The center mentions the potential to use radiation to produce radioisotopes for medical or industrial uses. The center also emphasizes the need for capacity building in technical nuclear fields.

The Atomic Energy Research Institute (AERI), also under KACST, is responsible for creating "a regulatory framework for the objectives, strategy, and applications of nuclear technologies in conjunction with relevant authorities in KSA."[106] AERI is also responsible for determining the Kingdom's need for nuclear technology experts, increasing knowledge of nuclear technology among the general populace, publishing information, and attracting new experts.

An additional minor research center is the Sustainable Energy Center (SET) at King Saud University. Its English-language website lists nuclear energy as one of its sectors of energy research, but it does not include details.[107] Under the website's section on technology, SET addresses nuclear safety applications in response to Fukushima. Finally, it mentions Saudi Arabia's agreement with South Korea to build SMART nuclear reactors developed by KAERI.[108] It states:

> *At SET center, we are developing theoretical model and conduct simulation for reactor safety specifically for small modular reactors. Currently, our main emphasize (sic) is on developing safer model for SMART reactor with coupled desalination unit. We have*

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[102] King Abdullah City for Atomic and Renewable Energy, "Summer Training Program for Nuclear Engineering Students in Korea and France, 2016," June 26, 2016, http://bit.ly/29rzf58

[103] King Abdullah City for Atomic and Renewable Energy, "Starting a Program to Build Capacity for the SMART Project," June 12, 2016, http://bit.ly/29tqOSo

[104] Nuclear Sciences Research Institute, King Abdulaziz City for Science and Technology, https://www.kacst.edu.sa/eng/rd/NSRI/pages/NSRI.aspx

[105] King Abdulaziz City for Science and Technology, "Nuclear Techniques," https://www.kacst.edu.sa/eng/RD/Pages/content.aspx?dID=75

[106] Atomic Energy Research Institute website, Accessed Summer 2016, http://www.kacst.edu.sa/en/about/institutes/Pages/ae.aspx

[107] King Saud University, Sustainable Energy Technologies Center, "Energy: Leading the Way in Energy Technologies Research," https://set.ksu.edu.sa/en/node/310

[108] King Saud University, Sustainable Energy Technologies Center, "Development of High Performance Thermoelectric Energy Harvester for Nuclear Safety Applications," https://set.ksu.edu.sa/en/node/331

already performed technical and economical analysis for three reactors namely ABV, CAREM and SMART.[109,110]

The reactors are discussed above.

On SET's Arabic-language website, the center offers more details about its nuclear energy research. Students focus their research efforts on the potential for using nuclear reactors for desalination and energy "through selecting the technologies and appropriate locations in Saudi Arabia."[111] Students also perform research on the application of radioisotopes in medicine and industry, analysis and design of a nuclear reactor used for desalination and electricity, and the extraction of uranium from phosphate ore. It appears that SET consults on radiation protection, health physics, and their scientists' views regarding the expected nuclear energy reactor in Saudi Arabia. Training at SET includes education on analysis of reactor design and nuclear fuel, radiation protection, safety, and applications for safe radiation.

The KFSHRC focuses on the medical applications of nuclear science. Here, three cyclotrons, a C-30, CS-30 and RDS-111 cyclotron (30, 26.5 and 11 MeV, respectively), are used to produce medical isotopes.[112] In theory, a cyclotron can be misused to irradiate uranium to Pu-239 or thorium to U-233; however, the machines are so small that it would take several hundreds of years to produce a 'critical mass' for a nuclear explosive.[113] While cyclotrons are not feasible to produce sufficient quantities of fissile material, they can be used to experiment and conduct research useful for nuclear energy purposes. The CS-30 was used to produce C-11, Pd-103, and I-123[114] and is, as of 2013, used to "produce Krypton and other non-standard isotopes such as I-124 and Cu-64."[115] None of them is related to uranium or thorium, but they are used for general research on nuclear reactions, such as for "nuclear reaction cross-section measurements."[116] The KFSHRC has also been producing Tc-99m generators for medical procedures since 2013.[117] A Tc-99m generator is, however, of no proliferation risk. Tc-99m is a decay product of Mo-99, which is typically produced in research reactors by irradiating and fissioning U-235 in enriched uranium targets, often highly enriched uranium (HEU). However, a

[109] Sustainable Energy Center at King Saud University website, https://set.ksu.edu.sa/en/node/332
[110] Russian, Argentine, and South Korean reactor designs, respectively.
[111] Sustainable Energy Center at King Saud University website, http://set.ksu.edu.sa/ar/8
[112] F. Alrumaya, M. Shawoo, and M. Vora, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, "Status Report of the Cyclotrons C-30, CS-30, and RDS-111 at KFSHRC, Saudi Arabia," *Proceedings of Cyclotron2013,* Vancouver, BC, Canada, 2013, http://accelconf.web.cern.ch/AccelConf/CYCLOTRONS2013/papers/moppt001.pdf
[113] Seth A. Hoedl and Derek Updegraff, "Medical Isotopes without Reactors or Uranium Enrichment," PONI Summer Conference, 2013, http://csis.org/files/publication/130807_Hoedl.pdf
[114] IAEA, "Directory of Cyclotrons used for Radionuclide Production in Member States," 2006, http://www-naweb.iaea.org/napc/iachem/cyclotrons/PDF/DCRP.pdf
[115] F. Alrumaya, M. Shawoo, and M. Vora, "Status Report of the Cyclotrons C-30, CS-30, and RDS-111 at KFSHRC, Saudi Arabia," King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, 2013, http://accelconf.web.cern.ch/AccelConf/CYCLOTRONS2013/papers/moppt001.pdf
[116] "Directory of Cyclotrons used for Radionuclide Production in Member States."
[117] "KSA Feat in Nuclear Medicine," Arab News, December 23, 2013, http://www.arabnews.com/news/497131

Tc-99m generator does not produce Mo-99; it only stores it.[118] One open question is whether the Kingdom will seek a research reactor to make Mo-99 for domestic use and sale in the region. So far, Saudi Arabia has promoted the world-wide usage of cyclotrons for Mo-99 production, which avoids the need for a research reactor and the need for enriched uranium.[119]

None of this equipment or these particular activities at KFSHRC are unusual or a direct proliferation risk. The knowledge and expertise needed to operate the above-mentioned devices is basic and is assessed by experts at the Nuclear Threat Initiative (NTI) as not applying to the development of nuclear weapons.[120]

The one exception could be hot cells. Because many of these isotopes are highly radioactive, they need to be handled in hot cells. Within the KFSHCR laboratory are a number of hot cells of unknown size.[121] Hot cells over a certain size can cause concern because they could be used in small-scale plutonium separation or irradiated fuel reprocessing experiments. For example, under the Iran nuclear deal, hot cells exceeding six cubic meters are banned unless expressly allowed by the executive body of the JCPOA, and allowed ones are subject to IAEA monitoring. Regardless of the size of the Kingdom's hot cells, so far, Saudi Arabia does not have any irradiated fuel it could use in such experiments. Nonetheless, learning more about these hot cells and limiting the size of any future ones makes sense. In addition, the IAEA should report on its knowledge of these hot cells.

Academic Infrastructure. As of 2016, Saudi Arabia has 38 official universities,[122] at least five of which offer nuclear related degree programs or teach nuclear related subjects: King Abdulaziz University in Jeddah, King Abdullah University of Science and Technology in Dhahran, King Faisal University in Abha, King Khalid University in Abha, and King Saud University in Riyadh.[123] The growth of the academic nuclear energy sector in past years emphasizes Saudis ambition to modernize and to equip the future generation with "technical nuclear capabilities."[124]

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[118] United States Food and Drug Administration, "TECHNETIUM Tc99m GENERATOR," Accessed January 2016, http://www.accessdata.fda.gov/drugsatfda_docs/label/2013/017693s025PI.pdf

[119] Joanie Dix, IAEA, "IAEA Activities Supporting Mo-99 Production without the use of HEU," ^{99}Mo Topical Meeting, Washington, D.C., June 24-27, 2014, http://mo99.ne.anl.gov/2014/pdfs/presentations/S5P3%20Presentation%20Dix.pdf

[120] Nuclear Threat Initiative, "Profile for Saudi Arabia," last modified April 2015, http://www.nti.org/country-profiles/saudi-arabia/

[121] A.S. Al-Kheliewi, "The Role and Responsibility of the National Regulator of Radiation Sources and Materials in Saudi Arabia," IAEA International Conference on Effective Nuclear Regulatory Systems: Further Enhancing the Global Nuclear Safety and Security Regime, Cape Town, South Africa, December 14 – 18, 2009, http://www-pub.iaea.org/mtcd/meetings/cn177p.asp

[122] 4International Colleges and Universities, "Top Universities in Saudi Arabia," 2016 University Web Ranking, Accessed December 2016, http://www.4icu.org/sa/

[123] Islamic-World Science Net, "Universities in Kingdom of Saudi Arabia," http://www.icpsr.org.ma/default.asp?Page=universities&countryID=SaudiArabia

[124] [Translated] Naif al-Waeil, "Nuclear Saudi...Dream Project for the Future of Energy is Brighter and Safer," *al-Riyadh,* June 22, 2015, http://www.alriyadh.com/1058888

At King Abdulaziz University's College of Engineering, under the Department of Nuclear Engineering, students are prepared in the field of nuclear energy technologies, the production and use of radioisotopes, radiation protection, and medical physics engineering.[125] Additionally, the school offers training in the fields of energy, engineering of nuclear reactors, and medical physics engineering through bachelors and graduate degree programs. One of the departments specifies its goal as the spread of "nuclear engineering culture and the Arabization of its sciences."[126] The Department of Nuclear Energy focuses on the physics of reactors and their dynamics, the transfer of heat in nuclear reactors, the design of nuclear reactors, radiation measurements, radiation protection, industrial applications of radiation, and medical applications of radiation.

King Abdullah University of Science and Technology does not offer a nuclear energy-focused degree program. However, the study of nuclear energy is included in some courses related to the Materials Science and Engineering Program[127] and the Physical Science and Engineering Division.[128]

At King Faisal University, the Department of Physics in the College of Science was established in 2002.[129] The department does not appear to have an emphasis on the study of nuclear physics, but it has a number of modern research devices.

King Khalid University announced openings for the 2015-2016 academic year to teach four different nuclear-related courses.[130] One opening for male or female applicants in the College of Science included course specialties in nuclear physics, solid-state physics, laser physics, atomic physics, nanophysics, theoretical physics, optics, and radiation physics. In the College of Applied Medical Science, specializations include nuclear medicine and radiation. In the departments of science, at women's colleges, a physics course included specializations in nuclear radiation physics and nuclear physics theory.

At King Saud University, in the College of Science's Department of Physics and Astronomy, there are seven research groups, according to an outline of the doctoral program from 2009-2010[131]

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[125] College of Engineering, Department of Nuclear Engineering, King Abdulaziz University, "About the Department of Nuclear Engineering," May 4, 2010, http://bit.ly/2h84iWK
[126] Ibid.
[127] King Abdullah University of Science and Technology, 2009 https://www.kaust.edu.sa/admissions/downloads/KAUST-grad-programs.pdf
[128] King Abdullah University of Science and Technology, "Physical Science and Engineering Division: 2015/2016 Program Guide," https://pse.kaust.edu.sa/Documents/PSE%20Division%20Program%20Guide.pdf
[129] [Translated] King Faisal University, Department of Physics, College of Science, "About the Department of Physics," https://www.kfu.edu.sa/ar/Colleges/Science/Departments/Dep_1/Pages/About.aspx
[130] King Khalid University, "The University Announces the Availability of Academic Jobs for 2015-2016 Year," http://www.kku.edu.sa/ar/node/2469/
[131] King Saud University, Department of Physics and Astronomy, College of Science, "PhD Program in Physics," 2009-2010, http://sciences.ksu.edu.sa/ar/node/585

and the master's degree program from 2010-2011[132] published on the university's website. They include the study of theoretical physics, nuclear physics, biomedical physics, materials science physics, laser and spectra physics, renewable energy and environmental physics, and astronomy.

A 2015 report by a lecturer at King Saud University, Naif al-Waeil, published in *al-Riyadh*, addressed the "brighter" and "safer" future for energy in a nuclear Saudi Arabia.[133] Al-Waeil re-emphasized the Kingdom's plan to build 16 nuclear energy reactors over the course of 20 years, worth $80 billion. These reactors are expected to produce 20 percent of the Kingdom's electricity. Other reactors, smaller in size and energy, will be used for desalination. Al-Waeil wrote that "one of the most important benefits of atomic energy is its contribution to the increase of high-level work opportunities, the establishment of technical nuclear capabilities, and the preparation of Saudi youth to become skilled leaders in coming years." Additionally, he wrote that atomic energy will contribute to development in industry for the future, including the development of atomic engineering, advanced research, nuclear reactor technology, and notably, fuel cycle research and development.

Research Publications

Research publications provide insight into nuclear programs of countries like Saudi Arabia. As a result, this study surveyed a wide range of scientific and engineering publications produced by Saudi Arabian academia and research centers. The research is both quantitative and qualitative in nature; topics include everything from detailed reactor technology and fuel cycle related work, to best practices in nuclear education and training. Based on a review of the published literature, Saudi Arabia is developing its technological and scientific nuclear infrastructure and creating a foundation upon which to build robust nuclear power capabilities. However, no indications were found that Saudi Arabia is specifically engaged in acquiring fuel cycle facilities beyond nuclear reactors. It has studied a range of activities associated with the fuel cycle, but these activities have not gone beyond theoretical studies, except with the possibility of uranium (see also next section).

Once this knowledge base is built, say over the next five to 10 years, however, Saudi Arabia would be in a favorable position to decide on building fuel cycle capabilities. Olli Heinonen, a former senior IAEA official, judges that Saudi Arabia is likely to decide on seeking sensitive fuel cycle technologies in as soon as five years.

Recent substantial research was not found on uranium enrichment technologies. In addition, a search was made for any work involving uranium hexafluoride gas, a key feed gas for gas centrifuges, gaseous diffusion, and certain types of laser enrichment. A possible indicator of uranium enrichment is research on uranium compounds but this review did not reveal concrete

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[132] King Saud University, Department of Physics and Astronomy, College of Science, "Master of Science in Physics," 2010-2011, http://sciences.ksu.edu.sa/ar/node/583

[133] [Translated] Naif al-Waeil, "Nuclear Saudi...Dream Project for the Future of Energy is Brighter and Safer," *al-Riyadh,* June 22, 2015, http://www.alriyadh.com/1058888

work on uranium hexafluoride. There is no indication that Saudi Arabia is synthesizing on a laboratory scale uranium fluorides or re-converting uranium metal alloys into uranium oxides (which could then be used to make uranium hexafluoride). Saudi Arabia does conduct a few hands-on experiments with uranium in general, but they are conducted on a small scale with natural uranium.[134]

Web of Science, a database of published scientific research, has collected only 167 publications affiliated with Saudi Arabian research institutions addressing uranium within the past 15 years. Iran, in comparison, has produced 390. Of the 167 publications, only around 50 are written independently, without collaboration with other nations' institutions. Most cooperation seems to be with China. Several of the domestically funded research efforts address extraction of uranium from acidic or aqueous solutions[135] -- techniques useful in various steps in the front-end of the nuclear fuel cycle. Uranium (VI) studies may be helpful in future enrichment programs because it is the oxidation form of uranium in uranium hexafluoride.

Public research focusing on fissile U-235 dates back to the 1980s, such as studies on fission of U-235 and fission yield,[136] or the production of Mo-99.[137] But these types of studies are not unusual.

In 2012, the Saudi government circulated a reference list for Saudi researchers on its Saudi Standards, Metrology and Quality Organization website.[138] Among others, links are provided for further information on transport of uranium hexafluoride and reprocessing of spent fuel. Specific uranium compounds are needed for the enrichment process, so knowing how to produce, handle, and store them would be crucial. Likewise, learning about reprocessing may not indicate a plan to build such plants, but merely an effort to be knowledgeable about such

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[134] For example, the following study was conducted at King Khalid University, using natural uranium oxide. See: Ahmed T. Mubarak, "Structural Model of Dioxouranium(VI) with Hydrazono Ligands," *Spectrochemica Acta Part A: Molecular and Biomolecular Spectroscopy,* Vol. 61, Issue 6, April 2005, pp. 1163-1170, http://www.sciencedirect.com/science/article/pii/S1386142504003385

[135] S. M. Yakout, "Effect of porosity and surface chemistry on the adsorption-desorption of uranium(VI) from aqueous solution and groundwater," *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 308, Issue 2, May 2016, pp. 555-565, http://link.springer.com/article/10.1007/s10967-015-4408-7; A. S. Al-Hobaib and A. A. Al-Suhybani, "Removal of uranyl ions from aqueous solutions using barium titanate," *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 299, Issue 1, January 2014, pp. 559-567, http://link.springer.com/article/10.1007/s10967-013-2772-8; O. Al-Dayel, "Determination of uranium by neutron activation analysis and delayed neutron counting," *Asian Journal of Chemistry,* Vol. 12, Issue 3, pp. 874-878, July 2000, https://www.researchgate.net/publication/286966955_Determination_of_uranium_by_neutron_activation_analysis_and_delayed_neutron_counting?_sg=Ne3tl-WoOFttV_plW9ovZEYtxE7FeYkTqXvXDGhctZ4HuJp1k-XQIXl4XM1TLa2d

[136] A. Naeem, "Engineering Measurements of Delayed Neutron Groups from 235U," *Journal of Engineering Sciences,* Vol. 4, 1978, pp. 31-37;
S. Sahin, A.A. Hassan and C. Chung, "Measurements of the Cumulative Fission Yield of 148Ce in 235U," *Radiation Effects,* Vol. 92, 1986, pp. 529-532.

[137] M. Ejaz and A.M. Mamoon, "Studies on the Recovery of 99Mo from Uranium Fission Products," Annual Meeting of the American Nuclear Society, Dallas, Texas, June 7-11, 1987.

[138] Saudi Standards, Metrology and Quality Organization, http://www.saso.gov.sa/en/pages/default.aspx

capabilities as nuclear power reactors are deployed. Nonetheless, Saudi Arabia appears to be slowly building up a detailed knowledge of the nuclear fuel cycle.

Published research on the back end of the fuel cycle, including plutonium or spent fuel, is available. Certain laboratories at Saudi Arabia's Atomic Energy Research Institute (AERI) research physical and chemical separation, as well as radiochemistry that could be used in plutonium separation, but "not in quantities that would present a proliferation risk."[139] Published scholarly articles, such as "Assessment of the global fallout of plutonium isotopes and americium-241 in the soil of the central region of Saudi Arabia" provide a glimpse into scale and sophistication of the conducted procedures.[140]

Research on reactor design, especially studies on modern hybrid fusion-fission reactors and light-water reactors, are common practice in Saudi Arabia. The same is true for detailed research using radioactive isotopes that are not fissile, and are not parents nor decay forms of fissile material.

Saudi Arabia has conducted research on Cm-244, which can be used in hybrid blankets for nuclear reactors and is potentially usable in nuclear explosives (its bare sphere critical mass is about 12 kilograms).[141] However, Cm-244 is not generally considered a proliferation risk because of its intense heat and radiation output, compared to other materials such as plutonium and HEU. Although the decay product of Cm-244 is Pu-240, this particular isotope is also very difficult to use in nuclear explosives.[142]

Also worth underscoring is Saudi Arabia's research on heavy water reactors, such as CANDU reactors, especially in combination with research on nuclear waste.[143] The studies on heavy water reactors are accompanied by studies on slow neutron flux.

Research on fast neutron flux conducted at the KFUPM Fast Neutron Activation Facility,[144] (probably mostly in the context of fast fission blankets for nuclear reactors), could, if necessary, be applied to the fission happening during a nuclear explosion.

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[139] *Nuclear Programmes in the Middle East.*

[140] Shabana EI and Al-Shammari HL., "Assessment of the global fallout of plutonium isotopes and americium-241 in the soil of the central region of Saudi Arabia," *Journal of Environmental Radioactivity,* Vol. 57, Issue 1, June 2001, pp. 67-74, http://www.sciencedirect.com/science/article/pii/S0265931X00002125

[141] S. Sahin and T. A. Al-Kusayer, "244 Cm as Multiplier and Breeder in a ThO2 Hybrid Blanket Driven by a (Deuterium-Tritium) Source," *Fusion Technology*, Vol. 10, pp. 1297-1302, 1986.

[142] The study used a tritium - deuterium source. Although these heavy isotopes of hydrogen are used to 'boost' or initiate fission nuclear explosives, the use of this source is not unusual for civilian experiments and applications.

[143] Ahmad Hussein and Dheya Al-Othmany, "Assessment of Aging of Zr-2.5Nb Pressure Tubes for Use in Heavy Water Reactor," *Journal of Natural Sciences Research,* Vol. 3, No. 2, 2013, http://www.iiste.org/Journals/index.php/JNSR/article/viewFile/4370/4433

[144] M.I. Al-Jarallah, A.A. Nagvi, Fazal-ur-Rehman and F. Abu-Jarad, "Fast and Thermal Neutron Intensity Measurements at the KFUPM PGNAA Setup," *Nuclear Instruments and Methods in Physics Research,* Section B, 2002, Vol. 195, pp. 435-441.

Non-technical publications can serve as an indicator of additional administrative and managerial priorities: Published papers with titles such as *Research Activities on Advanced Reactors*[145]and *Planning a Nuclear R&D Program*[146] show Saudi Arabia's interest in advanced research reactors. Research reactors were originally operated on HEU, before a global campaign was started to make them more proliferation-resistant. Now the majority of old reactors and almost all newly-built reactors run on LEU with a U-235 fraction of almost 20 percent. An example of Saudi interest in such a reactor is the above-discussed Russian ABV-6M, which operates on almost 20 percent enriched uranium.[147]

The reviewed publications suggest an earlier interest in understanding pathways to nuclear weapons. *Risk Assessment of Alternative Proliferation Routes* is a 1982 paper written by Shahid Ahmed and Abdo A. Husseiny, in which 11 routes for a non-nuclear country to become a nuclear weapon state are analyzed and compared.[148]

A similar paper is *The Connection Between Nuclear Industry and Atomic Weapons*, a study presented at the First Islamic Solidarity Conference in Science and Technology in 1976.[149] The conference seemed to have been the first and the last of that name, most likely because the King was assassinated on the night of the conference.[150]

One name appears frequently among publications -- Dr. Sumer Sahin. Turkish born and German educated, he has done extensive nuclear research, including at Saudi Arabian institutes. Topics include nuclear fission and explosives,[151] but also new proliferation-resistant reactor technologies. One of these new reactors is the fixed bed nuclear reactor (FBNR). In Turkish-Saudi collaboration, a criticality study of different fuels was conducted for the FBNR.[152]

Uranium Resources

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[145] Sumer Sahin and Tawfik A. Al-Kusayer, "Research Activities on Advanced Reactors at the King Saud University," Transactions of the Third International Conference of the American Nuclear Society, ICONTT-II, Madrid, Spain, 1985, pp. 46-48.

[146] Zeinab A. Sabri, A. Ezzedin, Abdo A. Husseiny, "Planning a Nuclear R&D Program: The Case of Saudi Arabia," *Transactions of the American Nuclear Society,* 1984, Vol. 46, pp. 47-50.

[147] IAEA, *Status of Small and Medium Sized Reactor Designs: A Supplement to the IAEA Advanced Reactors Information System (ARIS),* September 2012, https://www.iaea.org/NuclearPower/Downloadable/SMR/files/smr-status-sep-2012.pdf

[148] S. Ahmed and A.A. Husseiny, "Risk Assessment of Alternative Proliferation Routes*," Nuclear Technology*, Vol. 56, pp. 507-515.

[149] S. Sahin, "The Connection Between Nuclear Industry and Atomic Weapons," First Islamic Solidarity Conference in Science and Technology, University of Riyadh, Saudi Arabia, 1976.

[150] Sameen Ahmed Khan, "King Faisal Foundation and Its Awards," *Young Muslim Digest*, August, 2005, http://www.youngmuslimdigest.com/profile/08/2005/king-faisal-foundation-and-its-awards/

[151] One example is: "The Effects of 240 Pu on Neutron Lifetime in Nuclear Explosives," *Annals of Nuclear Energy*, Vol. 5, 1978, pp. 55-58. A list of his publications can be found on the Gazi University website, "Personal Data," Accessed January 2016, http://w3.gazi.edu.tr/~sumer/eng.htm

[152] Sumer Sahin et al., "Criticality investigations for the fixed bed nuclear reactor using thorium fuel mixed with plutonium or minor actinides," *Annals of Nuclear Energy,* Vol. 36, Issue 8, August 2009, pp. 1032-1038, http://www.sciencedirect.com/science/article/pii/S0306454909001790

Although our review did not find any evidence of work on developing sensitive fuel cycle facilities, it did find possible work on uranium exploration and early work on mining. Any country that would want to pursue nuclear weapons today or in the future would likely need a domestic source of uranium.

IAEA estimates put Saudi natural uranium deposits at 52,000-105,000 metric tons in three different sites (Al Jalameed, Ghurayyah, and Jabal Sayid). Two additional deposits lack an estimate of size.[153]

Sufficient weapon-grade uranium for a nuclear weapon would require the feedstock of about 10 metric tons of natural uranium. So, the Kingdom's uranium resources are more than sufficient for a nuclear weapons program.

The above amounts of natural uranium deposits would be sufficient to make roughly 5,200-10,500 metric tons of LEU, which is not a substantial amount for the nuclear power program ultimately envisioned by Saudi Arabia. It would likely require on-going imports of enriched uranium.

The status for Ghurayyah is "exploration," but that information was last updated in 2010.[154] In 2006 Tertiary Minerals PLC announced that it would consider "by-product recovery of the uranium" from ore in Ghurayyah. The World Information Service on Energy estimates the uranium contents to be 466,000 lbs of U_3O_8, or 179 metric tons of uranium, per year.[155] However, as of 2012, ore mining for various metals including zirconium seems to be suspended at Ghurayyah because of licensing renewal difficulties.[156]

The IAEA estimates the uranium grade range (in percent of uranium) to be at the very lowest end (0.01 - 0.05). At the Sayid site however, where mining of copper is already on-going,[157] sources report a much greater uranium concentration.[158]

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[153] "Uranium Deposits in Saudi Arabia," *World Distribution of Uranium Deposits*, IAEA INFCIS, https://infcis.iaea.org/UDEPO/UDEPOMain.asp?Region=The%20World&Country=Saudi%20Arabia&Type=All&Status=All&Order=1&DepositID=&DepositName=&RPage=1&Page=1&RightP=CountryReport

[154] Ibid.

[155] World Information Service on Energy, "New Uranium Mining Projects," updated February 2016, http://www.wise-uranium.org/upasi.html

[156] International Mining, Country Focus Saudi Arabia, "Mining in the Kingdom," August 2012, http://www.infomine.com/library/publications/docs/InternationalMining/Chadwick2012aa.pdf

[157] "Jabal Sayid," Byrnecut Offshore Pty Ltd., Accessed December 2016, http://byrnecutoffshore.com/projects/jabal-sayid-project-2/

[158] Yehia H. Dawood et al., "U-series isotopic composition of kasolite associated with aplite-pegmatite at Jabal Sayid, Hijaz region, Kingdom of Saudi Arabia," *Arabian Journal of Geosciences,* Vol. 7, Issue 7, pp. 2881-2892, July 2014, http://link.springer.com/article/10.1007/s12517-013-0963-9

Saudi Arabia may be looking to obtain uranium from West Africa for future nuclear programs.[159] In 2009, Saudi Arabia purchased approximately 1,235,526 acres of land in Tanzania. This purchase was mainly motivated by food production needs, and it is unclear from our investigation whether the land could include any of Tanzania's uranium deposits. Tanzania has uranium deposits of roughly 62,000 – 160,000 metric tons[160] and the potential to become a major producer.[161] The current government is even considering allowing uranium mining at the Selous Game Reserve, a World Heritage site.[162] Additionally, Saudi Arabia has reportedly expressed interest in South Africa's thorium supply, which can be used for nuclear fuel.[163] South Africa also has natural uranium, which it could sell to Saudi Arabia under safeguards.[164]

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[159] Nico Colombant, "Africa's Uranium Weights on World's Geopolitics," Voice of America, May 31, 2012, http://www.voanews.com/a/uranium-africa-iran/1145907.html

[160] "Uranium Deposits in United Republic of Tanzania," *World Distribution of Uranium Deposits*, IAEA INFCIS, https://infcis.iaea.org/UDEPO/UDEPOMain.asp?Region=The%20World&Country=United%20Republic%20of%20Tanzania&Type=All&Status=All&Order=1&DepositID=&DepositName=&RPage=1&Page=1&RightP=CountryReport

[161] "Tanzania Expected to Become Second-Biggest Uranium Producer," *Mining Weekly*, October 11, 2013, http://www.miningweekly.com/article/tanzania-expected-to-become-the-second-biggest-uranium-producer-2013-10-11/rep_id:3650

[162] "Open Letter: Uranium Mine Would Damage Selous World Heritage Site" (Switzerland: World Wide Fund for Nature, September 15, 2016), http://wwf.panda.org/wwf_news/?278214/Selous_uranium_letter

[163] Sue Blaine, "Thorium: 'SA's Best Kept Energy Secret,'" *Business Day*, February 16, 2011, http://www.bdlive.co.za/articles/2011/02/16/thorium-sa-s-best-kept-energy-secret

[164] David Albright with Andrea Stricker, *Revisiting South Africa's Nuclear Weapons Program: Its History, Dismantlement, and Lessons for Today* (Washington, D.C.: Institute for Science and International Security, 2016).

Part III: Pakistan

Allegations about Saudi Arabia's past and possibly on-going nuclear relationship with Pakistan arose many times during our review of open sources. Experts and media reports frequently noted that Saudi Arabia's route to nuclear weapons may be via Pakistan. For years, there has been speculation that Pakistan would sell or otherwise make available to the Kingdom nuclear weapons in a time of need.[165] The two countries have a history of cooperation, as aid flowed from Saudi Arabia to Pakistan's nuclear weapons program. Saudi Arabia financially backed Pakistan's nuclear weapons program in the 1970s, and Prince Sultan toured the country's uranium enrichment facility in 1999. Although such nuclear cooperation discussions cannot be excluded, a clear, binding agreement to provide nuclear weapons appears not to have been made, at least from Pakistan's perspective, according to knowledgeable government officials interviewed about this issue. As a result, we view the scenario of Saudi Arabia receiving nuclear weapons from Pakistan as highly unlikely, particularly given the impact such a sale could have on Pakistan's reputation and international relations. Academics have also tried to discredit this theory, citing recent improvement in Pakistan-Iran relations and Pakistan's recent refusal to support the Kingdom's military action in Yemen.[166]

However, nuclear cooperation cannot be excluded, some of which could be substantial. In August 2016, Saudi Deputy Crown Prince Mohamed bin Salman visited Islamabad and met with Pakistan's defense minister in a likely effort to strengthen defense ties.[167] Although it is unknown if Mohamed bin Salman and Pakistani officials discussed nuclear cooperation, the Crown Prince may have sought to renew closer nuclear relations with a nuclear-armed partner due to Saudi Arabia's concern over Iran's pursuit of atomic weapons.

The Institute did receive information from a Western government that a nuclear agreement with Saudi Arabia was mentioned in the Pakistani parliament in 2014 or 2015. We could not confirm this information.

A concern remains that Saudi Arabia may plan, or has undertaken, to receive nuclear assistance from Pakistan. This assistance could involve Pakistan supplying sensitive equipment, materials, and technology used in enrichment or reprocessing. An unanswered question is whether Pakistan and Saudi Arabia may be cooperating on sensitive nuclear technologies in Pakistan. In an extreme case, Saudi Arabia may be financing, or will finance, unsafeguarded uranium enrichment activities in Pakistan in return for nuclear material for use later in a civil or military program.

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[165] Mark Fitzpatrick, "Saudi Arabia, Pakistan and the Nuclear Rumor Mill" (London: International Institute for Strategic Studies, Survival Editors' Blog, May 20, 2015), https://www.iiss.org/en/politics%20and%20strategy/blogsections/2015-932e/may-7114/saudi-arabia-pakistan-and-the-nuclear-rumour-mill-1419

[166] Marvin G. Weinbaum, and Abdullah b. Khurram, "Pakistan and Saudi Arabia: Deference, Dependence, and Deterrence," *The Middle East Journal,* Vol. 68, No. 2, Spring 2014, pp. 211-228.

[167] Simon Henderson, "Prince Muhammad's Pakistan Detour" (Washington, D.C.: The Washington Institute for Near East Policy, August 29, 2016), http://bit.ly/2bxGOTW

Part IV: Nuclear Capable Missiles

A nuclear warhead is only one, albeit critical, part of a nuclear weapon. The other part is a delivery system. The most important of these are ballistic missiles. It is significant and concerning that in the 1980s, Saudi Arabia secretly purchased CSS-2 "East Wind," or DF-3, intermediate-range ballistic missiles (IRBMs) from China worth an estimated $3.5 billion.[168] According to a *Los Angeles Times* report, the Kingdom purchased between 20 and 24 CSS-2 missiles from China.[169] U.S. officials reportedly learned of this purchase from satellite reconnaissance, which showed a new missile site in the Arabian desert nearly two years after the fact. These missiles were originally designed to carry nuclear warheads; however, Chinese and Saudi officials said they would be utilized for conventional weaponry. Even in this period, Saudi Arabia may have sought increased missile capabilities to deter Iran and to gain leverage in terms of security ties with the United States. Saudi Arabia-China security relations never fully developed due to the latter's relationship with Iran, and the United States maintained its role as the Kingdom's primary security backer despite tensions in recent years.

An official 2013 U.S. *Ballistic and Cruise Missile Threat Assessment* mentions only Saudi Arabia as having less than 50 Chinese-made CSS-2 (conventional) missiles.[170] The maximum range is 4,000 kilometers, depending on payload, which is far enough to have the capability to strike several countries, including Israel and Iran. The missile is capable of delivering a single nuclear warhead.[171]

Further, in 2007, Saudi Arabia purchased additional missiles, called the DF-21 or CSS-5, from China. "The solid-fueled, medium-range DF-21 East Wind missiles are an improvement over the DF-3s [CSS-2s] the Saudis clandestinely acquired from China in 1988," reported *Newsweek*.[172] The DF-21 can be readied within minutes and has a precision of 30 meters, making it "accurate enough to be fired at smaller targets like headquarters, or compounds where senior leaders live."[173] *Newsweek* also reported that U.S. government experts ensured that they were not

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[168] Joseph A. Kechichian, "Saudi Arabia and China: The Security Dimension" (Washington, D.C.: The Middle East Institute, February 9, 2016), http://www.mei.edu/content/map/saudi-arabia-and-china-security-dimension

[169] Jim Mann, "Threat to Mideast Military Balance: U.S. Caught Napping by Sino-Saudi Missile Deal," *The Los Angeles Times,* May 4, 1988, http://articles.latimes.com/1988-05-04/news/mn-2143_1_saudi-arabia

[170] National Air and Space Intelligence Center with Defense Intelligence Agency, Space Intelligence Center, and Office of Naval Intelligence, *Ballistic and Cruise Missile Threat,* 2013, http://fas.org/programs/ssp/nukes/nuclearweapons/NASIC2013_050813.pdf

[171] Missilethreat.com, "Missiles of the World: CSS-2A" (Upland, CA: The Claremont Institute, updated May, 24, 2008), http://web.archive.org/web/20080524155801/http://www.missilethreat.com/missilesoftheworld/id.3/missile_detail.asp

[172] Jeff Stein, "Exclusive: CIA Helped Saudis in Secret Chinese Missile Deal," *Newsweek,* January 29, 2014, http://www.newsweek.com/exclusive-cia-helped-saudis-secret-chinese-missile-deal-227283

[173] "Artillery: Saudi Ballistic Missiles Secretly Upgraded," *Strategy Page*, February 10, 2014, https://strategypage.com/htmw/htart/articles/20140210.aspx

able to carry nuclear warheads.[174] However, another media report stated that these missiles could be made nuclear capable at a later date.[175]

In 2014, Saudi Arabia confirmed that it obtained the DF-21 from China. The Chinese news outlet *Xinhua Press* cited Saudi Arabia's newspaper *Okaz* and reported: "When asked about its new military purchase plan, Saudi Arabia's joint military commission adviser, retired rear general Anwar Eshqi [translated], confirmed that it obtained the DF-21 from China to 'protect two Muslim holy lands [Mecca and Medina] and its bay area allies."[176]

[174] "Exclusive: CIA Helped Saudis in Secret Chinese Missile Deal."

[175] "China Secretly Sold Saudi Arabia DF-21 Missiles without CIA Approval," *The Diplomat,* January 31, 2014, http://thediplomat.com/2014/01/china-secretly-sold-saudi-arabia-df-21-missiles-with-cia-approval/

[176] [Translated] 沙特首次证实从中国获得东风-21导弹 ["For the first time, Saudi Arabia confirmed to have obtained DF-21 from China,"] *Xinhua Press,* September 20, 2014, http://news.ifeng.com/a/20140920/42038660_0.shtml

Part V: Final Word

Although this report did not address the costs of Saudi Arabia creating a nuclear infrastructure, it is reasonable to conclude that it has the potential for establishing a substantial, broad-based nuclear infrastructure. It has the financial resources to educate a cadre of well-trained nuclear professionals, acquire nuclear technology, and create with foreign assistance a large nuclear program. In addition, the Kingdom has the financial means to acquire the capability to enrich uranium and separate plutonium, if it made the political decision to do so.

This survey of Saudi Arabia's nuclear capabilities and plans shows that its domestic nuclear program does not pose a proliferation risk in the near term, and the acquisition of domestic sensitive fuel cycle capabilities is at least several years away. The one uncertainty is its nuclear cooperation with Pakistan. That cooperation could short circuit Saudi Arabia's path to a nuclear weapons capability.

Moreover, for many more years, if not indefinitely, Saudi Arabia will be dependent on foreign supply of reactors and other nuclear and nuclear-related goods. Thus, the United States and its allies have great leverage over the future of the Kingdom's nuclear program. U.S. policy should be to prevent Saudi Arabia from obtaining sensitive nuclear facilities. It should of course not accept a move toward possession of nuclear weapons, or its immediate precursor, Saudi Arabia's withdrawal from the NPT. Drawing the policy line at the latter, namely the nuclear weapon itself, may end up undercutting efforts to prevent the acquisition of sensitive fuel cycle facilities. Since Saudi Arabia does not have domestic enrichment or reprocessing capabilities, preventing them now is easier than rolling them back after they gain them, as the Iran case shows.

It goes without saying that the Kingdom's motivation for getting nuclear weapons is tied to its relationship with Iran and, in particular, to the Iran nuclear deal. The current situation suggests that Saudi Arabia now has both a high disincentive to pursue nuclear weapons in the short term and a high motivation to pursue them over the long term. Acquiring nuclear weapons could become inevitable if the Iran deal is allowed to run its course. By year 15 of the deal, Iran expects to have installed a large uranium enrichment capability that would be hard to stop. Thus, from the point of view of preventing Saudi Arabia from seeking nuclear weapons, the nuclear constraints of the Iran deal need strengthening and Iran needs to be prevented from developing reprocessing programs or a large uranium enrichment program. As part of that effort, the United States should seek assurances from Saudi Arabia that it will not pursue uranium enrichment or reprocessing.