Facing the Nuclear Storm

Countries across the Middle East are building or have already started operating their nuclear power plants. To assess how "resilient" their nuclear energy systems are, one must look at a number of important risks and factors

By Ali Ahmad and Benedetta Bonometti

Soon enough, countries with nuclear power in the Middle East will have to face a storm when it comes to operating their power plants safely. That is why the focus on introducing resilient energy systems is receiving much attention in developed and developing countries alike. Across the globe, a variety of natural and human-induced risks and threats have caused substantial disruptions to the delivery of energy services and affected millions of people. From the massive July blackout in New York City that was linked to a sweltering heat wave to the conflicts in Yemen, Libya, and Syria that have caused power outages and severe damage to power generation and transmission, the need for resilient energy infrastructure is becoming more relevant than ever.

Energy resilience remains an evolving concept, but for now, it can be understood as the ability of an energy system to adapt to possible disruptive and challenging environments such as a tsunami or a heat wave, and to resume service provision swiftly. However, studies and experience have demonstrated the pivotal role that preemptive measures play when envisaging a resilient energy system.

The link between energy resilience and the proposals to build nuclear energy power plants across the region lies in the scale of the region's nuclear ambitions. Currently, there are six regional countries, including Iran, the United Arab Emirates (UAE), Egypt, Turkey, Jordan, and Saudi Arabia, which are developing nuclear power programs, with varied degrees of commitment. In a global energy landscape that is tilting toward renewable energy and an increased interest in decentralized systems, which combined together make for strong or resilient structures, one important question to ask is how the introduction of nuclear power will affect the resilience of national energy systems in these countries. This is especially important considering the exclusive set of risks associated with having a nuclear power program.

Nuclear Vulnerabilities and Disruptions

Understanding the resilience of proposed nuclear power plants in the Middle East requires a closer look at each stage involved in the generation of electricity

△ A hazard sign indicating radiation is seen in front of a containment shelter for the damaged fourth reactor at the Chernobyl nuclear power plant, April 24, 2012. *Reuters/Gleb Garanich*

from a nuclear reactor with respect to possible threats and consequences. The term "threat" refers to any event that might cause disruptions and enhance the vulnerability not only of the grid, but of the whole power system. Examples of threats range from weather conditions to disruptions of (enriched) uranium supplies and attacks on nuclear power plants.

Pre-operation risks

Nuclear power plant projects are exposed to numerous threats before they start operating. In fact, lengthy construction times, which are common in such projects, increase the probability of project cancellation before the plants start generating electricity. The years-long lead times, or in other words the time it takes to carry out financial and licensing procedures as well as construction, make nuclear projects vulnerable to financial and political risks and could lead to plant closure. The most common financial problems which arise from escalating costs and construction delays are due to either stringent licensing processes and/or project mismanagement.

Moreover, other sources of energy could become cheaper and more competitive, especially as gas or oil discoveries are made more often (such as the discovery of offshore gas fields like Egypt's Zohr). Nuclear energy programs in turn become highly sensitive political issues to the extent that a change of governments, as in the case of the so-called Arab Spring, might halt the construction of planned nuclear power plants.

Fuel supply

The main threat to front-end activities regarding fuel supply is the disruption of enriched uranium supply. Uranium fuel disruptions would more likely be linked to the regional political climate given that the global supply chains of uranium fuel face no major impediments. The model adopted by the UAE, which relies on the diversification of fuel suppliers, seems appropriate as it lowers the likelihood of a political disruption while taking advantage of competitive pricing. Additionally, the UAE procures its nuclear fuel for the Barakah nuclear power plant through its South Korean contractor, which has a commercial incentive to keep the reactors running since it also operates the facility and is a joint investor in the project. Therefore, for the UAE, the probability of a disruption to enriched uranium supplies is quite low.

In contrast to the UAE model, Iran has decided to carry out front-end activities within its borders. Since the Bushehr reactor began operating in 2013, Iran has relied on importing enriched uranium fuel from Russia. Such reliance has made Iran's nuclear power program vulnerable to disruptions from Russian suppliers, which might have played a role in Iran's insistence on developing domestic uranium enrichment and fuel manufacturing capabilities.

In any case, Russia proved itself to be an unreliable energy supplier on multiple occasions, for instance in 2006 and 2009, when it cut off gas supplies to Ukraine over political and economic disputes. Moreover, Russia has already used energy supplies as a political weapon even with its own allies, including Iran, by deliberately delaying the construction of the Bushehr nuclear power plant.

Since Iran possesses some uranium deposits and has recently discovered new ones within its territory, having enrichment facilities would make it self-sufficient. There are, however, two main caveats to Iran's attempt to localize front-end fuel cycle activities. The first is cost; it would be cheaper if Iran procured its nuclear fuel from external suppliers who have access to more cost-efficient production. The second is managing Russia's interest in selling its nuclear fuel, particularly to Russian-built nuclear reactors. In fact, Russia utilizes lifelong nuclear fuel supply contracts signed with countries that have adopted Russian VVER (water-cooled energy) reactors as a means to keep its market influence, since these exports represent an important business component for Russia. Limiting itself to selling reactors to other countries will not guarantee Russia high profits since the payment is subsidized and takes place only once.

Attacks against critical nuclear facilities

The recent drone and missile attacks on Saudi Arabia's ARAMCO facilities temporarily crippled its oil production, inflamed regional tensions, and sent shockwaves around the globe. Had the attack been on a nuclear power facility, the consequences could have been much more grave.

In the context of the ongoing volatility in the Middle East, the most prominent threat toward nuclear power infrastructure is perhaps using reactor units and their other critical auxiliary infrastructure as targets. The region has a history of attacks targeting nuclear facilities. Israel attacked Iraq's Osirak research reactor in 1981 and, more recently, a suspected undeclared Syrian nuclear reactor in 2007. During the 1980–88 war with Iran, Iraq attacked its Bushehr reactor several times when it was under construction. Iranian nuclear facilities also came under at least two highly damaging cyberattacks in 2010 and 2011.

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Terrorist attacks pose another challenge specific to the region. Jihadist and militia groups have become sophisticated in recent years, and their capabilities cannot be overlooked when countries plan the construction of nuclear facilities. For example, the claim by Yemen's Houthi rebel group that they launched a missile targeting the UAE's Barakah nuclear power plant, which is under construction, whether it was true or not, is an alarming sign that nuclear reactors are indeed considered as potential targets.

Clearly, the impact of an attack against a nuclear facility depends on several factors: whether the facility is under construction or operational; the nature of the target (whether it is the reactor core, cooling tower, power turbine, or the spent nuclear fuel pool); the destructive force of the attack; and the power of the instrument used.

While there have been no cases of terrorist attacks on operational nuclear reactors, such a possibility should not be dismissed. Even if we assume a "failed" attack on nuclear facilities, the level of panic and distress that it is likely to create would be significant. Such elevated levels of tension may lead authorities to shut down these nuclear facilities under public pressure, regardless of whether any physical harm has been done.

Foreign workforce

Another threat that may be linked to wars, instability, or exercising political leverage is the sourcing of labor to a foreign workforce. In the region—with the exception of Egypt and Iran which have a significantly higher level of human resources in the nuclear field—the great majority of personnel specialized in nuclear technology and power plants, particularly reactor operators, are not nationals of Middle Eastern countries.

Most workers come from countries that supply the nuclear technology such as South Korea or Russia. Even in countries with sufficient domestic human resources, the supplier may still request to utilize its own trained workforce, as is especially the case with Russian-supported projects.

The involvement of foreign workers, which may be necessary when the host country lacks the required human capital to run its own nuclear power program, may raise several issues. A foreign workforce may be recalled at any stage, leaving the nuclear facility non-operational. Although this may seem like an extreme case, it does reflect the dependency of the host country on the supplier, who could exploit this relationship for political leverage.

As a result, countries in the region are keen to establish local labor that is trained in nuclear science and engineering. However, to achieve the same level of expertise and practical knowledge that supplier countries have acquired over decades of research and training in just a few years would be a stretch, regardless of the level of talent available.

Climatic effects

When thinking of possible climatic effects on the resilience of the nuclear power plants in the region, heat waves are particularly concerning due to their impact on the temperature of the reactor's cooling water. The effects of variable cooling water temperature on the operation and safety of nuclear power plants located in the Gulf have been studied and researchers have generated design changes that would allow for higher seawater and ambient temperatures. However, with global weather patterns becoming more unpredictable and extreme, one can envisage a scenario where the existing design limits are crossed.

Moreover, a heat wave may affect the operations of nuclear power plants in two main ways: it could reduce their efficiency to turn fuel into electricity and it could increase the number of shutdowns. In 2003, for example, a heat wave forced the shutdown of more than thirty nuclear power plants in Europe. A similar event took place in 2018 when numerous nuclear power plants all over the world, from France to South Korea, had to cease their operations due to abnormally high temperatures. These events resulted in substantial economic losses. In a region where temperatures may rise to 60 degrees Celsius (140 Fahrenheit) in summer, the weather is a force to be reckoned with when planning for nuclear resilience.

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Nuclear reactors and the grid

An important feature of nuclear power plants (and all other energy sources) is the way they interact with the power grid. The resilience from the interaction of a nuclear power plant with the power grid can be examined through the reactor's ability to deal with the demanding and changing operational conditions without losing its ability to generate power safely. This reveals several relevant operational characteristics. First, the plant's ability to operate flexibly and "follow the load," that is, vary its power output based on the demanded load at any given time. Such a practice, however, is not the norm in operating nuclear reactors, which are designed to generate a maximally safe constant power at all times.

The reason it is preferable for nuclear power plants to generate constant power stems from technical and economic needs. On the technical side, it is more challenging to ramp up and ramp down reactor power as it requires delicate control and monitoring. On the economic side, it is more cost efficient to run nuclear reactors at their capacity level all the time because the cost of the fuel, i.e. the variable cost, contributes less than 10 percent of the overall cost of the generated electricity.

The significance of any disruption to a nuclear power plant and its impact on the power grid depends on the share of energy mix provided by the power plants. This is particularly important for countries like Jordan with a small grid capacity (~3.8 GW), where the addition of a single 1 GW reactor unit would be contributing more than a quarter of the country's power supply. This high share poses some serious technical and security challenges. However, in 2018, Jordan said it was willing to switch to small reactors, mostly because of their lower costs and better grid suitability. The details regarding the number and capacity of the small reactors Jordan intends to buy have yet to be made public.

Another requirement of a resilient nuclear power plant is its ability to operate in an "isolated" mode, that is, its ability to operate even when not connected to the transmission grid and electric supply. This would be particularly important if the transmission lines connected to the power plants are attacked and power supply is cut off. Transmission lines may be easier to target, especially by small and unsophisticated terrorist groups.

Spent nuclear fuel considerations

Spent nuclear fuel, in other words the irradiated (and radioactive) fuel waste generated by nuclear fission, must first cool down for a number of years in water-filled storage pools before it is ready to be handled and transported. Spent fuel pools will always be full as new spent fuel will continuously replace fuel that is removed. Consequently, various threats to the storage pools are possible. Firstly, like the case with nuclear reactors, natural disasters and extreme weather conditions could threaten the functionality of the storage pools.

Secondly, spent fuel pools may also be identified as targets during armed conflicts.

It is still an open question whether radiation leakages from the reactor are more dangerous than from spent fuel. In some circumstances, such as in Japan following the Fukushima disaster, Tokyo Electric Power assessed radiation leakages from spent fuel to be far more threatening than those from the reactor, because of the higher quantities of potential radioactive material.

Since storage pools are only a temporary solution for the disposal of highly radioactive nuclear waste, two main options have been envisaged for long-term storage in the Middle East. The first comprises two specific cases: if a country operates a Russian reactor and is reliant on Russian nuclear fuel, in that case Russia would be responsible for taking back the spent fuel. In the other case, a country with a long-term repository, such as Sweden, might agree to store the spent fuel in its permanent storage facility.

However, there are numerous threats related to how countries, especially in the Gulf, would transport highly radioactive spent fuel. Until now, maritime transport has been the only option available due to the lack of railway infrastructure in the region. In fact, spent nuclear fuel would be shipped through the quite unstable Strait of Hormuz (where some international and regional tankers were recently attacked) and even the more problematic Strait of Bab Al-Mandeb off Yemen, which is threatened not only by pirates but also because of its proximity to Houthi-controlled areas.

Further north on the route close to the Sinai Peninsula lie the bases of numerous non-state actors, including terrorist cells. The impact of an attack during the transport of highly radioactive spent fuel would be disastrous on the marine environment of the affected and surrounding areas. Moreover, the route is often relatively close to the coasts of numerous countries, where any attack would result in the release of highly radioactive elements, posing a real threat to their populations' public health.

The second option lies in the construction of a regional nuclear waste repository. The construction of this storage would pose numerous risks to Middle Eastern countries themselves since the threat of an attack (or robbery) on this infrastructure cannot be ignored in the context of current regional instabilities.

Impact and Consequences of a Nuclear Incident

The scale of the impact of an unplanned reactor shutdown due to any of these possible causes depends on three main factors. The first is the share of the lost power capacity vis-à-vis a country's total power generation capacity. The bigger the power loss, the more significant the consequences would be—in other words, how much of the population is affected. In fact, resilience is not only described in terms of adaptive capability, but also of restorative capability. The population affected might have to temporarily adapt to a lower power supply, while power generation is restored or brought back online.

The second factor is the time it takes to resume nuclear power plant operations after shutdown; recovery time is a pivotal factor in ensuring system resilience as well as the minimization of economic losses.

Lastly, the impact and the consequences of a sudden shutdown also vary depending on its cause, whether due to unforeseen weather conditions, fuel disruptions, physical attacks or cyberattacks. Each kind of threat triggers different scales of economic loss as well as of radiation discharge, affecting the population's health and the environment. Moreover, the level and nature of a disruption can also affect the duration of time needed for a nuclear power plant to recover and to bring the plant back online, again affecting overall resilience.

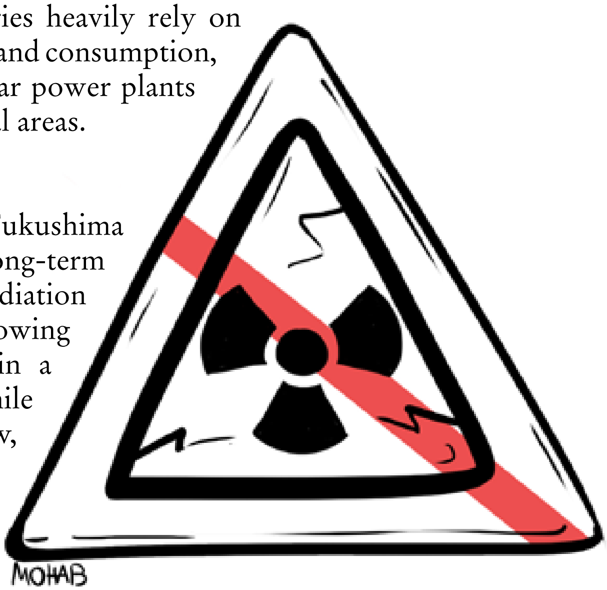
Economic consequences

Following the shutdown of a nuclear power plant, the utility incurs substantial economic losses, especially in case of an unscheduled outage. In fact, the plant may require quite a long time to resume its operations and to make different clogs in the system work in a safe and coordinated manner. Therefore, a nuclear power plant's shutdown may last longer than expected, amplifying economic losses. For instance, following a French reactor's unexpected shutdown in 2017, EDF, the French power utility, was estimated to have lost roughly $1.2 million per day.

The extent of economic loss due to an unplanned reactor shutdown also depends on the availability and cost of backup options. The power shortage would also entail extra costs to import electricity from neighboring countries. Additionally, Gulf countries would be particularly impacted by a temporary shutdown of a nuclear power plant if they were being used to generate electricity for their water desalination plants. GCC countries heavily rely on desalinated seawater for water provision and consumption, so that a temporary shutdown of nuclear power plants would have a domino effect in other vital areas.

Public health consequences

The accidents at Chernobyl and Fukushima have shown both the immediate and long-term detrimental effects of the spread of radiation on the population. For instance, following Chernobyl, thirty workers died within a few weeks from radiation poisoning while hundreds were injured. In the long view, children and adolescents were most at risk of exposure to radioactive material that rapidly made its way



into contaminated dairy and produce. The exposure to contaminated air, food, and water also led to a higher risk of leukemia as well as thyroid cancer for 6.5 million people. Similar consequences were predictable in the aftermath of the Fukushima disaster, but at a lower scale since the amount of radioactive elements released was considerably less than at Chernobyl.

Equally important, radiation leakages from a nuclear power plant could affect a country's entire water supply. Many countries in the region are among the world's most water stressed, especially those in the Gulf, and use desalinated seawater as the main water supply for households and industry—more than 90 percent in the case of Qatar and the UAE. Saudi Arabia is increasingly relying on seawater desalination to meet the demand for households and industry—around 60 percent of the total water consumed.

Desalination plants make up critical infrastructure in several Middle Eastern countries. Therefore, a threat related to the reliance on desalination plants might take place in case of a radiation leakage, especially for the GCC. In the case that the Gulf's water is contaminated, the countries affected must terminate the operations of their seawater desalination plants. Although such a scenario may seem unimaginable, it remains a real possibility.

The ability to conduct mass evacuations as was the case following the Fukushima disaster is another issue related to potential nuclear accident response. The majority of people in the Middle East live in densely populated urban areas scattered throughout largely undeveloped areas. This makes any evacuation even more challenging. For instance, the Barakah nuclear power plant is located on the Gulf coast, where the density of the population is higher and, in the UAE, few locations can be employed to relocate the displaced population. This endangers overall system resilience.

Major risks exist that show the contradiction between the development of nuclear energy in the Middle East and the emerging narrative of energy resilience. Nuclear power is not only vulnerable to climatic and nature-induced extreme events but also to attacks by state and non-state actors. The recent attacks on Saudi Arabia's oil infrastructure are reminders that the higher the value of the target, the more critical it becomes.

With nuclear power becoming a reality in the region, efforts by governments, academia, and civil society need to focus on promoting its resilient, safe, and secure operation. As a start, we need to invest in risk mitigation strategies and mechanisms as well as better emergency response and preparedness that utilize unhindered and depoliticized technical cooperation between all states in the region. Since the effects of nuclear accidents are often cross-border, even countries that do not have nuclear power programs must be part of these efforts.