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ALI VAEZ | KARIM SADJADPOUR

IRAN'S NUCLEAR ODYSSEY

COSTS AND RISKS

Carnegie Endowment
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—Ali Vaez and Karim Sadjadpour

SUMMARY

Iran's half-century nuclear odyssey has been marked by enormous financial costs, unpredictable risks, and unclear motivations. The program's covert history, coupled with the Iranian government's prohibition of open media coverage of the nuclear issue, has prevented a much-needed internal debate about its cost-benefit rationale. Critical questions about the program's economic efficacy and safety have been left unanswered.

ON THE GROUND: COSTS AND RISKS

- The program's cost—measured in lost foreign investment and oil revenue—has been well over $100 billion.
- The Bushehr nuclear reactor took nearly four decades to complete and cost almost $11 billion (measured in today's dollars), making it one of the most expensive reactors in the world.
- Bushehr provides merely 2 percent of Iran's electricity needs, while 15 percent of the country's generated electricity is lost through old and ill-maintained transmission lines.
- Despite aspirations to be self-sufficient, Iran's relatively small uranium resources will inhibit the country from having an indigenous nuclear energy program.
- Iran is the only nuclear state that is not a signatory to the Convention on Nuclear Safety, and its nuclear materials and stockpiles are some of the least secure in the world.
- Most ominously, the Bushehr reactor sits at the intersection of three tectonic plates.

POLICY IMPLICATIONS FOR THE UNITED STATES AND LIKE-MINDED ALLIES

Economic pressure or military force cannot "end" Iran's nuclear program. It is entangled with too much pride—however misguided—and sunk costs simply to be abandoned.

The nuclear issue will never be fully resolved absent a broader political settlement. The only sustainable solution for assuring that Iran's nuclear program remains purely peaceful is a mutually agreeable diplomatic solution. Given that political reconciliation is unlikely, the goal should be détente.

Alternative options exist and should be highlighted. For example, Iran's solar energy potential is estimated to be thirteen times higher than its total energy needs. By offering Iran cutting-edge alternative energy technologies, a positive precedent could be set for other nuclear-hopefuls.

Public diplomacy should complement nuclear diplomacy. Efforts should make clear to Iranians that a prosperous, integrated Iran—as opposed to a weakened and isolated Iran—is in America's interests. Washington should clarify what Iranians would collectively gain by a nuclear compromise (other than a reduction of sanctions and war threats) and explain how a more conciliatory Iranian approach would improve the country's economy and advance its technological—including peaceful nuclear—prowess.

INTRODUCTION

Iran's controversial nuclear program has dominated the international stage for more than a decade. The United States and like-minded allies have relentlessly strived to coerce and compel Tehran to curb its nuclear activities. Its uranium enrichment program and efforts to obtain full nuclear fuel-cycle capabilities have been of particular concern. Attaining such capabilities would mean that Iran could fuel both nuclear power plants and atomic bombs. But negotiations, punishing economic and political sanctions, covert sabotage, and military threats have at best delayed Iran's nuclear progress.

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In February 2013, the International Atomic Energy Agency (IAEA) estimated that Iran's stockpile of net fissile material had grown to nearly 7 tons of uranium enriched to 5 percent and 167 kilograms of uranium enriched to 20 percent.[1] The latter development is particularly worrisome as the stockpiling of 20 percent enriched uranium significantly reduces (by more than 90 percent) the time required to obtain weapons-grade fissile material from natural uranium. The material Iran has currently accumulated, if further enriched, could be sufficient for at least five nuclear weapons. Of further concern is the fact that Iran has started to install more advanced centrifuges at its Natanz enrichment facility, which would further upgrade its enrichment capacity.[2]

While the Nuclear Non-Proliferation Treaty (NPT) entitles Iran to civilian and peaceful nuclear energy, at issue is whether Tehran is in compliance with Article II of the treaty, which prohibits nations from weapons-related activity. The same technology that produces low-enriched uranium for nuclear reactors can be employed to produce highly enriched uranium for a nuclear weapon.

The United States and Israel have described the prospect of a nuclear-armed Iran as "unacceptable" and an "existential threat." Meanwhile, the Iranian government has exhaustively portrayed its nuclear program—which it insists is peaceful—as the nation's "inalienable right" and a symbol of modernity and technological advancement on par with landing on the moon. Surveys, notwithstanding the inherent limitations of polls conducted over the phone in closed societies, often show a majority of Iranians in favor of the country's continued development of a civilian nuclear energy program. Even the country's opposition leaders, labeled "seditionists" by the Iranian government, have asserted that Iran's nuclear rights should be preserved.

The environmental and technological gains of nuclear power have come at the expense of Iran's existing hydrocarbon sector and renewable-energy potential.

The Iranian government prohibits its open media coverage of the nuclear issue, which has helped stifle a much-needed internal debate on the cost-benefit rationale behind the country's nuclear agenda. Crucial questions have not been asked in the public domain, let alone answered. For instance, what is the scale of Iran's nuclear expenditure in financial terms? Why does Iran need to invest in front-end technologies, such as uranium mining, conversion, enrichment, and fuel fabrication plants? Does nuclear power guarantee Iran's long-term energy self-sufficiency? Also unclear is how Iran's nuclear program compares with those of other countries, the environmental burden of nuclear energy, and the safety and security of Iran's nuclear plants and facilities.

But these questions need answers. And a good place to start is with an estimation of the price tag on Iran's half-century-long pursuit of nuclear technology. While most nuclear programs are financially opaque, years of clandestine activities render objective assessments of Tehran's nuclear expenditure especially challenging. Additionally, the nuclear program has imposed indirect costs on the country's economy in the form of colossal financial, technological, and energy sanctions. By examining publicly available data and interviewing key individuals, the broad contours of direct and indirect costs of the program materialize. The economic merits of investment in front-end technology and insistence on domestic uranium enrichment deserve to be evaluated, based on Iran's self-reported uranium resources and uranium refinement and fuel fabrication capabilities.

The Iranian government uses a range of arguments to justify its pursuit of indigenous uranium enrichment. One that is often made by Iranian officials is that nuclear energy would allow them to consume less petroleum and gas domestically, and instead export it for greater economic benefit. But the environmental and technological gains of nuclear power have come at the expense of Iran's existing hydrocarbon sector and renewable-energy potential.

Although Iran is the first Middle Eastern country to harness nuclear energy for electricity production, its neighbors, including the United Arab Emirates, Saudi Arabia, Bahrain, Kuwait, Oman, Qatar, Egypt, and even Yemen, have vowed, perhaps perfunctorily, to follow suit. A comparative analysis, from technological and economic vantage points, reveals that Iran's nuclear power plants could soon appear outdated and overpriced in comparison with the nuclear reactors of regional countries.

In the aftermath of the natural-cum-nuclear disaster at Japan's Fukushima nuclear power plant, long-held fears about the safety and security of Iran's nuclear installations were rekindled.[3] Given Iran's earthquake-prone topography, a growing number of Iranian opinionmakers are questioning their government's nuclear policies.[4] The preparedness of the country to face nuclear emergencies is another issue that requires thorough examination.

A better-informed Iranian public will be better placed to judge the wisdom of a nuclear program that, up until now, has had enormous costs and uncertain benefits.

An in-depth look at these crucial issues could offer the international community a potent tool for grassroots public diplomacy. The Iranian people have been largely absent from the nuclear discussion. A better-informed Iranian public will be better placed to judge the wisdom of a nuclear program that, up until now, has had enormous costs—above all for Iranians—and uncertain benefits. Likewise, less controversial subjects, such as nuclear safety and security or alternative energy sources, could broaden the diplomatic discussions in an effort to untie the Gordian knot of Iran's nuclear crisis.

THE MAKING OF A CRISIS

THE NUCLEAR PROGRAM UNDER THE SHAH

CONCEPTION (1957–1979)

The genesis of Iran's nuclear program can be traced back to 1957. Ironically, it was the United States—then Tehran's key strategic patron—that sowed the seeds of nuclear development by signing an agreement with Iran under the auspices of President Dwight Eisenhower's Atoms for Peace initiative.[5] The American Machine and Foundry Company supplied Iran's first nuclear facility at Tehran University with a 5 megawatt (MW) reactor at the cost of $1 million. Another American firm, General Dynamics, provided 5.15 kilograms of weapons-grade highly enriched uranium to Iran for fueling the Tehran Research Reactor. Initial progress, however, was slow, with the reactor only becoming operational in November 1967.[6]

In 1968, Iran was among the first countries to sign the NPT, which was ratified by the Iranian parliament two years later. Tehran completed its safeguards agreement with the IAEA in 1974.[7] In the same year, the Atomic Energy Organization of Iran was established, and Akbar Etemad, a French- and Swiss-educated reactor physicist, was appointed its president.[8]

Boosted by the 1974 oil boom, Shah Mohammad Reza Pahlavi abruptly decided to make nuclear energy a priority for his government. The official narrative was that oil, "a noble material," should not be wasted, and thus Iran's energy portfolio should be diversified. For the shah, nuclear technology was not only essential to modernity, but it also symbolized Iran's newly attained power and prestige.

An American firm, the Stanford Research Institute, determined that if Iran were to achieve energy autonomy fit for a "great power," it needed to generate 23,000 megawatts electrical (MWe) from nuclear power by 1994. Partly based on this advice, the shah then announced an ambitious plan to rapidly develop several full-fledged nuclear reactors in record time.[9] Although no decision was made on the total number of reactors, the unrealistically ambitious goal was to develop one reactor per year.[10]

Meanwhile, Iran's nuclear cadre was being trained. The Atomic Energy Organization of Iran signed special contracts with prestigious universities and technical centers around the world to cultivate the human capital for its nuclear program. Among these institutions was the Massachusetts Institute of Technology, which received a $20 million endowment from Iran in return.[11] Many of the future decisionmakers in the Islamic regime's nuclear program, including Ali Akbar Salehi, the current foreign minister and former head of Iran's Atomic Energy Organization, were among the trainees of this program.[12]

By 1977, with exceptional royal support, the Atomic Energy Organization of Iran had undergone a stunning expansion and employed more than 3,800 experts, engineers, technicians, and interns.[13] Students sent abroad for training returned home as nuclear experts. The organization witnessed a twelve-fold increase in the number of its nuclear scientists, from 67 in 1974 to 862 in 1977. In the last years of the Pahlavi monarchy, the organization had the second-highest budget in the country following the National Iranian Oil Company. Its employees were among the highest paid in Iran.[14] Etemad had the monarch's carte blanche for his agency's expenditures, and the annual budget skyrocketed from $30.8 million in 1975 to $1.3 billion in 1976 and over $3 billion (corresponding to more than $11 billion in 2012 dollars) in 1977.[15]

The shah's insistence on mastering the complete fuel cycle and on possessing plutonium reprocessing capabilities—at the time an easier way to fuel a nuclear weapon than enriched uranium—intensified U.S. concerns about Iran's proliferation intentions. Washington, still reeling from India's nuclear test in 1974, was suspicious, and the administration of Gerald Ford required assurances that Iran's intentions were peaceful.

Recently declassified documents reveal striking details about the bitter U.S.-Iranian nuclear negotiations from 1974 to 1978. Surprisingly, the same issues that have caused the current nuclear showdown between Iran and the West—access to sensitive technology, fuel stockpiles, and additional safeguards—were in contention then.[16] When no agreement could be reached, the U.S. government barred American companies from selling nuclear technology to Iran. The shah reciprocally decided that, "unless it was clear that Iran was not being treated as a second-class country," he would look for alternative vendors.[17]

France and West Germany filled the gap. The Atomic Energy Organization of Iran commissioned the German firm Kraftwerk Union (a joint venture of Siemens AG and AEG Telefunken) to build two 1,196 MWe pressurized water reactors. The turnkey contract, which would deliver the power plate in a completed state, was worth $4.3 billion (nearly $21 billion in 2012 dollars).[18] Construction began in August 1975, with a planned completion date of 1981. The choice of location, the southeastern city of Bushehr, rendered the enterprise particularly costly, as it was prone to seismic activity and located in an underdeveloped region that lacked essential physical infrastructure. Yet Bushehr was chosen mainly due to its location on the shores of the Persian Gulf to facilitate shipping of the nuclear power plant's machinery and equipment.[19]

The shah also had an extensive plan for acquiring nuclear fuel. In 1975, he provided a $1 billion (and another $180 million in 1977) loan for the construction of the Eurodif nuclear consortium enrichment plant in France. As part of the agreement, Sofidif enterprise was established with Iran and France holding 40 and 60 percent of its shares, respectively.[20] Subsequently, Sofidif acquired a quarter of Eurodif stocks, which gave Iran a 10 percent share of the enriched uranium produced.[21] Furthermore, Iran signed a $700 million contract to purchase 600 tons of uranium yellowcake from South Africa and obtained a 15 percent stake in the RTZ uranium mine in Namibia.[22] In parallel, Iran started an extensive uranium exploration effort both inside and outside the country.

An agreement was also reached with French company Framatome to build two 900 MWe nuclear power generators valued at $2 billion at Darkhoveen, near the city of Ahwaz on the banks of the Karun River.[23] Moreover, France indicated its willingness to build eight additional plants for Iran if the United States continued to bar American firms from selling Iran nuclear power plants at an estimated price of $16 billion.

Finally, in 1978 there was a breakthrough in nuclear negotiations between Tehran and Washington. The shah agreed to forego plans to build a plutonium processing plant, to put Iran's nuclear activities under enhanced monitoring, and to send spent nuclear fuel to the United States. Reciprocally, the Carter administration agreed to allow American companies to sell reactors to Iran.[24] The coming political tumult in Tehran, however, would render these agreements moot.

Income disparity and economic malaise had begun to fuel domestic discontent with the shah's rapid modernization programs, which many Iranians perceived as profligate and corrupt. The monarch was forced to rein in his atomic dreams.[25] The storm of an Islamic revolution was brewing on the horizon, and the government of Prime Minister Jamshid Amouzegar began a review of the nuclear program. In 1979, Prime Minister Shahpour Bakhtiar began to roll the program back. When the country descended into revolutionary turmoil later that year, one of Bushehr's reactors was 85 percent complete and the other was half constructed.

THE NUCLEAR PROGRAM UNDER THE ISLAMIC REPUBLIC

CAESURA (1979–1984)

One of the first debates among the revolutionaries who overthrew the shah was about the legacy of the ancien régime. The royal heritage included the nuclear program, deemed by the revolutionaries as a costly Western imposition on an oil-rich nation.[26] Yet, antinuclear rhetoric was not purely ideological. A pragmatic cost-benefit analysis indicated that while a gas-fired power plant would cost $300/kilowatt in Iran, the predicted costs of Bushehr would be between $2,500 and $3,000/kilowatt.[27] Moreover, in the aftermath of the 1979 nuclear incident at Three Mile Island in the United States, safety concerns about the nuclear installations in Iran preoccupied the new authorities. Other arguments against the program included Iran's limited uranium resources, earthquake-prone terrain, and lack of expertise.

The death knell for Iran's nuclear program was Ayatollah Khomeini's pronouncement that the unfinished plants in Bushehr would be used as "silos to store wheat."[28] In July 1979, construction of all nuclear power plants came to a halt. The transitional government of Prime Minister Mehdi Bazargan abandoned all of the existing nuclear contracts. But the decision was not cost free.

In retaliation and against the backdrop of the seizure of the U.S. embassy in Tehran, Western countries refused to deliver machinery Iran had already purchased at a hefty price. The United States—whose diplomats were taken hostage in Tehran for 444 days—ceased supplying highly enriched uranium fuel for the Tehran Research Reactor, which was forced to temporarily shut down.[29] The halt of nuclear plant construction led to an exodus of Iranian nuclear scientists.

The Kraftwerk Union also terminated its Bushehr contract, but Iran had already sunk $5.5 billion deutsche marks (nearly $2.8 billion in 1979 dollars and $9.6 billion in 2012 dollars) into the project.[30] A bitter legal dispute ensued in several international courts. Based on a 1982 International Chamber of Commerce ruling, the German companies had to deliver some 80,000 pieces of equipment,[31] but Iran's efforts to obtain compensation for unfinished reactors and paid nuclear fuel came to naught.[32] A German offer to provide Iran with modern gas-fired power plants to settle the $5.4 billion claim also fell on deaf ears.[33]

Lawsuits with the French over Eurodif were eventually settled in 1991; Iran was reimbursed a total of $1.6 billion for its original 1974 loan plus interest.[34] To date, Iran is still listed as an indirect stockholder of Eurodif but under the 1991 settlement has no right to enriched uranium from the facility. This experience soured prospects of any future joint ownership of foreign facilities for Iran.[35]

In September 1980, Saddam Hussein's Iraq invaded an Iran still in the throes of post-revolutionary chaos. What would become an eight-year war severely damaged Iran's nuclear infrastructure. In retaliation for Iran's failed raid on Iraq's Osirak nuclear reactor, Iraqi air forces attacked the Bushehr power plant seven times during the war, leaving the plant in ruins.[36] According to estimates by engineers from both Siemens and Technischer Überwachungsverein, the repair bill for the damages and environmental exposure of the two reactors in Bushehr ranged between $2.9 and $4.6 billion.[37]

CONCEALMENT (1984–2002)

By the mid-1980s, as revolutionary fervor in Iran began to subside while the country was still in a full-blown war with Iraq, Tehran's leaders began to reconsider their nuclear program as a deterrence option. Iranian leaders felt isolated—a calculus that was exacerbated by the fact that Saddam Hussein was abetted by great powers with sophisticated weapons and (courtesy of the United States) crucial intelligence to locate Iranian military targets. Moreover, the drain of war had pushed the country into a severe energy crisis, evidenced by frequent blackouts.

It was against this backdrop that Iran's nuclear program, dormant since 1979, was resurrected. A nuclear program could potentially alleviate Iran's dire electricity needs and serve as a deterrent against the Islamic regime's foreign foes.[38] In 1984, then President Ali Khamenei, the current supreme leader, obtained authorization from Ayatollah Khomeini to restart the nuclear program and allocated funds for the effort in the national budget.

Facing unprecedented international isolation, the Iranian government searched in vain for a partner to complete the Bushehr project, but due to U.S. opposition all efforts came to naught. Only one man provided Tehran with a promising response—the father of Pakistan's nuclear weapons program, Abdul Qadeer (A. Q.) Khan. He visited Bushehr twice, in February 1986 and January 1987.[39] But soon it became clear that the completion of Bushehr was beyond A. Q. Khan's ability. Tehran grew convinced that the only option available to it was self-sufficiency.

Their first step was to acquire nuclear fuel-cycle capabilities. A. Q. Khan had already offered assistance by providing enrichment technology to Iran. With the endorsement of the then prime minister, Mir Hossein Moussavi (who was put under house arrest, accused of "sedition," in the aftermath of the 2009 disputed presidential election), a deal was struck between the representatives of the Atomic Energy Organization of Iran and A. Q. Khan's illicit nuclear network.[40] Iran's uranium enrichment program was thus born in secret through the acquisition of technical drawings, manufacturing instructions, and samples of components for P-1 centrifuges (a 1970s Dutch design stolen by A. Q. Khan).[41]

With design information in hand, Iran started a wide-ranging procurement effort to obtain critical parts for building centrifuge cascades. For example, in 1988 the Iranian front company Kavosh Yar, a subsidiary of the Atomic Energy Organization, acquired centrifuge components and vacuum valves from the German company Leybold worth $500,000.[42] In 1995, Iran revisited A. Q. Khan's "nuclear Walmart" and bought parts and designs for the more advanced P-2 centrifuge.[43]

Iran also sought to upgrade the Tehran Research Reactor, the renovation of which had been pending since the shah's era.[44] In 1987, while renovating the reactor's core, Argentina's

Applied Research Institute converted the reactor's fuel from weapons-grade 93 percent enriched uranium to slightly less than 20 percent.[45] The cost was $5.5 million. Argentina's Nuclear Energy Commission also signed an agreement to supply 115.8 kilograms of the Tehran reactor's required 19.75 percent enriched uranium, which was eventually delivered in 1993.[46]

By the mid-1990s, the nuclear program had once again become a national priority with more than $800 million allocated to it in the national budget.[47] The nuclear technology center located in the city of Isfahan, south of Tehran, was inaugurated in 1990 and with it a wide-ranging quest to find additional nuclear partners. Despite generous offers from Iran, the government of Pakistan remained reluctant to share its nuclear know-how with its neighbor.[48] But China was interested. Beijing conducted nuclear trade worth $60 million annually with Tehran, turning China into Iran's primary nuclear partner.[49] In 1991, Tehran secretly imported approximately one ton of uranium hexafluoride from China but failed to report the purchase to the IAEA, a requirement under its NPT safeguards agreement.

U.S. pressure brought the Sino-Iranian cooperation to an end—another wakeup call that Iran would have to rely on native expertise. Thus began a renewed effort to bring Iran's migrated nuclear talents back home and to train new experts. A group of 77 Iranian nuclear scientists were sent to study at Italy's International Center for Theoretical Physics in Trieste, which was saved from financial crisis by a $3 million loan from Iran.[50]

Finally, a cash-strapped Russia took on the task of completing the Bushehr nuclear plant in 1992. Moscow's impetus for entering the Iranian market was above all to rescue its post-Soviet nuclear industry from insolvency. A turnkey agreement was signed between the Atomic Energy Organization of Iran and AtomStroyExport, a subsidiary of the Russian Atomic Energy Agency.[51] Moscow was to supply a 915 MWe VVER-1000 light-water reactor, which is suitable for power generation and not prone to proliferation. Tehran, in turn, agreed to pay 80 percent of the value of the contract in cash and the remaining 20 percent in kind.[52] On the ruins of the crippled reactor, the Russians planned to build a sui generis nuclear plant—cobbled together with residual German equipment and scrambled Russian technology.

From the outset, the project was plagued with problems. The design of the Russian VVER reactor was incompatible with the German foundations of the Bushehr plant. It cost Iran an additional $140 million to solve the problem.[53] Due to American objections, Moscow also backed off from constructing a centrifuge-based uranium enrichment facility in Iran and instead agreed to supply the reactor's nuclear fuel for a ten-year period with a price tag of $300 million.[54] After a sixteen-year hiatus, the Bushehr reactor was once again a construction site. The initial completion date was set for 2001, but the estimate would prove off by more than a decade.[55] But since construction began, between 250 to 3,000 engineers and technicians from Russia and other former Soviet Union countries have been working in Iran, reportedly earning $5,000 to $20,000 per month.[56]

From 1992 to 2002, Iran made steady progress toward an indigenous nuclear fuel cycle.[57] Enrichment experiments were secretly conducted, contrary to Iran's NPT safeguards obligations, on test centrifuges in a research and development facility installed at Kalaye Electric Company. Another vast clandestine enrichment facility was built underground near the city of Natanz. Buried under 25 feet of cement and concrete, construction of the gas centrifuge facility at one point consumed all of the cement produced in Iran.[58] The Atomic Energy Organization of Iran had also started to secretly construct a heavy-water production plant and a 40 MW research reactor near Arak.

CRISIS (2002–2008)

In August 2002, an Iranian opposition group, the National Council of Resistance (a front for the Mojaheden-e Khalq, a militant Marxist-Islamist cult that helped topple the shah and now calls for the overthrow of the Islamic Republic), revealed information about Iran's undeclared nuclear enrichment facilities in Natanz and heavy-water production plant in Arak. The revelation ignited an international crisis.

Between 2003 and 2005—against the backdrop of the U.S. invasion of Saddam Hussein's Iraq—France, Germany, and Britain (the EU-3) led a diplomatic effort to resolve the nuclear crisis. Iran, sobered by the fact that the United States had just defeated an Iraqi army in three weeks that they had fought to a standstill over eight years, initially agreed to suspend its enrichment program. It also voluntarily implemented the IAEA's Additional Protocol, which allows for more intrusive inspections, for more than two years. But as the situation in Iraq began to deteriorate, turning in Iran's favor, oil prices began to soar, and the EU-3 failed to bridge the gap between Iran and the United States, Tehran's leaders grew emboldened enough to reject what they believed to be the West's underlying objective: to get them to permanently give up their right to enrich uranium.[59] On August 8, 2005, in the final days of Mohammad Khatami's presidency, Iran restarted uranium conversion at its Isfahan facility.

With the election victory of President Mahmoud Ahmadinejad in 2005, Iran adopted a harsher stance in negotiations. Eventually, in January 2006, it broke the IAEA seals and restarted uranium enrichment. On February 4, 2006, the IAEA's Board of Governors voted to refer Iran to the United Nations Security Council for its noncompliance with its NPT safeguards agreement obligations. On July 31, 2006, Security Council Resolution

1696 was issued by unanimous vote, calling on Iran to stop uranium enrichment efforts within one month.[60]

Tehran continued to insist on its “inalienable right” to pursue uranium enrichment on its soil. Consequently, on December 23, 2006, the Security Council passed Resolution 1737, imposing international sanctions on Iran.[61] This was the beginning of a mutual cycle of escalation. A third Security Council Resolution (1747) was adopted in March 2007.[62] Several weeks later, Iran announced that it had reached industrial-scale uranium enrichment capabilities with the installation of 3,000 centrifuges in Natanz.[63]

Amid growing concerns about the possibility of a U.S. or Israeli military strike on Iran’s nuclear facilities, an unexpected U.S. National Intelligence Estimate was released in 2007, stating that Tehran had halted its structured nuclear weapons program in 2003.[64] The report cooled temperatures, providing space for Iran and the IAEA to work on a “modality plan” for resolving outstanding issues within a year, and by February 2008, the IAEA closed the file on most of those issues.

But new evidence surfaced from a stolen laptop that allegedly contained information about Iran’s clandestine nuclear weapons program. The incident soured relations between Tehran and the IAEA and resulted in a four-year-long stalemate in talks about Iran’s pre-2003 activities. In March 2008, Security Council Resolution 1803 was passed, imposing further economic sanctions on Iran.[65] The United States and its allies also started levying increasingly burdensome individual sanctions against Tehran.

THE RESULTS

The nuclear crisis has imposed an immense cost on the Iranian economy. The divestment that resulted from the rounds of sanctions helped deprive Iran’s energy sector of foreign ventures—along with the critical technology and know-how that comes with them. Annulled energy contracts were estimated to be worth as much as $60 billion in 2010.[66] This figure has likely increased several-fold in recent years as more draconian sanctions were put in place. In 2012, oil revenue declined by as much as $40 billion compared with that of 2011, with Iranian production plummeting from 4.2 million barrels per day (mb/d) in 2008 to 2.5 mb/d in 2012.[67] Its oil exports have dropped equally precipitously, falling from 2.5 mb/d

The nuclear crisis has imposed an immense cost on the Iranian economy.

in 2011 to 0.9 mb/d in September 2012. The Iranian rial lost nearly 80 percent of its value between 2011 and 2012.[68]

Still, Iran's nuclear activities continue apace. The official annual budget of the Atomic Energy Organization of Iran has hovered around $300 million in the past few years, trumping many other ministries and state-affiliated agencies.[69] The country's extensive and expensive nuclear program now includes at least sixteen facilities.[70] The cost of the front-end facilities has been roughly estimated at around $1 billion.[71] The concealed nature of most of these facilities results in atypically high construction costs because dummy buildings, bunker facilities, and anti-aircraft systems are required. As such, it is nearly impossible to have an accurate estimate of the Iranian nuclear program's direct and indirect costs.

Iran is unable to access more advanced reactor technology at competitive prices, mainly because of its insistence on domestic uranium enrichment.

Construction of the country's sole nuclear power plant in Bushehr was completed in 2011, but—at the time of this writing—its inauguration has been delayed because of technical problems. The reactor—the exact cost of which is kept confidential—epitomizes the high price Iran has paid for its nuclear ventures. Even members of the Iranian parliament's budgetary committee were denied access to a detailed report about its costs.[72] Inflation, currency fluctuations, and increasing prices of material and equipment over the years have certainly increased the Bushehr project's price tag. Some Iranian officials unconvincingly claim that the cost of the reactor has been only 10 percent higher than estimated in the initial contract.[73] Others, investigating repeated delays in its launch, contend that it would have been more economical for Iran to start constructing another reactor from scratch than to continue finalizing the existing plant in Bushehr.[74]

A simple calculation of the costs of the contracts with the Germans and the Russians in today's dollars—using publicly available information—results in an astonishing price tag of approximately $11 billion for the Bushehr plant.[75] The carrying costs of over four decades and other associated soft costs make Bushehr one of the most expensive reactors in the world. Interestingly, Russia is now negotiating the construction of a more advanced VVER-1200 nuclear reactor in Turkey at a price of $4 billion.[76] Iran, however, is unable to access more advanced reactor technology at competitive prices, mainly because of its insistence on domestic uranium enrichment.

THE ILLOGIC OF DOMESTIC ENRICHMENT

Uranium enrichment is at the core of Iran's standoff with the West. Tehran insists that indigenous uranium enrichment is essential for the country's energy independence. But over the years, despite internal doubts and external criticism, the Iranian government has abstained from explaining the economic rationale behind its enrichment policies. A close analysis indicates that domestic enrichment comes along with a high cost and a host of limitations for Iran.

For now, Iran's need for nuclear fuel is fairly small.[77] But Iranian leaders contend that eventual expansion of the country's nuclear program necessitates indigenous nuclear fuel production. If Iran were denied access to nuclear fuel, it would lose a return on its investment of at least $200 million per year for each idled reactor.[78] In the past, efforts to allay Iranian mistrust by offering several years' worth of stockpiled low-enriched uranium have reportedly been rejected by Tehran.[79]

Absent from the Iranian contentions about fuel security has been any mention of the scarcity, and low quality, of its domestic uranium resources. These limitations inevitably compel Iran to rely on external sources of natural or processed uranium, thus defeating the purpose of possessing an autonomous nuclear fuel cycle. Iran's foreign procurement of raw and processed uranium have been limited to a purchase from South Africa under the shah and from China after the revolution.

According to the IAEA, Iran is not even among the top 40 countries endowed with significant uranium reserves.[80] Iran's uranium resources are negligible compared to a number of countries (see table 1). As of 2011, Iran had 700 tons of reasonably assured resources, mostly in the high-cost category (which means that extractions cost more than $260/kilogram).[81] Iran's less certain "prognosticated" and "speculative" resources are estimated at about 28,000 tons.[82] Tehran's February 2013 announcement that new discoveries have increased its indigenous uranium resources remains to be independently verified.[83]

Table 1. Comparison of Identified Uranium Resources in Iran

COUNTRY	COST RANGES			
	USD 40/Kg U	USD 80/Kg U	USD 130/Kg U	USD 260/Kg U
Australia		1,349,400	1,661,600	1,738,800
Brazil	137,900	229,300	276,700	276,700
China	59,200	135,000	166,100	166,100
Iran			2,500	2,500
Jordan			33,800	33,800
Kazakhstan	47,400	485,800	629,100	819,700
Russia		55,400	487,200	650,300
Sweden			10,000	13,500
Turkey		7,300	7,300	7,300
United States		39,100	207,400	472,100

Note: Includes reasonably assured and inferred resources

Source: Organization for Economic Cooperation and Development and International Atomic Energy Agency, *Uranium 2011: Resources, Production and Demand* (Paris: OECD Publishing, 2012)

More important than quantity of uranium resources is often their quality.[84] The lower the grade of uranium, the higher its overall processing costs would be. In addition to having limited uranium resources, Iranian mines have a low uranium grade of 0.05 percent. Given this low concentration, mining uranium ore in Iran is uneconomical. Moreover, most of Iran's prognosticated and speculative resources fall into a high-cost category as well because they contain large amounts of impurities, such as molybdenum, that render enrichment arduous.[85]

Despite the Iranian leadership's assertions to the contrary, Iran's estimated uranium endowments are nowhere near sufficient to supply its planned nuclear program, which includes at least seven reactors of similar capacities. The Bushehr VVER-1000 reactor requires 27 tons of fuel per year in the form of uranium dioxide. This amount translates to about 500,000 tons of uranium ore.[86] Considering the most optimistic variants, Iran's known conventional uranium resources are sufficient for the operation of the Bushehr reactor for less than nine years. If the total known and speculative resources are taken into account, they will be exhausted after supplying a nuclear fleet of seven reactors for nearly ten years.[87]

Iran's uranium exploration has also lagged behind its enrichment efforts. New areas in the provinces of Kerman, Sistan and Baluchistan, South Khorasan, and Khorasan Razavi in the southeast and east of Iran are now under exploration, and total exploration and mine development expenditures grew from $3.9 million in 2007 to $32.2 million in 2010.[88] In 2010, Iran produced nearly 6 tons of uranium by open-pit mining of the Gachin deposit and is working toward opening a second facility at Ardakan (the Saghand plant) with a nominal production capacity of nearly 50 tons per year in 2013. Yet, the approximately 70 tons annual total capacity of these mines is not even sufficient to fuel the Bushehr reactor for one year.[89]

All of this exploration comes with a price. Uranium mining and milling has a significant environmental cost—extracting uranium to fuel a 1,000 MW reactor produces 300,000 tons of radioactive waste annually.[90] Uranium mining is thus expected to significantly exacerbate the rate of Iran's current environmental degradation, estimated by the World Bank as three times higher than the region's average.[91]

Moreover, mining operations require millions of liters of fresh water daily. But Iran's major uranium mines are located in arid and semi-arid areas of the country, so the per capita fresh water allowance in these regions is one of the lowest in Iran.[92] Uranium mining and milling could well expedite desertification and land degradation in these areas and cause water shortages and aquifer depletion.

Indeed, Iran's investment in front-end fuel-cycle technologies defies economic logic. The cost of producing low-enriched uranium fuel must take into account the cost of extracting uranium, converting uranium oxide to uranium hexafluoride, enriching that, reversing the conversion to uranium oxide, and fabricating fuel.[93] The average cost for fabricating 1 kilogram of fuel for a nuclear reactor on the international market in 2011 was around $2,770.[94] A one-year supply of fabricated fuel for a 1,000 MWe reactor requires about 20,000 kilograms of fuel—a cost of about $55 million.

Small enrichment facilities like those in Iran fail to exploit economies of scale, which means they cost more than large facilities. For example, Brazil's enrichment facility at Resende with 203,000 separative work units (SWU)—the amount of work done during an enrichment process—can hardly compete commercially with Urenco's 3,000,000 SWU facility in New Mexico. And while the capital cost of the smaller Brazilian facility is estimated at nearly $1,500 per SWU, Urenco's costs about a third of that.[95]

Despite considerable investment, Iran's enrichment program is still relatively small in size. The average SWU in 2012 was between 7,000 and 8,000 kilograms per year. The Natanz facility is sized for approximately 50,000 centrifuges, and the bunkered Fordow facility has a capacity of 3,000 centrifuges. Although Iran has completed centrifuge installation in Fordow, it has not been able to operate more than 12,000 centrifuges in Natanz.[96] This is mainly due to export controls that deny Iran rare materials needed for producing centrifuges (such as maraging steel, carbon fiber, and high-vacuum valves).[97]

Because of these restrictions on Iran's procurement of equipment and frequent mechanical failures with its main centrifuge models (IR-1), Iran's capital costs are inordinately high. While specific expenditures are not known due to years of clandestine activities and black-market procurements, it is possible to estimate the total cost of these facilities based on similarly sized installations in other developing countries. Some of Iran's facilities are buried deep underground and protected by air defense systems, so it could be expected that they cost significantly more than similarly sized facilities in other countries. Based on the design information provided to the IAEA, a rough estimate put the cost of Iran's existing fuel-cycle facilities at around $1 billion.[98]

All things considered, some estimates show that domestic enrichment in Iran could exceed the cost of purchased fuel from the international market by nearly $125 million per year.[99]

Technological limitations will also have an impact on Iran's domestic enrichment future. Iran has had difficulties refurbishing enriched uranium into fuel rods. After nearly three decades of attempting to manufacture nuclear fuel, Iran has only succeeded in producing prototypes with natural and low-enriched uranium that still need to be tested under rigorous conditions.[100] Iran lacks special testing reactors that are used to irradiate nuclear fuel rods for long periods of time and under extreme conditions to ensure their safety.[101]

But even if Iran possessed such technology, proprietary rights disallow manufacturing fuel assemblies for the Bushehr reactor so long as the reactor is under contract with Russia. Any infringement will terminate Russian safety and performance guarantees for the reactor. Of course, Iran is not alone in these difficulties. The complexity of centrifuge technology compels many countries—including states not subject to international sanctions—to use foreign expertise, especially Russian and European (Urenco) technology, in their enrichment facilities. China, for example, opted to use Russian centrifuges rather than its own in its enrichment plants.[102]

And many developed countries have made the cost-effective choice to rely on imported fuel—an interesting contrast to Iran's pursuit of a national uranium enrichment program. After evaluating the feasibility of operating front-end facilities, both Belgium and Sweden decided it would be a better choice economically to import enriched uranium rather than enrich it domestically. Belgium's seven reactors currently provide for more than half of the country's electricity needs without the support of any domestic enrichment facilities.[103] Sweden has ten operating nuclear power reactors, which provide over 40 percent of its electricity; however, the country imports all of its required nuclear fuel.[104]

For Iran, the investment in domestic technology has already been made and is thus considered a sunk cost. But there is also an opportunity cost of pursing domestic enrichment, which looms over Iran's main source of energy: fossil fuels.

NUCLEAR POWER: ENERGY SECURITY OR INSECURITY

Successive Iranian governments present their quest for nuclear energy as indispensable to the country's preparations for life after oil. This aspiration, however, turned into the nemesis of Iran's energy sector when it invited draconian international sanctions. These measures have left Iran's oil and gas industry in shambles and Iran's other natural energy resources overlooked.[105] It is evident that Tehran's rationale for investing in nuclear energy, especially in uranium enrichment, is consistent neither with the realities of its resource endowments nor with the near-term needs of its energy sector.

No sound strategic energy planning would prioritize nuclear energy in a country like Iran. The country's proven oil reserves stand at 151 billion barrels, ranking fourth in the world.[106] After Russia, Iran holds the second-largest gas reserves in the world, which stands at 1,046 trillion cubic feet (Tcf).[107] And the energetic value of the uranium resources in Iran pales in comparison to other resources—it is 0.13 percent of the country's petroleum resources, 0.09 percent of its gas endowment, and 8.8 percent of its hydropower potential (see table 2). That means the energy potential of nuclear power in Iran is almost negligible. So although nuclear energy is environmentally preferable, it is not an economically competitive choice.[108] In 2009, for instance, each kilowatt of installed nuclear capacity cost $4,000, while the equivalent amount for gas cost $850. (Since 2009, natural gas prices have plummeted due to newly accessible reserves in shale gas.)[109]

Table 2. Estimates of Iran's Total In-Place Energetic Reserves

	FUEL TYPE					
	Solid	Oil	Natural Gas	Uranium	Hydro	Total
ESTIMATED RESOURCES (Exajoule)	6	1,105.6	1,626.6	1.5	17	2,756.7

Notes: Solid fuels include coal, lignite, and commercial wood
For comparison purposes, a rough attempt is made to convert hydro capacity to energy by multiplying the gross theoretical annual capability (World Energy Council, 2002) by a factor of 10.
Source: International Atomic Energy Agency, "Energy Profile Islamic Republic of Iran," 2002, www.iranwatch.org/international/IAEA/iaea-irannuclearpowerprofile-2002.pdf

Before the Islamic Revolution, Iran's oil production hovered around 6 mb/d, of which 5 million was exported.[110] By 1980, oil production had declined to less than 1.5 mb/d, and then gradually increased to the level of 4.5 mb/d. Today, reeling from the EU oil embargo and oil shipment insurance ban, it hovers around 2.6 mb/d.[111] In the meantime, however, local consumption has risen rapidly, and crude volume exports have declined gradually to more than half of its 1979 level, while the population has more than doubled.[112] Currently, oil and gas play a central role in supporting Iran's economy, generating about half of the government's revenues and 80 percent of its export proceeds in 2011.[113]

Natural gas accounts for 53 percent of Iran's total domestic energy consumption, with the remaining 44 percent coming predominately from oil. Consumption of natural gas was estimated at 5.1 Tcf in 2010, but it is expected to grow by 7 percent annually for the next decade.[114] With a natural gas production level of 5.2 Tcf in 2010, Iran has only depleted 5 percent of its gas reserves.[115] Hydropower's share is less than 2 percent, and coal accounts for just below 1 percent of primary energy consumption in Iran.[116]

Demand for energy grew at approximately 5 percent per year during the past decade. The need for new capacity in Iran is vital. Some power plants are operating at 10 percent of their nameplate capacity, as the country's electricity infrastructure is largely in a state of dilapidation and rolling blackouts are endemic in summer months.

The oil recovery rate is low at around 20 to 30 percent, which means that Iran's production capacity is depleting at rates as high as 13 percent per year in the offshore oil sector and around 8 percent for onshore wells.[117] As much as 400,000 to 700,000 b/d of new capacity is needed every year just to maintain current production levels.[118] According to the chairman of the Iranian parliament's energy committee, Iran even risks becoming a net oil importer in seven years.[119]

As with the oil industry, the Iranian gas sector is struggling. Over two-thirds of the country's natural gas reserves are located in non-associated fields (containing only gas and no oil) and have not been developed.[120] Despite having the second-largest natural gas reserves in the world, Iran ranks only 25th among natural gas exporters.[121] Roughly 70 percent of Iranian natural gas was released to the market and approximately 16 percent was reinjected for enhanced oil recovery. Shrinkage, loss, and flaring accounted for the remaining 14 percent.[122]

Despite having the second-largest natural gas reserves in the world, Iran ranks only 25th among natural gas exporters.

The country's archaic power infrastructure desperately requires repair and renovation. While power generated by the Bushehr plant accounts for less than 2 percent of Iran's electricity production, approximately 15 percent of the country's generated electricity is lost through transmission lines because of aging infrastructure and mismanagement.[123] The annual amount of energy loss in Iran is staggering: 15 percent by power plants, 13 percent by refineries, and 8 percent by transportation.[124] Iran flares a higher fraction of its natural gas at the wellhead than most other member states of the Organization of Petroleum Exporting Countries (OPEC).

Wasteful consumption plagues Iran's energy sector, mainly stimulated by three decades of profuse energy subsidies. Electricity subsidies alone were estimated to have exceeded $11 billion in 2009,[125] and in 2010, subsidies in total were estimated to swallow around 10 percent of Iran's gross domestic product.[126] With energy prices at 11 percent of the competitive market price, until recently even water was more expensive than gasoline in Iran.[127]

Positive steps have been taken to resolve this chronic problem. In December 2010 the Iranian government launched an economic reform program to phase out the subsidies. The price of gasoline, which fuels the nation's estimated 12 million cars, quadrupled overnight.[128] Diesel fuel, which powers Iran's commercial transportation sector, increased nine-fold. Natural gas, which flows directly to the homes of 75 percent of the population, became eight times more expensive.

If the removal of subsidies significantly reduced the demand for energy, the saved energy could be several times more than the amount of electricity generated by a few nuclear power plants.[129] But the nuclear standoff and the pressure of sanctions subsequently undercut the subsidy reform program. The Iranian parliament suspended the reforms' second phase in October 2012, citing the effects of Iran's massive currency devaluation, and the initial increase in energy prices was nullified.[130]

Changing this situation will come at a high price. To stem or reverse these trends and develop new upstream oil and gas projects, Iran needs substantial investment capital and modern technology. The nuclear standoff has soured the international climate and resulted in loss of foreign investment in the energy sector, estimated as to be as much as $60 billion.[131] According to Iranian authorities, the country requires at least $300 billion of investment over the next decade to successfully turn around its oil sector.[132]

Natural gas may be a better solution than nuclear to some of Iran's energy woes.

Natural gas may be a better solution than nuclear to some of Iran's energy woes. Natural gas plants have low capital cost, are rapidly built, offer high reliability, and present the most attractive carbon balance among fossil fuel options. Moreover, Iran has now acquired significant expertise in producing gas turbines and is largely self-reliant in this area.[133] And if Iran were to reduce its waste of natural gas at the wellhead, it could generate electrical power at a small fraction of the cost of nuclear energy. Capturing and using the flared gas in excess of the Middle East's or North America's average flaring rates would support electrical generation projects that amounted to the equivalent to two to four nuclear reactors with 1,000 MWe capacity.[134]

Of course, it can be argued that conventional resources have limited lifespans and are not environmentally friendly. But, Iran has other resources as well that are ecologically attractive and have remained largely unexplored.

With about 300 clear sunny days a year, 60 percent barren land, and an average of 2,200 kilowatt hours of solar radiation per square meter, Iran has a great opportunity to tap into solar energy.[135] This potential is estimated at 3.3 million terawatt hours per year, which is thirteen times higher than Iran's total energy consumption.[136] Other studies show that the amount of energy received by just 1 percent of the country's land surface could fulfill the entire country's current energy demands and produce an equal amount for exports.[137]

Yet, photovoltaic electric power generators remain underdeveloped in Iran. Only a 250 kW solar thermal power-generating system is installed in Shiraz, and about 150 kW capacity is scattered around the country.[138] In May 2011, Iran's first integrated solar combined cycle plant in Yazd came online. The project cost nearly $30 million and has a nominal capacity of 478 MW, of which only 17 MW comes from solar.[139]

A mountainous country located between two great bodies of water, Iran also has significant potential to harness wind energy. According to a wind energy survey of 45 suitable sites in the country, Iran could produce at least 6,500 MW of wind power.[140] This corresponds to more than six times the energy generated by the Bushehr reactor.

Despite being among the first nations to harvest wind energy in ancient times, Iran's wind-energy sector is still at the rudimentary stage. The 91 MW produced by the country's two main wind farms, located in northern cities of Manjil and Roodbar, are used for local purposes.[141] If resources were invested in this area, Iran could conceivably become one of the world leaders in wind energy.

Iran also has several geothermal resources (hot spots), with a generation-capacity potential of nearly 7,000 MW.[142] Yet, with just $81 million allocated for investment in this energy resource from 2000 to 2010, only a 55 MW geothermal power plant has been installed in Iran.[143]

The need for energy security is often cited by Iranian leaders as a motivation for embarking on a nuclear energy program. That security would, in theory, be achieved through diversifying the country's energy mix and releasing more petroleum for export.[144] This logic was probably valid in the Iran of 1970s, when the country's electricity consumption was about 14,000 MWe, mostly generated from oil.[145] Today with about 61,000 MWe generating capacity, the share of oil in the country's electricity production is 14 percent.[146] Thus, a more credible argument can be made for natural gas that generates 75 percent of the nation's electricity.[147]

But would nuclear energy be the best vehicle for boosting Iran's gas exports? The Bushehr reactor, for example, would make available no more than one billion cubic meters per year (bcm/yr) of natural gas, which pales in comparison with the 11 bcm/yr that is flared at the wells.[148]

Instead of enhancing Iran's energy security, the nuclear program has diminished the country's ability to diversify and achieve real energy independence.

Altogether, the record of nuclear energy in Iran is a bleak one. Instead of enhancing Iran's energy security, the nuclear program has diminished the country's ability to diversify and achieve real energy independence. It has also invited a wide range of sanctions and exacerbated Tehran's isolation, adversely affecting Iran's role as a major oil exporter. This damage is likely to have long-term consequences. The International Energy Agency predicts that even if the nuclear crisis were to be resolved promptly and sanctions lifted, Iran would not be in a position to recover to an oil production rate of nearly 4 mb/d before 2020.[149]

A COMPARATIVE DISADVANTAGE

The Bushehr reactor—the first nuclear reactor of its kind in the Middle East—and Iran's extensive nuclear fuel-cycle infrastructure are often portrayed by the Iranian government as symbols of the country's scientific adroitness, especially in comparison with other regional states. But Iran does not have that much of a technological edge. Neighboring countries, in contrast to Iran, have unimpeded access to global markets and are likely to bridge the technology gap rapidly. The same world powers that have imposed sanctions on Iran are supporting these nuclear-hopefuls that have opted to make their programs optimally transparent.

In fact, interest in nuclear energy is growing throughout the region. Several competing countries have intensified their attempts to obtain nuclear technology. Similar to Iran's claims, all of these countries have framed their ambitions in terms of civilian power generation. While the Bushehr reactor was under construction, Saudi Arabia, Bahrain, Kuwait, Oman, Qatar, and the United Arab Emirates declared their interest in pursuing civilian nuclear programs. The UAE signed a landmark contract with a Korean-led consortium, valued at roughly $20 billion, to construct four nuclear reactors in the UAE.[150] The country passed over old Russian technology and Canadian proliferation-prone heavy-water reactors. Instead, it opted for advanced APR-1400 nuclear reactors from South Korea.[151] The tiny Gulf state has proposed building a total of ten reactors by 2030. The construction of the first unit started in July 2012, and the chosen site for constructing the plants, Barakah in the UAE's western region, is, in contrast to Bushehr, far from any city.[152]

The UAE has sought to become a nonproliferation model by signing and ratifying the Additional Protocol to its IAEA safeguards agreement as well as renouncing any ambition to enrich uranium or reprocess spent fuel to extract plutonium.[153] Russian and French companies have already signed fifteen-year agreements to supply nuclear fuel, conversion, and enrichment services for the UAE's four planned nuclear reactors.[154] By concluding the gold-standard "123 Agreement" with the United States, the UAE has gone the extra mile in providing additional binding assurances on nuclear nonproliferation, safety, and security issues.[155] The U.S. Export-Import Bank approved $2 billion in financing for the Barakah plant in September 2012 for U.S.-sourced components and services. The United Kingdom and Japan have signed memoranda of understanding on nuclear energy cooperation with the UAE, and France has a nuclear cooperation agreement with the UAE as well. Australia signed a bilateral safeguards agreement with the UAE in August 2012.[156]

In August 2009, the UAE advised the United Nations nuclear agency that it was ready to join the IAEA Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Later that year, the federal law regarding peaceful uses of nuclear energy was enacted, providing a system for licensing and control of nuclear material as well as establishing an independent Federal Authority of Nuclear Regulation to oversee the whole UAE's nuclear energy sector. Separate from that authority, Abu Dhabi has also set up an International Advisory Board of experts, headed by former IAEA director Hans Blix.[157]

These policies have allowed the UAE to procure nuclear reactors with higher safety standards, rugged designs, longer operating lives, less fuel consumption, and less waste production than Iran has.[158] For instance, while Iran's Russian-built Bushehr reactor is considered a generation II reactor, the UAE will be receiving advanced generation III reactors from South Korea that have simpler designs, enhanced safety, and increased fuel efficiency.[159] The Emiratis will also be able to have open access to global nuclear technology and safety expertise.

If other Middle Eastern countries move forward in building nuclear power plants, their much-faster construction rates will offer better economic rates of return. The nuclear industry claims that advanced nuclear reactors such as the AP-600 and AP-1000 from Westinghouse can be constructed in as little as three years.[160] Larger advanced nuclear reactors such as the ABWR-1300, developed in a joint effort between GE-Hitachi and Toshiba, can be constructed in nearly four years.[161] Even taking preoperational and regulatory delays into consideration, which can prolong the average time between initial consideration of nuclear power plant construction and the commencement of operation to ten years, Iran's record of thirty-eight years for the Bushehr reactor is hard to match.[162]

The vision of a nuclear Middle East could prove to be no more than a mirage, but undoubtedly Iran's atomic activities have increased nuclear energy's appeal in the region.[163] It is true that after a fifty-six-year-long journey, Iran now has an indigenous nuclear infrastructure that distinguishes it from other countries in the region. Yet, the country's nuclear power plants are not as modern, commercially competitive, and safe as those that its neighbors are likely to procure for a fraction of Iran's time and capital investment.

UNHEEDED WARNINGS

A quarter-century after the world's worst nuclear catastrophe at Chernobyl, the nuclear disaster at Japan's Fukushima Daiichi power plant rekindled a worldwide debate on the wisdom of nuclear power and the vulnerabilities of the world's more than 430 operational nuclear power plants.[164] The calamity in Japan compelled countries like Germany and Switzerland to decide to phase out all of their nuclear reactors within ten years.[165] Rising concerns could eventually bring about the closure of around 30 vulnerable nuclear plants worldwide, mostly located in seismic zones or close to national boundaries.[166]

The issue, however, remained a political taboo for the Iranian government. Nonetheless, a new phenomenon emerged within the broader Iranian society. A growing number of Iranians started arguing in open letters, media interviews, and blogs that the government's nuclear program is in fact endangering, not enhancing, the security and economic well-being of its citizenry.[167]

In the wake of the Fukushima catastrophe, President Mahmoud Ahmadinejad, who had once compared Iran's nuclear program to "a train with no brakes,"[168] responded to safety concerns about the country's sole nuclear reactor in Bushehr by declaring that it meets "all safety rules and regulations and the highest standards have been applied to the nuclear power plant."[169] Faulting Japan's "outdated technology," Ahmadinejad asserted that a similarly massive earthquake wouldn't create "any serious problem" for Iran.[170] There are, however, many reasons to be seriously fretful about the Bushehr nuclear power plant. These dangers should be neither exaggerated nor neglected.

Iran's Bushehr plant is a hybrid German-Russian reactor that resembles a virtual petri dish of amalgamated equipment and antiquated technology. The sui generis nature of the reactor means that Iran cannot benefit from other countries' safety experiences. Problems rooted in this situation emerged even before the reactor became operational. During tests conducted in February 2011, all four of the reactor's emergency cooling pumps were damaged, sending tiny metal shavings into the cooling water.[171] These pumps were German and from the 1970s. Russian engineers pressured Iran to unload the 163 fuel assemblies of low-enriched uranium from the core of the reactor in order to prevent any damage to them and conduct a thorough cleaning, which further delayed the long-overdue launch. Again in October 2012, the reactor was shut down and fuel rods were unloaded after stray bolts were found beneath the fuel cells.[172]

More ominously, Bushehr is located at the intersection of three tectonic plates.[173] According to the Russian builder of the reactor, the model that was used as basis for the Bushehr reactor is designed to endure an earthquake of intensity 7 on MSK-64 scale when it is in operation (corresponding to 6 on the Richter scale) and an earthquake of intensity 8 on MSK-64 scale under safe shutdown (corresponding to 6.7 on the Richter scale).[174]

Iran frequently experiences earthquakes that register at higher than 6 on the Richter scale.[175] The seismic analyses for the Bushehr site were conducted in the 1970s when technology was not yet capable of properly detecting blind thrusts (breaks in the Earth's crust with no visible evidence on the surface) and salt domes (massive underground salt deposits) along the Persian Gulf's shoreline.[176] The paucity of historical and instrumental data makes assessing earthquake hazards and understanding the fault mechanisms at work in the Bushehr area extremely difficult. Iran's sole nuclear power plant is not at risk of a tsunami similar in size to the one that knocked out the electricity and emergency cooling systems at Fukushima.[177] But, repeated warnings about the threat of earthquakes for the Bushehr nuclear plant appear to have fallen on deaf ears.

Any nuclear disaster at Bushehr would have regional implications. Given that prevailing wind in Bushehr is in the direction of south/southwest, the release of radioactive material could be quite threatening for other Persian Gulf countries. Bushehr is closer in proximity to the capitals of Kuwait, the UAE, Qatar, Oman, Bahrain, and Saudi Arabia's oil-rich eastern province than it is to Tehran.[178] The cost of cleanup, medical care, energy loss, and population relocation could approach hundreds of billions of dollars over decades, and release of highly radioactive fission products would be highly detrimental to human health and the environment.[179] Radioactive elements such as iodine-131, cesium-137, stontium-90, and plutonium-239 with physical half-lives ranging from a few days to hundreds of years damage the thyroid gland, lungs, bone marrow, and other critical organs.[180] Disturbingly, as a nonparty to the Vienna Convention on Civil Liability for Nuclear Damage, Tehran could shun responsibility if its nuclear program creates a regional cataclysm.[181]

The Bushehr reactor is not the only source of nuclear safety concerns in Iran. After forty-six years, the research reactor in Tehran has also outlived its thirty-five to forty-year operational lifetime. Several incidents have already taken place at the reactor. Reportedly, the control rods got stuck in the reactor in 2001 and 2003, and Iran sought technical assistance from the IAEA to fix the problem.[182]

Iran plans to construct two additional reactors: a 40 MW research reactor currently under construction in Arak, 260 kilometers southwest of Tehran, and a 360 MW power reactor at Darkhovin, near the border with Iraq. But its lack of experience in building nuclear reactors independently and the international sanctions currently in place cast doubt on the safety standards the reactors will reach.

Although enrichment and fuel-processing facilities are safer in nature, they are not risk free, and the proximity of these plants to urban areas is also alarming. Thousands of people live in Heleylah and Bandargah villages, just 18 kilometers south of Bushehr.[183] The Uranium Conversion Facility in Isfahan is only 15 kilometers away from the center of the city, which has a population of over 2 million.[184]

The Iranian government's poor record of anticipatory governance and crisis management is another source of concern. The scale of destruction, morbidity rates, and number of casualties stemming from Iran's natural disasters are unusually high. In 1990, the northwestern city of Rudbar was struck by a 7.4 magnitude (on the Richter scale) earthquake, which resulted in 40,000 fatalities, 60,000 casualties, and 500,000 displaced people.[185] The economic loss caused by this earthquake has been estimated at $7.2 billion, which amounted to more than 7 percent of the country's gross national product in that year.[186] And in December 2003, when a 6.6 Richter earthquake hit the southeastern city of Bam, more than 26,000 Iranians perished, nearly 30,000 were injured, 100,000 were displaced, and 85 percent of the buildings and infrastructure in the city were destroyed.[187] In contrast, a 6.5 Richter quake that struck San Simeon in California just a few days earlier resulted in only three fatalities and damaged 40 buildings.[188]

The Iranian government has neglected to address basic questions about its preparedness for a nuclear emergency, including evacuation drills for Bushehr residents. These problems are rooted in the fact that unlike many nuclear countries, Iran's Nuclear Regulatory Authority is not an independent body. In the absence of a proactively vigilant public and a pervasive culture of safety, a rigorous and independent nuclear regulator is vital for prioritizing safety and security over all other interests.[189] The IAEA has encouraged the Iranian government to provide its national regulatory body with all authority and resources needed to fulfill its functions independently. To date, there is no evidence that Iran has heeded this recommendation, along with other suggestions, such as increasing the quantity and the level of expertise of body's technical staff.[190]

Security has become another menacing liability for Iran's nuclear program. Iran is ranked among the worst countries (30 out of 32 countries surveyed) in terms of the security of its nuclear materials and stockpiles.[191] The government has been shown to be inept at safeguarding its nuclear installations and protecting its scientists. Several Iranian nuclear physicists have been mysteriously assassinated.[192] In 2010, the Stuxnet computer virus caused the gas centrifuges at the Natanz plant to malfunction and contaminate the Bushehr reactor's control systems.[193] Stuxnet damaged about 20 percent of centrifuges in Natanz and temporarily brought most enrichment activities to a standstill.[194] The contamination in Bushehr even prompted warnings from normally incautious Russian nuclear officials.[195] More viruses, such as Stars and Flame, followed.[196] Such a record accentuates concerns about the Iranian government's ability to prevent nonstate actors and terrorists from obtaining sensitive nuclear materials.

As a result of the politicization of Iran's nuclear program, safety and security concerns have become secondary issues.

But as a result of the politicization of Iran's nuclear program, safety and security concerns have become secondary issues. The Iranian leadership's political drive to demonstrate the ineffectiveness of international sanctions and boast about its technological capabilities has repercussions, such as the premature opening of the Bushehr reactor on August 21, 2010. The Iranian state-controlled media presented the plant as "not only a nuclear power plant but also a symbol of national resistance against global powers."[197] But the reactor's official inauguration had to be delayed because of numerous problems during the testing phase.[198]

That Iran insists its plant should be managed by Iranians as soon as possible also appears to be politically motivated. The Russian technicians are to run the Bushehr reactor for the first two years after its official startup, then hand over control to the Iranians.[199] Taking into account that most nuclear accidents around the world have been caused or exacerbated by human error, these policies increase the likelihood of a humanitarian catastrophe. To make matters worse, international sanctions have deprived Iran of the IAEA's nuclear assistance and prevented Iranian scientists from participating at the agency's safety workshops.[200]

Iran's refusal to adhere to international conventions that define the norms of safety and security in the field of nuclear technology is also troublesome. Iran has not yet joined the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.[201] These conventions establish a system of mutual oversight that sets international benchmarks on the siting, design, construction, and operation of reactors as well as on safety assessments. It requires parties to submit progress reports for "peer review." Tehran conflates its current disputes with the IAEA with the ratification of these conventions.

With Bushehr becoming operational, Iran is the only nuclear power country that is not a signatory to the Convention on Nuclear Safety.[202] The Iranian government has ratified the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident,[203] but it is party to none of the international nuclear security conventions such as the Convention on the Physical Protection of Nuclear Material and the Convention for the Suppression of Acts of Nuclear Terrorism.[204]

Although at times politics can eclipse safety, any accident could have significant political repercussions. A quarter of a century ago, the nuclear disaster at Chernobyl became a momentous political event with aftershocks that hastened the collapse of the Soviet Union. Efforts to contain the spread of radioactive material and cleanse the contaminated outlying areas involved 500,000 workers and cost $18 billion. The Soviet empire never recovered from that shock.[205]

POLICY IMPLICATIONS

THE POLITICAL CONTEXT (2009–PRESENT)

Hopes for a peaceful resolution of Iran's nuclear crisis were raised with U.S. President Barack Obama's election victory in 2008 and his pledge to pursue a policy of engagement with Iran. Indeed, more than any U.S. president since the 1979 Iranian Revolution, Obama attempted to change the tone and context of the U.S.-Iran relationship. Given Iran's influence on key U.S. foreign policy challenges—namely Afghanistan, Iraq, Arab-Israeli peace, terrorism, energy security, and, most urgently, nuclear proliferation—Obama seemingly concluded that shunning Iran was no longer an option, bombing Iran would likely exacerbate these issues, and engaging Iran was a win-win. A successful attempt could help bring about détente (if not rapprochement), while an unsuccessful attempt would strengthen international resolve.

Beginning with his inauguration speech in January 2009, Obama offered, in a thinly veiled reference to Iran, to "extend a hand if you are willing to unclench your fist." Two months later, on the occasion of the Iranian New Year, Nowruz, Obama recorded a videotaped greeting to both the Iranian people and the leaders of the "Islamic Republic of Iran"—a subtle but unprecedented acknowledgment of the nature of the Iranian political system.[206] Still more significant than President Obama's public overtures to Tehran were two private letters he wrote to Ayatollah Ali Khamenei, making it clear that the United States was interested in a confidence-building process that could pave the way for reconciliation. Iran's supreme leader, however, continued to focus—both openly and in his written response—on past American misdeeds rather than prospects for future cooperation.[207]

The possibility of reaching a negotiated solution further diminished when Iran descended into turmoil after the contested reelection of Iranian President Mahmoud Ahmadinejad in June 2009, which spurred Iran's largest political protests since the 1979 revolution. Nonetheless, the Obama administration continued in earnest to pursue a negotiated resolution. At a meeting between Iran and the P5+1 (the five permanent members of the United Nations Security Council and Germany) in Geneva in October 2009, Iranian and American negotiators held bilateral nuclear talks for the first time.[208] Iran agreed in principle to swap 80 percent of its stockpiled low-enriched uranium with fuel rods for the Tehran Research Reactor. But within days, domestic opposition in Iran scuttled the deal.[209] Russian efforts to salvage the agreement in Vienna several weeks later also proved fruitless.

The nuclear crisis once again rose to prominence when in September 2009 Iran disclosed a covert enrichment facility at Fordow, deep under a mountain near Qom, shortly before

President Obama, British Prime Minister Gordon Brown, and French President Nicolas Sarkozy revealed its existence at a press conference.[210]

With seemingly no hope for a negotiated compromise, the threat of U.S. or Israeli attacks on Iran's nuclear facilities grew more acute. In February 2010, Iran began enriching uranium to 20 percent purity. In May 2010, six months after the first swap agreement collapsed, Brazil and Turkey tried to revive the deal in the form of the so-called "Tehran Declaration," which Iran signed. Given that Iran had doubled its stockpile of low-enriched uranium in the time that elapsed, the P5+1 turned it down, on the grounds that the terms no longer were adequate.[211]

A few weeks later, the most stringent United Nations sanctions on Iran were adopted under Resolution 1929.[212] While Russia and China, as well as some European countries, thwarted tougher sanctions against Iran during the George W. Bush era, they gradually came to conclude that Iran, not America's unwillingness to engage, was the greater obstacle and rejecting sanctions could increase the likelihood of a U.S. or Israeli military attack. As such, international support grew behind the Obama administration's effort to establish a sanctions regime whose breadth and depth would exceed all expectations. Exhorted by an impatient Congress, the Obama administration levied the most comprehensive American sanctions against Iran in more than a decade.[213] The European Union followed suit with its own tighter restrictive measures.[214]

Another two rounds of negotiations between Iran and the P5+1 in Geneva and Istanbul in December 2010 and January 2011, respectively, ended in failure. Iran's chief negotiator, Saeed Jalili, made the total removal of sanctions and recognition of Iran's right to enrichment a precondition for negotiations, and that was a nonstarter for the West. Fifteen months of diplomatic stagnation—punctuated by mysterious assassinations, sanctions, sabotage, and saber-rattling—was to follow.[215]

The year 2011 came to an end with the most damaging IAEA report on the possible military dimension of Iran's nuclear program. In a fourteen-page annex, the IAEA detailed charges that Tehran experimented with technologies critical for the development of nuclear warheads before 2003 and warned that some of the activities may still be ongoing.[216] The report paved the way for tighter sanctions, and Canada and Britain cut off the Central Bank of Iran, a move that was followed by Washington's restrictions on Iran's oil exports.[217]

The pressure track continued in full force in 2012. In January, the European Union imposed a gradual oil embargo on Iran, effectively halting any Iranian oil imports as of July 2012. In a tit-for-tat move, Tehran tripled its monthly production of 20 percent enriched uranium. Likewise, in February, under pressure from Western countries, SWIFT—the world's most important financial clearinghouse—agreed to expel Iran from its network.[218] In response, Tehran announced several nuclear "achievements," including connecting the Bushehr nuclear reactor to the national grid, loading the Tehran Research Reactor with homemade nuclear fuel rods, and unveiling a new generation of centrifuges activated at Natanz.[219]

While the two sides agreed to resume talks in spring 2012, the new round of nuclear diplomacy was forged in the old crucible of mistrust and misapprehensions between Iran and the West. Going into the talks, both sides were persuaded that they had the upper hand. In mirror image, each party saw the other's renewed interest in diplomacy as a sign of weakness and an attempt to avert further escalation in volatile times.[220] The first meeting in Istanbul in April 2012 focused on platitudes. The next round, in Baghdad in May, saw the two sides formally exchange proposals—composed mainly of opening salvos based on maximalist demands.[221] No agreement was reached, other than deciding to meet again at the level of technical experts.[222] Two of these lower-level meetings took place followed by eight months of stagnation. Negotiations were resumed in February 2013 in Kazakhstan.

THE ROAD AHEAD

One of the foremost foreign policy challenges of President Barack Obama's second term will be dealing with Iran's nuclear crisis, while avoiding another military conflagration in the Middle East. While U.S. officials maintain that Tehran has yet to make a decision on whether to produce nuclear weapons, President Obama made clear in his first term that if faced with a binary choice—bombing Iran or allowing Iran to get a bomb—he would choose the former. Given the potentially enormous ramifications of either of these unpalatable outcomes—on the global economy, regional stability, international law, America's standing in the world, and the well-being of thousands of Iranians—every effort should be pursued to avoid such a lose-lose choice. To begin, it is helpful to take stock of Iran's five-decade-long nuclear odyssey.

> **The only long-term solution for assuring that Iran's nuclear program remains purely peaceful is to find a mutually agreeable diplomatic solution.**

Iran's nuclear program has deep roots. It cannot be "ended" or "bombed away." It is entangled with too much pride—however misguided—and sunk costs. Given the country's indigenous knowledge and expertise, the only long-term solution for assuring that Iran's nuclear program remains purely peaceful is to find a mutually agreeable diplomatic solution.

The contours of such a deal are becoming increasingly clear. Any agreement would have to include commitments by Iran not to undertake specific experiments, imports, and other activities that would be vital to making nuclear weapons and therefore illegitimate for a peaceful nuclear program. The IAEA has already identified some of the benchmarks of nuclear weaponization and others could be specified. Tehran will be asked to operationalize its supreme leader's repeated religious declarations that Iran would not seek nuclear weapons.[223]

The establishment of detailed and mutually agreed boundaries between Iran's nuclear program and a nuclear weapons program could then give tolerable confidence that Iran could continue to enrich uranium to power-reactor levels (below 5 percent). In addition to saving face domestically, continued enrichment would give Iranian leaders leverage to keep the United States from reneging on its commitments. Iran would have the option of ratcheting up the level of enrichment in a tit-for-tat response to failures by the United States or others to keep their side of any deal. Such a deal would also require the United States and European Union to ease the most punishing sanctions, namely those against Iran's central bank and oil sales.

To be sure, many members of the U.S. Congress will continue to demand that Iran be left with "no capability" to produce nuclear weapons. Though often vague, such positions seem to require Iran to "end its nuclear program"—that is, cease all uranium enrichment. Indeed, this would be optimal but not essential from a nonproliferation standpoint. The Iranian enrichment program is limited in size and scope and thus could be monitored by the IAEA's enhanced safeguards. More importantly, there is virtually no chance that Iran will abdicate what it and many developing countries now insist is a right—a right to enrichment. Above all, history has proven that unfair deals beget unfaithful dealmakers.

It has also become clear over the years that the Iranian nuclear program is multidimensional. Yet, since the outset of Iran's nuclear standoff, proliferation concerns have understandably dominated the program's other dimensions. Discussing cost-benefit angles of Iran's nuclear policy, safety, and the security of its nuclear facilities as well as alternative energy options broadens the discussion and expands diplomatic avenues. As these subjects are less politically charged, they will allow both the negotiators and their domestic constituents to view issues in a less ideological and emotional light.

During recent negotiations between Iran and the P5+1, there were initial attempts to offer nuclear safety cooperation as an incentive to Tehran.[224] Addressing this and other hitherto-unheeded dimensions strengthens "the correlation of fortunes" among key players, increasing the chances of breaking free of zero-sum games and creating win-win opportunities.[225] The potential areas of collaboration, however, should be clearly identified and concrete incentives should be proposed in return for Iran's verifiable concessions. The initiative on nuclear safety and security cooperation should be pursued more rigorously, employed more systematically, and explained more clearly. Another potential area for substantiating the concept is in the field of renewable energies. Offering assistance in that area will undermine the narrative of "advanced technology denial," set a positive precedent for other nuclear-aspiring developing countries, and allow both sides to take a face-saving way out.[226]

For the last several years, the primary focus of U.S. policy has been to subject Iran to escalating multilateral pressure in order to compel and coerce the Islamic Republic's leadership into curbing its nuclear program. Despite Tehran's growing economic woes, however, there has been little indication that the country's leadership is prepared to significantly change course. Nor, so far, has domestic pressure mounted to do so. But the Iranian public is indeed suffering deteriorating economic conditions as a result of the crisis-incurred economic crunch. In the absence of credible polling, it is impossible to discern exactly what percentage of Iranians remain supportive of the country's nuclear program—which is not necessarily the same as the government's current nuclear policies.

Public criticism of Iran's nuclear calculus is completely stifled, as newspapers are ordered to keep silent. Western governments have also largely ignored public opinion in Iran. Consequently, despite being the most important stakeholders, the Iranian people have been sidelined, and their interests and aspirations have played a secondary role in both the U.S. and Iranian governments' calculations.

On the one hand, by overplaying jingoism with regard to its nuclear aspirations, the Iranian leadership has rendered any significant nuclear retreat tantamount to an act of capitulation, if not political suicide. On the other hand, Washington's overwhelming focus on coercion and military threats has backed U.S. policymakers into a rhetorical corner and played into the Iranian government's narrative of "negative nationalism," which depicts the United States as an unjust imperialist power seeking to prevent Iran's rise by depriving it of sophisticated nuclear technology.[227] While U.S. officials and members of Congress frequently speak of "crippling sanctions," they rarely impress upon Iranians the concrete costs of their country's nuclear policies and the potentially myriad benefits of a more conciliatory approach.

Regardless of economic hardships, the Iranian people are unlikely to comprehend the U.S. strategy unless Washington provides answers to key questions: What could Iranians collectively gain by a nuclear compromise, other than a reduction of sanctions and the threat of war? How could a more conciliatory Iranian approach improve the country's economy and advance its technological—including nuclear—prowess? U.S. public diplomacy efforts should make clear to Iranians that a prosperous, integrated Iran—as opposed to a weakened and isolated Iran—is in America's interests.

A more effective U.S. public diplomacy campaign is contingent upon not only an improved message but also a much better medium. The Voice of America's Persian News Network (PNN)—which is estimated to reach as many as 20 million Iranians—has long been beset by mismanagement and poor quality programming. Its viewership has been eclipsed by other satellite networks with equal or much smaller resources than the PNN's annual $20 million budget.[228] It's telling that in September 2010 even President Obama chose to communicate with the Iranian public in an interview with BBC Persian rather than the PNN.[229] Rendering the PNN a public-private partnership—similar to the BBC—is necessary in order to transform it from a sclerotic government bureaucracy to a twenty-first-century media outlet.

The time does not appear ripe for rapprochement between Washington and Tehran, so the two sides should opt for détente.

At this stage, the time does not appear ripe for rapprochement between Washington and Tehran, so the two sides should opt for détente. After thirty-four years of compounded mistrust and ill will, absent a broader political settlement between the United States and Iran, a full resolution of the nuclear crisis is highly unlikely. Both countries should step back from the edge of the confrontation cliff, reassess their respective positions and principles, and adopt a new and innovative approach, cognizant of the fact that a military conflagration would be disastrous for all parties.

APPENDIX

TIMELINE OF THE BUSHEHR NUCLEAR POWER PLANT

1970s

1974 West German company Kraftwerk Union agreed to construct the Bushehr nuclear power plant

1975 Work began on plant

1976 Formal contract was signed

1978 Reactor I was 85 percent complete and reactor II was 50 percent complete

1979 Work was suspended

1980s

1982 International Chamber of Commerce ruled that the German companies should deliver some 80,000 pieces of equipment for the Bushehr reactor

1984 Germans conducted feasibility study to restart the work

Iraq attacked the reactor

1985 Iraq targeted Bushehr with aerial attacks twice

1986 Abdul Qadeer Khan, the father of Pakistan's nuclear program, visited Bushehr

Iraq attacked the Bushehr reactor

1987 Iraq attacked Bushehr reactor twice

1988 Iraq finally conducted attack on Bushehr before the ceasefire

1989 President Akbar Hashemi Rafsanjani discussed nuclear cooperation with his Russian counterpart

1990s

1992 Iran and Russia signed a nuclear cooperation agreement

1994 Russian specialists toured the Bushehr plant for the first time

1995 Work restarted

1998 Ukraine declined to sell two turbines for use at the Bushehr reactor

Russia added an addendum to the main contract to exclude Iranian subcontractors

1999 Iran approved the final set of Russian designs and specifications for the Bushehr plant

2000s

2002 The work to assemble the reactor's heavy equipment began

2005 Iran agreed to return all spent fuel rods to Russia

2007 Construction stopped because of funding shortages

After resolving the funding issue, Russia began delivering nuclear fuel to Iran

2010s

2010 Iran began loading the plant with fuel

In February 2011, fuel was unloaded from the core of the reactor because of a damage to one of the four main cooling pumps

Computers at the Bushehr reactor were contaminated with Stuxnet virus

2011 The reactor went critical and started to run at a minimum power level for final commissioning tests

2012 The reactor inauguration was postponed to 2013

2013 The IAEA reported in February that the reactor was shut down

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