Nuclear Power Option

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The Fukushima Daiichi accident initiated by a tsunami triggered a cycle of heightened fears and anxiety about nuclear power. It prompted governments around the world to assess the safety situation of their nuclear fleets or revisit their plans to start national nuclear power programs. Some countries decided to phase out the technology. Other countries decided to postpone the launch of nuclear power programs and put more emphasis on a comprehensive development of their national nuclear infrastructure. While the accident is expected to delay growth in nuclear power, it has not led to a significant retraction of national nuclear power programs globally. The factors that led before March 2011 to the revival in interest have not changed after the accident. Those are: rapidly growing electricity demand, the need for reliable base load electricity at stable and predictable costs, volatile fossil fuel prices, concerns for energy security, and environmental concerns, especially as related to GHGs emissions.

Several Arab countries have also shown an interest in nuclear power despite the fact that these countries hold the largest conventional oil and gas reserves globally. Why then would they consider the nuclear option or, as in the case of the UAE, launch a national nuclear power program with two nuclear power plants already under construction? The factors that rekindled the interest globally are to, a certain extent also, valid for many Arab countries. In addition, at current international market prices oil and gas rich countries can increase overall export revenue by deploying nuclear power domestically and sell the avoided domestic oil and gas use (for electricity generation and desalination) profitably in the international market place.

While there are many promising benefits, there are also demanding challenges and daunting obstacles to overcome on the road to nuclear power. Nuclear power is a highly complex technology. Mastering these to reap its benefits is a challenge. Nuclear power is less forgiving than other energy technologies, requiring persistent discipline in operation and strictest adherence to safety standards. Equally important is competent and effective regulatory oversight. Even technologically advanced countries can have serious weaknesses in their national nuclear programs. In technologically less advanced countries without a well-developed safety culture, the introduction of nuclear power needs to balance the added risk with the benefits. A successful, safe and secure nuclear power program requires a strong and unwavering long term national commitment, with high initial efforts to develop the required infrastructure, especially human resources and an effective and disciplined management system for all components of the nuclear fuel cycle. While technical solutions for the safe and secure ultimate disposal of nuclear waste do exist and are being pursued, lingering doubt and debate will continue globally until several implementations currently underway have been successfully demonstrated.

What is right for the Arab countries depends on the region's national preferences and policy priorities. For now, the unfolding changes in the region are pointing to delays in planning and implementation of nuclear power programs in several Arab countries.

I. INTRODUCTION

A. Overview of nuclear power development

i. Brief history

Although electricity was generated for the first time by a nuclear reactor in 1951 at the EBR-I experimental station near Arco-Idaho in the USA, the grid connection in 1954 of the 5 megawatt electrical (MW) Obninsk Nuclear Power Plant in the former Soviet Union (FSU) marked the dawn of commercial nuclear fission energy. Since then, global nuclear power development evolved through four stages.

The initial prototype plants of the 1950s in the FSU, United Kingdom and the United States led to stage 1, a period of early growth until about 1965, with an average growth rate of about seven reactors per year. In the second stage from 1966 to 1985, the technology quickly spread around the world. By the end of 1973 two-thirds of the 30 countries operating nuclear power plants today had started the construction of their first nuclear plant. The oil crises of 1973-74 and 1979 added further momentum to the global expansion of nuclear power. The second stage of accelerated growth saw an average of 25 construction starts and 18 grid connections per year (see Table 1).

The third stage extended from 1986 to the mid-2000s. In this period, global nuclear power development entered a major downturn dropping to an average of five construction starts (and less at the end of the period). This slowdown was the result of several factors: initially rapidly rising construction costs of nuclear plants, in large part caused by the then prevailing high inflation and interest rates; the Three Mile Island accident (USA, 1979) which severely undermined public confidence in the technology; and nuclear regulators who, responding to the heightened public concerns about nuclear operating safety, mandated plant retrofits and design modifications of plants under construction which caused long construction delays and substantial cost overruns, and led to the suspension and/or cancellation of many projects. Moreover, high energy prices and efficiency policies, introduced in response to the oil crises, reduced base load electricity demand by more than half of the historically observed annual growth rates of 6 to 7 percent in many OECD countries.

Collapsing oil and gas prices in the mid-1980s, the commercialization of inexpensive, modular and high efficiency combined cycle turbines, and electricity market deregulations in many countries further eroded nuclear power's competitiveness and caused additional nuclear project delays and cancellations.[1]

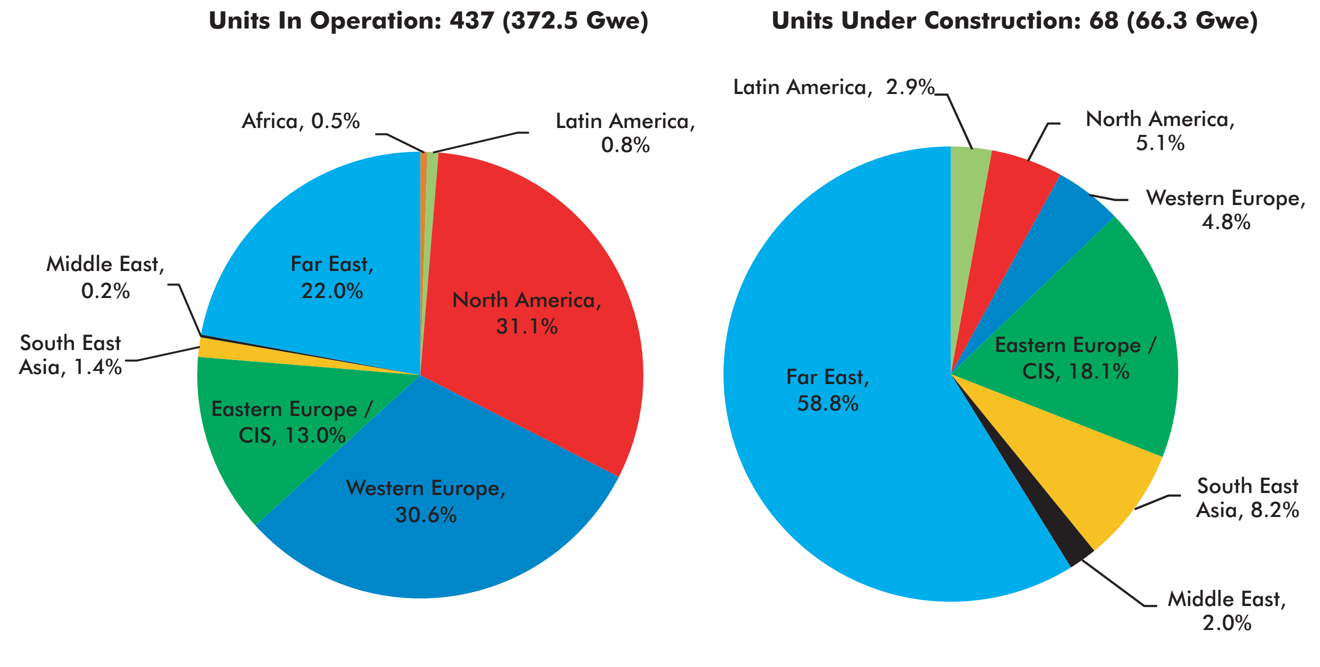
The disastrous accident at the Chernobyl nuclear power plant (Ukraine, 1986) then was "the straw that broke the camel's back". The combined effect of economic woes in many markets, lower than projected demand, excess generating capacity plus rapidly rising public opposition led to a general slowdown in the expansion of nuclear power - except Asia where populous developing countries with high industrialization aspirations or countries with limited indigenous resources but energy security concerns continued a nuclear expansion course.

TABLE 1 THE FOUR STAGES OF CIVIL NUCLEAR POWER DEVELOPMENT

		Construction starts		Grid connections	
		Reactors per year	MW per year	Reactors per year	MW per year
Early growth	1954-1965	7	1,300	4	432
Accelerated growth	1966-1985	25	20,800	18	12,500
Slow growth	1986-2004	5	3,900	9	8,400
Rising expectations	2005-2010	9	8,700	3	2,000

Source: IAEA 2012

FIGURE 1 DISTRIBUTION OF NUCLEAR POWER IN MAJOR WORLD REGIONS - CURRENT GENERATING CAPACITY (LEFT PANEL) AND GENERATING CAPACITIES UNDER CONSTRUCTION (RIGHT PANEL) (AS OF 19 MARCH 2013)



During the third stage, market liberalization and low fossil fuel prices exposed nuclear operators to previously unknown competition, which forced nuclear plant operators to better utilize their assets, shorten maintenance outages and reduce overhead costs. The net result was enormous performance improvements of the global fleet of reactors. By 2005 the global load factor had reached more than 80 percent, up from the 65 percent level prevailing in the early 1990s, which allowed continued growth in nuclear generation, despite aggregate generating capacity expanding only 14 percent over the period.[(2)]

Competitive economics and good safety records, mirroring the economic performance, led to license extension of up to 20 years and power-uprates, through replacement of aged equipment and safety upgrades in several countries. Still, while existing plants thrived, new builds “waited “except in China, India and, to a lesser extent, Russia.

The fourth stage started in the mid-2000s and lasted until the Fukushima Daiichi accident in March 2011. It was the result of four factors: (a) Rapidly rising energy and electricity demand in large developing countries; (b) steeply ascending fossil fuel market prices to ever higher levels while exhibiting intense volatility; (c) energy security concerns, forgotten for two decades, were back on the political agenda; and (d) the climate change debate and the entry into force of the Kyoto Protocol which brought to the fore the climate mitigation benefits of nuclear power. These factors, plus generally promising nuclear economics and a

TABLE 2 **NATIONAL POLICY RESPONSES TO THE FUKUSHIMA DAIICHI ACCIDENT**

Country	Policy response
Belgium, Germany, Switzerland	Nuclear phase out – no new build
Taiwan, Province of China	Nuclear phased out announced but plant construction of new builds continues
Japan	Plants under construction suspended, Fukushima 1-4 to be decommissioned, remaining 50 plants successively shut down by 5 May 2012. Two restarts in July 2012. Future use of nuclear power contested. Subsequently, phase out intentions by late 2030s announced.
China	The award of new construction licenses was suspended but lifted again in October 2012 - four new constructions starts in November/December 2012
United Arab Emirates	Construction start of first nuclear power plant in 2012
Belarus, Turkey	First plant ordered
Chile, Indonesia, Malaysia, Morocco, Saudi Arabia, Thailand, Vietnam	Active preparation with final decision delayed or no final decision
Bangladesh, Egypt, Jordan, Ghana, Nigeria, Poland	Continue preparing infrastructure
Italy, Kuwait, Oman, Senegal, Venezuela	Plans to introduce nuclear power cancelled or postponed indefinitely

solid safety record created a positive outlook for nuclear power, leading to what was often referred to as the "nuclear renaissance". Countries with operating nuclear power plants contemplated new nuclear builds while more than two dozen countries currently without nuclear power programmes started preparations for the introduction of the technology into their national energy mixes. By 2010 plant orders and construction starts reached levels not seen for a quarter of a century.

The accident at the Fukushima-Daiichi Nuclear Power Plant (NPP), caused by the extraordinary natural disasters of the earthquake and tsunamis that struck Japan on 11 March 2011, compounded by a poor national regulatory regime and lack of adequate emergency preparedness for the management of severe accidents, brought this trend to an abrupt halt and construction starts dropped to four plants that year compared with the sixteen plants a year earlier.

The period during these four stages was coupled with a steady increase in the volume of nuclear electricity production. Nuclear production increased to about 2,600 terrawatt hour (TWh) by the mid-2000s and has been almost constant over the last ten years. The nuclear share of total electricity production increased to a level of about 17 percent by the late 1980s but since has been falling behind overall growth in electricity generation and consequently its market share slipped to 13.5 percent in 2010 and 12.3 percent in 2011 (IAEA 2012a).

ii. Current status

Until the turn of the century, nuclear power was primarily an industrialized countries' technology. Only a few developing countries introduced nuclear power at a limited scale. Graphically this is shown in Figure 1 (left panel). Looking at plants currently under construction, Figure 1 shows a fundamental shift of the nuclear power momentum to Asia. Here China and India are the countries with the fastest growing nuclear programmes followed by Russia and the Commonwealth of Independent States. The rest of the world, in particular the traditional nuclear power countries of North America and Western Europe, has fallen behind Asia by a wide margin.

iii. The Fukushima impact

The Fukushima Daiichi accident of 11 March 2011 re-ignited the debate about the role of nuclear power in the future global energy mix. Initial government policy responses varied (see Table 2). In a few cases, this prompted the outright cancellation and phase-out of nuclear power (e.g., Germany(3)) - policy responses which were in part fuelled by public sentiments and strategic electoral considerations. These developments have pointed towards an even more uncertain future of the technology than before.

As of 19 March 2013 – two years after the accident- 68 reactors were under construction worldwide. This number is the highest since the mid-1990s, despite the sharp drop from 16 construction starts in 2010 to only 4 in 2011 (and a rebound to 7 in 2012).

The Fukushima Daiichi accident, like in the immediate aftermaths of Chernobyl and the Three Miles accidents, triggered a cycle of heightened fears and anxiety about nuclear power. It also stimulated a lot of reflection about the future of nuclear power. Public acceptance has dropped noticeably in several countries. Two years later, acceptance has been on the rise again in some countries, while others are more resolved than before to abandon the technology. Construction starts of new nuclear worldwide slumped in 2011 to early renaissance levels but rebounded in 2012 again. While the accident is expected to delay growth in nuclear power, it has not led to a significant retraction of national nuclear power programmes globally - at least not yet. Indeed, the governments of Bulgaria, Czech Republic, Finland, France, Hungary, Lithuania, the Netherlands, Poland, Romania, Slovakia, Spain and the UK called for a level playing field afforded to all low-carbon emitting technologies for meeting future EU climate mitigation targets. This joint communiqué affirms the position that nuclear power should "play a part in the EU's future low carbon

NUCLEAR PLANT SAFETY AND WASTE DISPOSAL

Excerpts from Towards a Sustainable Energy Future, InterAcademy Council (IAC, 2007) and America's Nuclear Future, Blue Ribbon Commission (BRC, 2012)

"Nuclear power suffers from several difficult and well-known problems that are likely to continue to constrain future investments in this technology. Chief hurdles for primary investors include high upfront capital cost, siting and licensing difficulties, public opposition, and uncertainties regarding future liabilities for waste disposal and plant decommissioning. In addition to -and inextricably intertwined with- these issues, many experts agree that concerns about reactor safety, waste disposal, and nuclear weapons proliferation must be resolved if nuclear technology is to play a prominent role in the transition to a sustainable global energy mix. A further obstacle in many parts of the world relates to the need for significant amounts of capital and considerable institutional capacity and technical expertise to successfully build and safely operate nuclear power plants."

"In sum, nuclear power plants are much more complicated than fossil-fuel power plants, and the consequences of accidents are far greater. In fact, potential dependency on other countries for technological expertise or nuclear fuel may discourage some governments from developing nuclear capacity, even as a desire for technology status or energy security may motivate others in the opposite direction."

"An IEA analysis of nuclear economics shows that various OECD governments already subsidize the nuclear industry by providing fuel-supply services, waste disposal, fuel reprocessing, and R&D funding. Many governments also limit the liability of plant owners in the event of an accident and help with remediation."

"Accidents at Three Mile Island in 1979 and Chernobyl in 1986, as well as accidents at fuel-cycle facilities in Japan, Russia, and the United States have had a long-lasting effect on public perceptions of nuclear power and illustrate some of the safety, environmental, and health risks inherent in the use of this technology (the report was published in 2007, before Fukushima accident). While a completely risk-free nuclear plant design, like virtually all human endeavors, is highly unlikely, the role of nuclear energy has to be assessed in a more complete risk-benefit analysis that weighs all factors, including the environmental impacts of different energy options, their energy security risks and benefits, and the likelihood of future technology improvements…A related challenge is training the skilled personnel needed to construct and safely operate nuclear facilities..." (IAC)

"In recent years, of course, the threat of terrorism has added a new and potentially more difficult dimension to long-standing concerns about the safe and secure operation of nuclear facilities and the transport of nuclear materials."

"Disposing of high-level radioactive spent fuel for the millennia-scale period of time that nuclear waste could present a risk to public safety and human health is another problem that has long plagued the industry and that has yet to be fully resolved in any country with an active commercial nuclear energy program… Without a consensus on long-term waste storage, various interim strategies have emerged… Reprocessing reduces the quantity of waste by more than an order of magnitude and has the potential of reducing the storage time by several orders of magnitude; but even after reprocessing, hundreds of years of safe storage are required. Reprocessing also raises significant proliferation concerns since it generates quantities of plutonium—the essential ingredient in nuclear weapons—that must be safeguarded to prevent theft or diversion for weapons-related purposes."

"Until a long-term solutions can be found, however, the waste issue is likely to continue to present a significant and perhaps intractable obstacle to the significant expansion of commercial nuclear power capacity worldwide."

"The events of Fukushima underscore how important it is to ensure that safe and secure interim storage for spent fuel and high-level wastes is part of an integrated approach to nuclear waste management."

"This generation has an obligation to avoid burdening future generations with finding a safe permanent solution for nuclear wastes they had no part in creating, while also preserving their energy options." (BRC)

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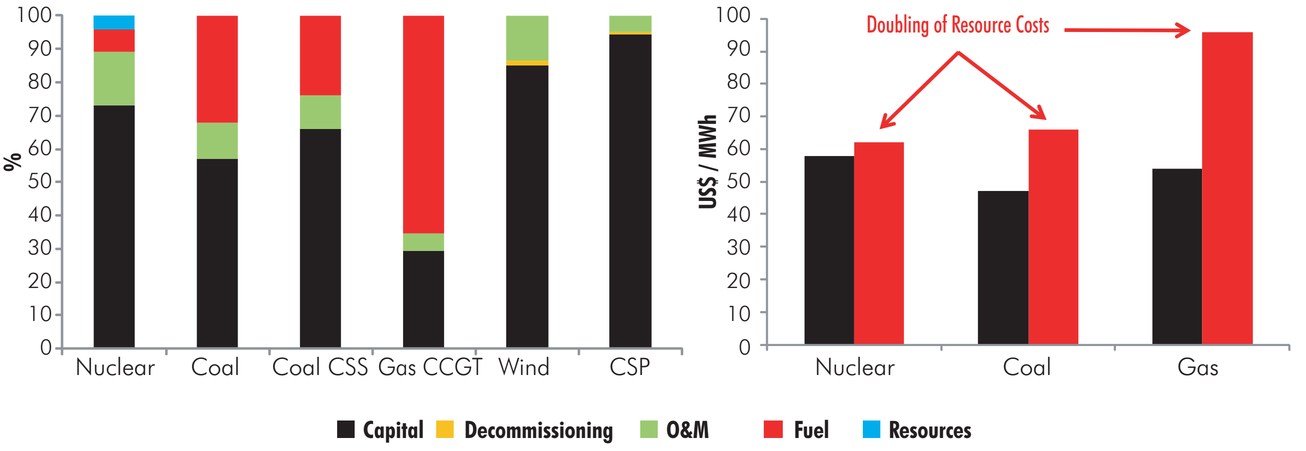
FIGURE 2 SHARES OF COST COMPONENTS IN TOTAL GENERATING COSTS AT A 10% DISCOUNT RATE (LEFT PANEL) AND THE IMPACT OF DOUBLING RESOURCE INPUT COSTS ON GENERATING COSTS



Source: ADAPTED FROM IEA/NEA 2010 AND NEA 2003.

energy mix” (UKG 2013). It also refers to the energy security features and economic benefits of nuclear energy. In the USA construction of 2 AP 1000 reactors (1117 MW each) began in March 2013, which ended a 30 year period of construction draught. Nonetheless, the accident has resulted in a temporal shift in the projected growth of nuclear power over the longer term (see Section IV).

II. DRIVERS FOR NUCLEAR POWER GLOBALLY

In the past countries have turned to the peaceful use of nuclear power for one or more of the following reasons: Limited domestic fossil resources and concerns for energy security, rapidly growing energy and electricity demand, the need for reliable base load electricity generation at stable and predictable generating costs, low environmental impacts (local air pollution and regional acidification) and technological spin offs. More recently nuclear power has often been advanced as an effective climate change mitigation option.

A. Energy security

Nuclear energy enhances energy security due to its low fuel volume which allows for easy stock-piling, i.e., on-site storage of the raw material uranium for the entire life time of the plant. Long-refuelling cycles of 18 to 24 months plus the practice of on-site storage of fuel elements for one refuelling event provides sufficient time to seek alternate suppliers in case of the original supplier defaults on contractual arrangements.

The economics of nuclear power are characterised by large up-front capital costs but low and stable fuel and operating costs - in short nuclear power is expensive to build but cheap to run. Variable operating costs, essentially fuel costs, are a comparative advantage of nuclear power. The share of uranium in nuclear generating cost is about five per cent, the remaining fuel costs include enrichment, fuel element fabrication and spent fuel management costs (see Figure 2 - left panel). Therefore, once construction is completed and plant operation has commenced, nuclear power offers stable and predictable generating costs. Unlike coal and natural gas fired electricity generation, a doubling of resource prices hardly affects total generating costs of nuclear power (see Figure 2 - right panel).

Emerging economies, like China and India, acknowledge that nuclear power is critical for energy security (and also to help alleviate climate change concerns). Energy security has motivated many countries currently without nuclear power to explore the nuclear option alongside renewable technologies to diversify the energy resources mix (World Future Energy Summit 2012).

PEACEFUL NUCLEAR OPTION IN THE ARAB WORLD – THE JORDAN MODEL

Saed Dababneh

In Jordan, as well as in other countries in the Arab region, considerable interest has been devoted during the last few years to the nuclear industry; not only due to its potential use as a power source, but due to the necessity to promote peaceful applications of nuclear sciences as well. In this context, His Majesty King Abdullah II directed the government in 2007 to review and update the national master strategy of energy sector, sanctioned by the Cabinet in 2004, with the aim to meet the Kingdom's energy needs and to achieve energy supply security. Nearly 98 percent of Jordan's energy is produced using imported oil and gas at a cost of nearly one-fourth of the gross domestic product. Continued interruption in the country's Egyptian natural gas supplies forced Jordan to rely on the more costly heavy oil imports, driving electricity subsidies to over US$1 billion. The issue of the country's energy independence consequently surfaced the local and regional policy debate, which obviously has its implications on the country's position amid the political unrest in the region. According to the updated national strategy, a potential scenario to meet the demand in the year 2020 includes the nuclear option in the mix for electricity generation. Moreover, and at an early stage, Jordan's foreseen uranium reserves encouraged officials in 2007 to declare "a transformational opportunity to convert Jordan into a net exporter of electricity by implementing a nuclear program".

There are, however, many hurdles standing in that route. Among other things are the need for skilled human resources, high investment capital cost, the limited suitable sites for nuclear power plants, the lack of adequate bodies of water for cooling, and the clearly volatile regional political climate. Though local university programs, as well as international technical cooperation, have just started to fulfill the minimum of the unambiguous need for capacity building, the other challenges are apparently vigorously hampering the project. The cost, which was anticipated to be partly covered by marketing locally produced yellowcake, is still a critical issue. In 2012, the Lower House of the Parliament found that Jordan's nuclear project is neither based on solid facts, nor is it progressing according to the declared timetable. It was assumed, according to officials, that by 2012 Jordan will start producing 2000 tonnes of U3O8 annually, which presumably meant providing the treasury with hundreds of millions of dollars. Jordanian experts early warned this scenario was not realistic; based on the low-grade quality and limited minable quantities, together with the increasing water requirement and environmental impact associated with the huge amount of ores to be processed when the uranium content is low. Consequently, the departure of AREVA in 2012, and before that Rio Tinto, actually marked a hinder to Jordan's uranium mining aspirations. During its four-year presence, AREVA acknowledged these challenges that are facing any feasible extraction of Jordanian uranium deposits, which despite being close to surface level, are found intermittent and at lower-than-standard commercially viable grades, especially with the sharp fall in the uranium price after the Fukushima tragedy. Though some officials told the Parliament, the public and decision makers that the uranium project was feasible, no feasibility study had been actually conducted. For Jordan, which would be highly unlikely to be able to finance a nuclear power plant by itself, this conclusion reinforced the need for foreign partners to take an equity stake and bring with them finance and financial guarantees. Uncertainties on this last option recently pushed officials to explore the possibility of involving the Social Security Corporation in the project. This move triggered a prompt harsh community opposition to be added to the already severe public acceptance problems facing the nuclear power project.

B. Economics

The investment in a NPP amounts to several billion dollars (approximately US$ 2-8 billion depending on design, location, finance, etc.) for a typical 1000 MW nuclear power plant which accounts for some 60 percent to 75 percent of total generation costs. The most recent report of the IEA/NEA "Projected Costs of Generating Electricity" (IEA/NEA 2010) shows a large overlap and spread of specific investment costs (US$/kW) for different electricity generating technologies (see Figure 3-left panel), typically explained by varying local conditions, technology designs as well as regulatory and environmental constraints.

In addition to the high upfront capital cost, long lead time for planning, environmental impact

In another recent development, the multi-year long process to select vendor and technology looks set for more delay, with an official recommendation to select a strategic investor rather than to choose one of the current short-listed (French-Japanese or Russian) bidders. Officials could not further narrow down the list on technical and financial grounds, because vendors were not given a specific site, and there were issues with the proposed sites that were still uncertain. Vendors were therefore unable to provide hard data on costs. The initial site for the reactors on the Gulf of Aqaba was too vulnerable to seismic activity, in addition to political uncertainties, and a planned move inland was opposed by local communities. A third site was then added to the list, but both inland sites require pumped grey water produced by the Khirbet Al Samra Wastewater Treatment Plant. This raised serious questions regarding the feasibility of the cooling scheme, though officials defended the scheme which is based on the experience in Palo Verde, Arizona; the only nuclear plant in the world not located near a body of water. Though warned at an early stage, officials insisted to go ahead with the tender knowing that there are genuine problems, from different aspects, regarding site selection. How can one think about site characterization, which should be part of the tender documentation, if there is no site secured yet? Public acceptance, which is also a key factor, was also not guaranteed.

Though, in principle, nuclear power like any other option should not be excluded from the country's consideration for energy mix, time is a critical parameter. The country's very existence depends on solving the energy crisis (by all means). We should stop arguing, a priori, about what to keep and what to exclude. Only facts, numbers and dates should decide on priorities and percentages in the energy mix. Postponing, or fabricating any achievement, is lethal. Therefore, the consecutive delays associated with the relative lack of transparency and experience in the nuclear program, imply a much more important cost; the opportunity cost of not pursuing other options that could have met Jordan's needs.

Nevertheless, the nuclear challenge should, however, be kept on the table for future consideration. Jordan is acquiring experience in the field, young Jordanians are definitely proving capable of absorbing and even actively promoting different aspects in the nuclear technology, making Jordan one of the Arab countries that could positively contribute to the mutual exchange of expertise, which will be of great benefit to all Arab partners. Jordan as, well as other Arab countries, need to realize the time span required to properly catch up, domestically, in the human resources sector. The legal tools regulating the nuclear field, building a credible and transparent management system, the necessity to create a proper safety culture, the fundamental educational infrastructure, the proper legislative and regulatory frameworks concerning safety, security, emergency preparedness and response, and radioactive waste management planning, among other issues, should all be pursued in a systematic manner.

We should establish the best example for the next generation. We may ultimately need nuclear, but we don't need to "play" nuclear!

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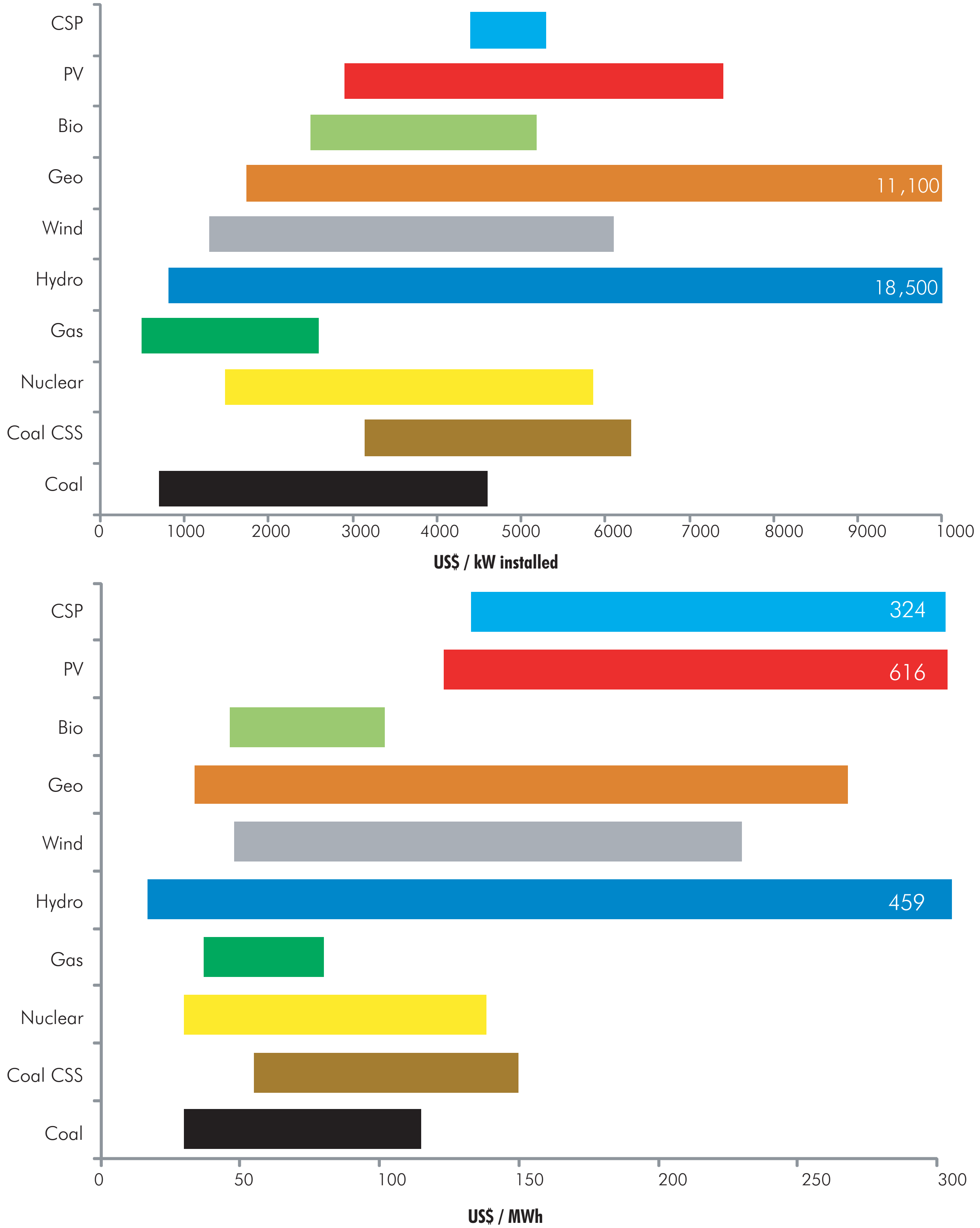
assessments, licensing and public hearing periods, construction, and plant completion on time and on budget, cost sensitivity to interest rates, regulatory and policy risks all pose a challenge (Rogner, 2010). Recent experience with new build in Finland and France with long construction delays and substantial cost overruns have alienated investors and fuelled the suspicion that nuclear power is simply too risky a proposition.

Investment costs are but one consideration - what matters are actual generating costs. Figure 3 (lower panel) shows the ranges of levelized costs of electricity (LCOE) generation of the IEA/NEA report for real discount rates between 5 percent and 10 percent per year. LCOE includes all cost components throughout a technology's life cycle - construction, finance, operation and maintenance, fuel, waste disposal and decommissioning.

FIGURE 3 **INVESTMENT COST RANGES PER KW INSTALLED (UPPER PANEL) AND LEVELIZED COSTS OF ELECTRICITY GENERATION (LCOE) IN US$/MWH OF DIFFERENT GENERATING OPTIONS FOR DISCOUNT RATES BETWEEN 5% AND 10% (LOWER)**



Source: IEA/NEA 2010.

C. Environmental characteristics of nuclear power – air pollution, GHG emission

On a life cycle basis, the full technology chain for nuclear energy from uranium mining to decommissioning emits only a few grams of GHG per kWh of electricity. The bulk of greenhouse gas emission arises from plant construction and in the upstream fuel stages, with values between 1.5 and 20 g CO_2-eq./kWh. This span is largely due to the type of enrichment processes considered in the various assessments (gaseous diffusion versus gaseous centrifuge) and the extent to which nuclear fuel recycling was accounted for. The enrichment industry has been increasingly switching to gaseous centrifuge technology, which requires only about 2 percent of the energy input needed for gaseous diffusion.

During the operational stage of the reactor GHG emission are negligible - ranging between 0.74 and 1.3 g CO_2-eq./kWh. The GHG emissions associated with downstream activities, such as decommissioning and waste management, range between 0.46 and 1.4 g CO_2-eq./kWh. Cumulative emissions for the studies reviewed by Weisser (2007) lie between 2.8 and 24 g CO_2-eq./kWh. Figure 4 presents a summary of life cycle GHG emissions for a range of power generation technologies and fuels.

In addition to helping to mitigate climate change, the use of nuclear power plants can also avoid emissions of air pollutants other than GHG with negative health and environmental impacts at local and regional scales. In contrast to fossil based electricity generation, nuclear power plants (as well as renewable technologies) emit virtually no air pollutants such as nitrogen oxides (NO_x), sulphur dioxide (SO_2) or particulate (PM_{10}) emissions during operation.

D. Nuclear technology spin-offs

The application of nuclear science and technology reaches far beyond the energy sector. Countries with active nuclear energy programs have also enjoyed numerous economic and social spin-offs from nuclear related R&D. Typical areas of non-energy nuclear applications include cancer diagnosis and treatment, food security, soil productivity, disease prevention and control, water resources, quality control and environmental management.

FUKUSHIMA NUCLEAR DISASTER

Tetsunari Iida

On 11 March 2011 (3.11), the Great East Japan Earthquake and its Tsunami changed the lives of hundreds of thousands of people in Japan forever. The earthquake and tsunami destroyed large part of the northeast coast of Tohoku region of Japan. About 20,000 people died. Among other things, a 12 meter-high tsunami flooded the Fukushima No.1 nuclear plant, cutting the power supply to water pumps cooling the nuclear reactors. This was the largest nuclear disaster since the Chernobyl disaster of 1986 and only the second disaster to measure Level 7 on the International Nuclear Event Scale. It showed once again the inherent risks of nuclear power and exposed the failures in the whole system, even though Japan had its global reputation for excellence in engineering and technology.

A "manmade" disaster "made in Japan"

Both the utility and the Japanese authorities failed not only to prevent the accident but also to respond properly after the accident. Although the Earthquake and Tsunami were historically among the largest, the risks of such scale natural disasters were well known years before. Emergency planning for a nuclear accident was not functional, and the evacuation process became chaotic, which lead to many people being unnecessarily exposed to radiation. Government was simulating radioactive materials spread from Fukushima Daiichi throughout Japan and the North Pacific in real time with real wind data even before and after 3.11 disaster. However, data released only a month later revealed that many people were evacuated exactly in the direction of the most heavily contaminated region.

The Fukushima Nuclear Accident Independent Investigation Commission defined it as a "manmade" disaster, caused by serious deficiencies in the response to the accident by TEPCO (the utility company), regulators and the government as the result of collusion between the government, the regulators and TEPCO, and the lack of governance. Also, they defined it as a disaster "made in Japan", that means the mindset that supported the negligence behind this disaster. So, its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our collectivism; and our insularity. Those mindset and conceit had been produced and reinforced since the 1970s "oil shocks". In quest of national energy security, nuclear elites as bureaucrats put organizational interests ahead of their paramount duty to protect public safety, and nuclear power became an unstoppable force, immune to scrutiny by civil society.

Breaking up the "nuclear myth"

The Fukushima nuclear disaster broke up the "myth" of nuclear safety. Nuclear industries and the government assumed that the "multiple barriers" to be engineered would keep radiation away from the environment and people, but it failed rapidly. In less than 24 hours following the loss of cooling at the first Fukushima reactor, a major hydrogen explosion blew apart the last remaining barrier between massive amounts of radiation and the open air. At any time, an unforeseen combination of technological failures, human errors or natural disasters at any one of the world's reactors could lead to a reactor quickly getting out of control.

Nuclear power was originally described as "too cheap to meter". Before 3.11, owing to massive "propaganda" from the government, electricity monopoly and nuclear industry, this nuclear "myth" had been widely believed to be a cheap alternative to fossil fuels and a necessity for the economy and national energy security. After 3.11, these "myths" were wiped off, but sadly some people still believe in them.

Another myth was a strong belief of security of supply by nuclear power as compared to renewables. This myth was also wiped off through the nation's experience of supply risk of large-scale centralized power when it stopped suddenly after 3.11.

Never ending disaster

Two years after the Fukushima nuclear disaster, over 150,000 people who had been evacuated could not return. They lost nearly everything, with insufficient support and compensation to allow them to rebuild their lives. Families have been split apart, and have lost their homes, jobs and communities.

There are growing concerns that the full scale of the disaster is yet to be seen. There are claims of complacency and a cover-up about radiation effects and consequences. Most worrying are the results of tests carried out on more than 170,000 children who lived in Fukushima. More than 10 cases of thyroid cancer were already found (6 per 100,000), which is obviously higher than that of natural background (average 1-2 per 100,000). Other forms of the disease may not become apparent for a decade. It is also feared that the food chain has been contaminated. Radioactive material has been detected in a range of produce, including spinach, tea leaves, milk and beef, up to 300 kilometers away.

The Fukushima accident is not over and may never end. The radioactive fallout, which remains toxic for hundreds to thousands of years and covers large swaths of Japan, will never be "cleaned up". It will contaminate food, humans and animals forever. The three reactors which experienced total meltdowns will almost certainly never be disassembled or decommissioned, not least because of the enormous amount of radiation they will emit.

In addition, if the reactor No.4 at Fukushima daiichi, which was severely damaged in the original earthquake, should collapse, the massive cooling pool on its roof containing 300 tonnes of extremely radioactive spent fuels could fall to the ground and lose its cooling water. The radioactive rods would spontaneously ignite, releasing further massive amounts of radiation.

Lesson learned

Similar disaster could be experienced in other nuclear plants at Japan East Coast, and did almost happen, such as at the Fukushima No.2, Tokai No.2 and Onagawa nuclear plant. The institutional failures in Japan are a warning to the rest of the world. These failures are the main cause of all past nuclear accidents, including the accident at Three Mile Island and the disaster at Chernobyl.

The failure of the human institutions inevitably led to the Fukushima disaster. The risks of earthquakes and tsunamis were well known years before the disaster. The industry and its regulators reassured the public about the safety of the reactors in the case of a natural disaster for so long that they started to believe it themselves. The tight links between the promotion and regulation of the nuclear sector created a 'self-regulatory' environment that is a key cause of the Fukushima nuclear disaster.

Most countries limit the liability of reactor operators to only a small fraction of real damages, which allows

the nuclear industry to basically escape paying for the consequences of an accident. The Japanese legislation on liability and compensation stipulates that there is no cap on liability for a nuclear reactor operator for damages caused to third parties. However, it does not include any detailed rules and procedures about how and when the compensation will be paid. Nor does it define who is eligible and who is not. TEPCO has so far managed to escape full liability and fails to properly compensate people and businesses that have been dramatically impacted by the nuclear accident. Should larger compensation schemes, which reflect real losses, be established, the cost of nuclear power will skyrocket.

The true risk to be learned from Fukushima disaster is opportunity loss, caused by sticking to nuclear power and the current power structure. This burdened seriously exploring other opportunities and benefiting from the dynamic change outside Japan, especially in the renewables policy and market. Renewables have been rapidly mainstreaming worldwide in the past years. Some consider this as the "fourth revolution for humankind" with its nature of energy shift, technology evolution and regime change into small-scale distributed network type of energy system. This trend could be historical chance for Japan's energy future because of its multiple benefits, especially for post 3.11 Japan.

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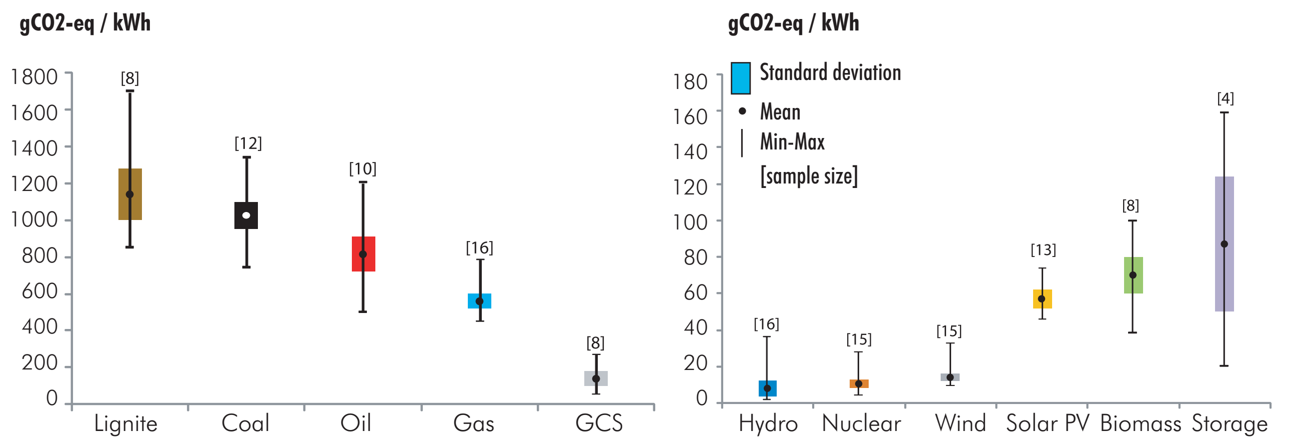
FIGURE 4 LIFE CYCLE GHG EMISSIONS OF DIFFERENT ELECTRICITY GENERATING OPTIONS



Source: WEISSER, 2007

Furthermore, nuclear power, science and technology foster a highly educated and skilled workforce with above average income levels. Depending on the localization factor of plant construction, there are significant economic benefits associated with a national nuclear power programme.

III. ISSUES SURROUNDING NUCLEAR POWER

A. Safety

The essence of nuclear operating safety is the protection of the population, workforce and the environment from ionized radiation. Operating safety, therefore, ranks as the highest priority for nuclear power plant design and operation.

Radiation levels from normal operation of nuclear power plants are significantly low compared with the average radiation exposure from natural and other anthropogenic sources (see Figure 5).

However, things are different, in cases of severe nuclear accidents. Radioactive surface concentrations in the plant vicinity can be high and can last for years or decades, and decontamination is very expensive. In areas further away from the site of the accident, agricultural production and fishing may need to be temporarily suspended. Environmental impacts due to radiation may cause significant economic damages due to suspended economic activity in the affected area. Moreover, non-radiation impacts can be significantly larger than radiation impacts. Nonetheless, a recent UN reports states that “radiological impacts from the expanded use of nuclear power as part of the world’s electricity generation mix continue to engender concerns among many policy makers and members of the public regarding the safety of the technology and the appropriateness of its continued use. Such concerns are exacerbated by high profile incidents and serious accidents associated with nuclear energy such as those that occurred at Three Mile Island (1979) in the United States of America, at Chernobyl (1986) in the former Soviet Union, and recently at the Fukushima-Daiichi plant (2011) in Japan”(UN 2011).

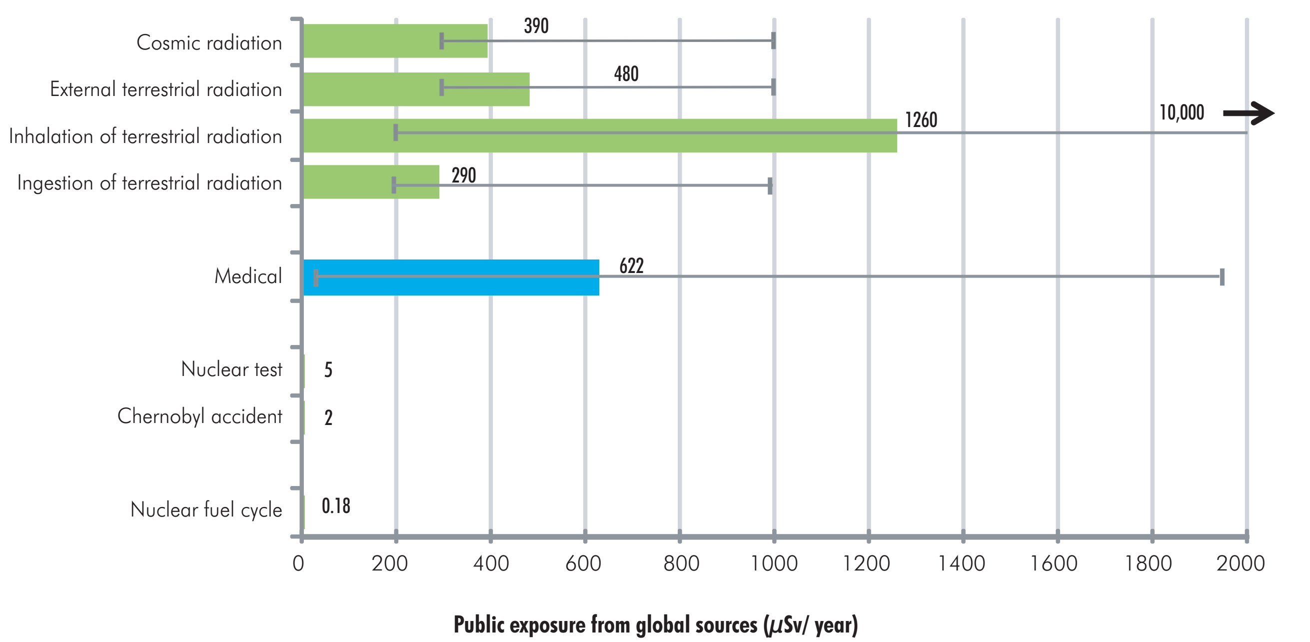
The long term health effects from the Chernobyl accident, expressed in terms of increased radiation-induced cancer fatalities in the general public, have been subject to intensive studies. Credible studies point to increases of 4,000 to 30,000 cancer-induced late life deaths(4) which is (outside the small three most exposed groups of workers and evacuees) a statistically insignificant increase from the natural rate of cancer deaths (Garwin and Charpak 2001; Chernobyl Forum 2006). For Three Mile Island, the estimated total number is negligible (less than one). For Fukushima it is expected that the effect will be an order of magnitude less than Chernobyl’s (Ten Hoeve and Jacobson 2012). According to a most recent WHO report, “outside the geographical areas most affected by radiation, even in locations within Fukushima prefecture, the predicted risks remain low and no observable increases in cancer above natural variation in baseline rates are anticipated" (WHO 2013). To put these numbers into perspective the OECD Environment Directorate suggests that PM10 particles from fossil fuel combustion caused approximately 960,000 premature deaths in the year 2000 (OECD 2008). Kharecha and Hansen (2013) calculate "a mean value of 1.84 million human deaths prevented by world nuclear power production from 1971 to 2009 with an average of 76,000 prevented deaths/year from 2000 to 2009 (range 19,000–300,000)".

The nuclear accidents reveal the importance of independent, competent and effective nuclear oversight institutions)[5].In the case of the Fukushima Daiichi accident, the combination of accident conditions including total station black-out, the loss of essential safety functions (heat sinks) and the effects of "beyond design basis" (BDB) event had not been envisaged and emergency preparedness was lacking (NAIIC 2012). Enforcing such analyses and, if necessary, corrective action are the principal responsibilities of the nuclear regulator - with the ultimate task to order closure of plants failing to meet all safety requirements. In response to the accident, the IAEA convened a Ministerial Conference on Nuclear Safety in June 2011. IAEA Member States agreed to review the safety of their nuclear power plants with particular focus on strengthening protective measures against extreme BDB events such as earthquakes and tsunamis, ensuring their capability to maintain power and cooling following a BDB event, enhance their arrangements to manage severe accidents and re-examine the design bases for their nuclear power plants, i.e. the assumptions about a predetermined set of accidents to be taken into account.

B. Nuclear waste management

All electricity generating chains generate wastes. The nuclear energy chain produces radioactive waste of different levels of radiotoxicity. Low level wastes (LLW) and intermediate level wastes (ILW) account for the bulk of radioactive waste (some 97–98 percent) and represent only a small proportion of total radioactivity (about 8 per cent). LLW and ILW arise mainly from routine facility maintenance and operations as well as fuel cycle activities. The radioactivity in these wastes ranges from just above nature's background level to more elevated levels. Safe disposal options for LLW and

FIGURE 5 **PUBLIC EXPOSURE TO RADIATION FROM GLOBAL SOURCES (AVERAGE SHOWN BY A BAR, AND TYPICAL RANGE SHOWN BY A LINE)**



Source: UNSCEAR (2010).

ILW have been in operation routinely for decades in many countries. On a volumetric basis around four-fifths of all the nuclear waste created since the inception of the nuclear industry has already been sent for safe and controlled disposal.

It is this so-called high level waste (HLW) which is a controversial issue in the sustainable development and green growth debates. HLW represents two to three per cent of total nuclear radioactive waste but presents particular challenges in terms of its radiotoxicity and long half-life. HLW is either spent nuclear fuel or separated waste from reprocessing the spent fuel.

Reprocessing of spent fuel drastically reduces the volume of HLW. Reprocessing separates the unused uranium and plutonium produced during reactor operation. The uranium and plutonium are re-used as fuel in reactors, while the separated fission products and minor actinides are treated as HLW. HLW will remain more radioactive than its natural surroundings for thousands of years and must be isolated from the biosphere until the level of radioactivity has decayed to natural background levels. Disposal facilities will need to be monitored and safeguarded for many generations.

From a safety perspective, the nuclear industry has practiced the safe temporary surface storage of spent fuel for more than half a century[(6)]. Over the last two decades, however, there have been major advances towards the first operating disposal facility (e.g. Sweden and Finland). A number of planned repository projects have been assessed for potential radiation leakage for a period of up to 10 million years. These studies have shown that the released doses are limited to "at most one tenth of a per cent of the exposure to natural radioactivity at the surface" (Taylor, 1996). Yet until HLW disposal facilities have been built and operated successfully and safely for several decades, the nuclear waste debate is likely to continue, which no doubt will influence public acceptance and may delay the introduction and development of nuclear power in many countries.

C. Proliferation

Nuclear energy must not only be safe and economical but also be used solely for peaceful purposes. It is its weapons legacy and the dual nature of nuclear technology that raise concerns. The IAEA has the mandate to reconcile the dual nature - to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and to ensure that peaceful nuclear energy "is not used in such a way as to further any military purpose".

Nuclear power plants per se are no immediate proliferation risk. Proliferation concerns relate to the nuclear fuel cycle, i.e., uranium enrichment (front-end) and reprocessing of spent fuel (back-end). The technology that facilitates the enrichment to reactor fuel levels (about 3-4 percent U235, from only 0.71 percent for natural uranium), however, can easily be reconfigured to enrich uranium to weapons-grade (about 90 percent U235) - a classical dual use technological process. Advances in enrichment technology have dramatically reduced the footprint as well as the electricity use of enrichment facilities which alleviates covert operations.

Reprocessing presents another proliferation risk, as it separates the fissile plutonium isotope Pu239 which, like U235, is a weapons material at concentrations higher than 93 percent. Pu is a by-product of the U235 fission process. It can be mixed with uranium and recycled as mixed-oxide (MOX) reactor fuel or accumulated for later use in fast breeder reactors. Reprocessing and stockpiling Pu239 is seen by many analysts as the real proliferation risk (von Hippel, 2012) of the nuclear fuel cycle.

The prevention of diversion of nuclear technology or fissile material for non-peaceful purposes is at the core of the IAEA safeguards system and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). While both have been largely successful, proliferation risks continue to be serious. One significant gap in the NPT is the possibility for a state to acquire enrichment technology and operational expertise for "peaceful" purposes and then withdraw from the treaty to develop nuclear weapons (e.g. North Korea). It has been repeatedly proposed to place all enrichment and reprocessing facilities under multinational control (e.g. international or regional enrichment facilities, international fuel banks, etc.) and implement multinational approaches (MNA) to the management and disposal of spent fuel and radioactive waste. The main objective is to globally limit the number of facilities for enrichment and reprocessing and thus the opportunities for diverting fissile materials for nuclear weapon development. However, none of many MNA proposals has been able to resolve the contentious issue of fairness and to what extent they would encroach on the "unalienable right" of all countries (under NPT) to the development of their own fuel cycles.

The concept of an international fuel bank appears to be a workable compromise. The fuel bank is a stockpile of low enriched uranium under control of the IAEA. Fuel would be made available at market prices on a non-political and non-discriminatory basis to countries that are denied access to fuel for political reasons as long as they are in compliance with their nuclear safeguards obligations. The fuel bank concept contributes to non-proliferation as it provides for nuclear fuel supply security, thus reducing the incentive for the establishment of national enrichment facilities, while not impinging on a country's rights to developing its own fuel cycle technologies. In March 2010, the first fuel bank was formally established by the IAEA and the Russian government, and became operational by the end of 2010[7].

Another aspect not foreseen in the NPT is the emergence of non-state actors (terrorists, criminal groups) and consequently the need to prevent access of such groups to nuclear weapons or radioactive materials for malevolent. Several United Nations Security Council resolutions aim at combating nuclear terrorism address this concern as well as a number of both legally binding and non-legally binding instruments, e.g., the Convention on the Physical Protection of Nuclear Material or the International Convention for the Suppression of Acts of Nuclear Terrorism.

IV. NUCLEAR POWER FOR THE ARAB COUNTRIES

A. Why nuclear power in the oil and gas rich Arab countries?

The Middle East, and Arab countries in particular, hold the largest conventional oil and gas reserves globally. Its production costs are still largely below US$ 10 per barrel equivalent. This raises the question of why a region so well endowed with

low-cost hydrocarbon resources would consider the nuclear option. More precisely is there an economic rationale why the UAE has launched a national nuclear power program (the first two of four reactors are currently under construction) and why others (e.g. Saudi Arabia, Jordan and Egypt) are actively engaged in the preparation of such programmes?[8]

There are several reasons why exploring the nuclear option could have been appealing for some Arab countries:

- Demand for electricity, liquid fuels and desalination, due to water scarcity, has grown very rapidly in all Arab countries, especially the member states of the Gulf

Cooperation Council (GCC), thanks to low and subsidized domestic tariffs and prices, growing population and expanding economies;

- Not all countries of the region are well endowed with conventional hydrocarbon resources, e.g., Bahrain, Jordan, Morocco or Yemen;
- Low cost conventional hydrocarbon occurrences will not last forever and the lowest hanging fruit has been harvested in some countries already;
- Rapidly growing domestic energy demand reduces volumes available for exports (and thus governments' revenues) in the longer run;
- The associated gas share in oil production is often declining –low cost associated gas (with no potential for exports and tied to OPEC production quotas) has been a dominant fuel for electricity generation and desalination in several countries in the region;
- Climate Change concerns are slowly arising; and
- Diversification and economic structural change.

Most Arab countries' economies are dynamic, facing high rates of demand for electricity and desalinated water, as the populations grow and the utilization of low-priced electricity and desalinated water accelerates.

Since the turn of the millennium, annual final electricity demand growth rates for the region average at 7.3 percent - more than doubling electricity demand between 2000 and 2010. National growth rates vary considerably over this period - from 4.4 percent/yr in Tunisia to 12.3 percent/yr in Qatar. For the countries listed in Figure 6 aggregate demand expanded from 308 TWh in 2000 to 624 TWh in 2010. Using the projections of the World Energy Outlook (IEA 2012a) as a guide, the aggregate final demand will range between 1020 TWh and 1240 TWh by 2030 necessitating net capacity addition between 175 GW and 210 GW.

B. Simple Economic Rationale

A simple calculation demonstrates the economic rationale for nuclear power: A nuclear power plant with investment costs including interest during construction of US$ 6500 per KW and a 5 percent interest rate generates electricity for 72 US$/MWh. A highly efficient combined cycle gas turbine (CCGT) plant operating on light-oil (investment costs 1150 US$/kW) would require an oil price of 50 US$/bbl to break even. In the case of natural gas, the break-even price would be around 8 US$/GJ. Both prices are significantly higher than the subsidized oil and gas prices in most countries in the region and nuclear power is not competitive under these conditions.

Now consider this: Light oil and liquefied natural gas (LNG) are currently traded at much higher prices than these break-even prices. Futures for light oil are around 100 US$/bbl while LNG originating from the Middle East trades around 11 - 13 US$/GJ. The deployment of nuclear power instead of oil and gas for electricity generation would release oil and gas volumes for exports. The extra revenues are more than sufficient to pay for costs of a nuclear power plant. In short, nuclear power is competitive with CCGT as long as average oil export prices are above 50 US$/bbl and LNG above 8 US$/GJ.

C. Concerns and Challenges

While there is a clear economic rationale and other promising benefits for adopting nuclear power, there are also many demanding challenges and stringent requirements that must be met.

Most Arab countries interested in nuclear power are still in the "planning" stage with regard to the deployment of nuclear power for electricity generation and desalination. The exception is the UAE which commissioned four Korean APR-1400 reactors in March 2010 to be built at its Baraka site. It is not expected that other Arab countries will embark on the construction of a nuclear plant much before 2020, with the exception of Saudi Arabia and possibly Egypt and Jordan. For the time being most countries focus on addressing daunting challenges of the development of prerequisite nuclear infrastructure requirements such as human resource development, nuclear education, nuclear safety culture, national nuclear law and nuclear regulation.

D. Nuclear Infrastructure

The introduction of nuclear power requires the establishment of a wide range of infrastructures to ensure the safe and effective operation of nuclear power plants. Currently most Arab countries lack a basic nuclear infrastructure. Key are comprehensive nuclear law (that regulates safety, security, safeguards, and liability), highly qualified and disciplined human resources and efficiently and effectively managed institutions (well protected from political interferences) on all aspects of the use of the technology, an independent and competent nuclear regulatory entity, a deeply rooted safety culture, stakeholder involvement, long-term policies and solutions for nuclear waste management and eventual plant decommissioning and well established and credible emergency preparedness.

While nuclear infrastructure issues are not insurmountable barriers to the introduction of nuclear power, they involve a lengthy preparation process that can last up to ten years and more. They also require substantial financial commitment. While outsourcing parts of the nuclear infrastructure may facilitate fast-track to the introduction of a nuclear power plant, it cannot be a long term solution. Especially nuclear safety and reliability remain national responsibilities. Regional approaches to infrastructure development (rather than individual countries developing them separately) may yield considerable benefits. This may also include the joint ownership of nuclear power plants by several countries.

Economies of scale suggest that embarking on nuclear power means the eventual deployment of more than one nuclear power plant so as to distribute certain fix infrastructure costs (e.g., maintenance, waste management).

Current commercially available reactor technology of 1000 to 1600 MW may not fit the grid capacity of several Arab countries (notwithstanding the fact that these grids are going to be at least twice today's sizes by the time nuclear power can realistically be introduced in 10 to 15 years). Numerous smaller unit sizes are under development and may be commercially available by 2020 to 2025.

Energy security

Other considerations are enhanced energy security through diversification of primary energy sources and the mounting pressure on Arab states to adopt climate mitigation measures and curb national greenhouse gas emissions. Nuclear power can play an important role in this regard but so can the large scale deployment of renewable technologies, once economics and storage considerations are demonstrated, especially photovoltaic (PV) and concentrated solar power (CSP) given the high levels of insolation and the huge extent of desert areas in the region.

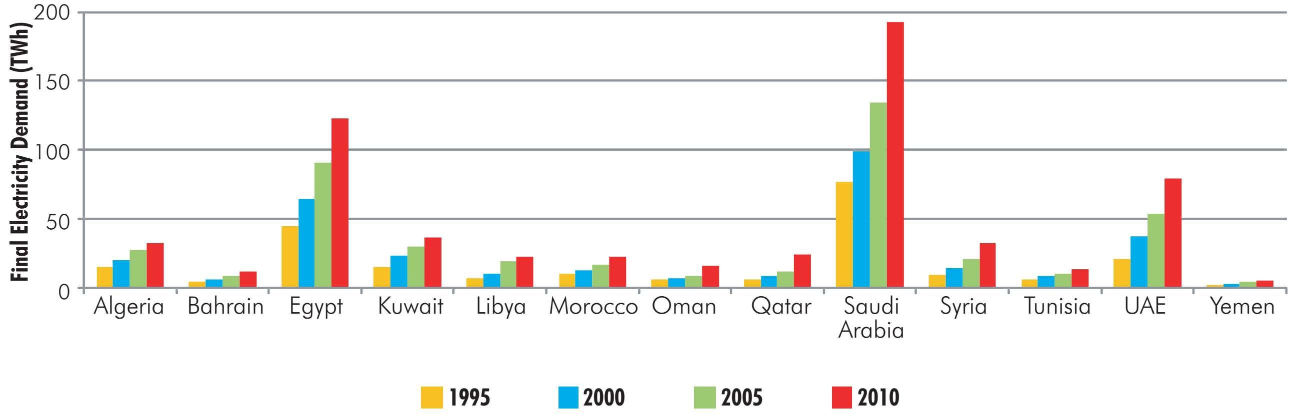
While nuclear power is a means for supply diversification, in an Arab context the technology can represent certain supply security risks. As technology recipients, the Arab countries would be fully dependent on technology and fuel imports from abroad as well as politically motivated restrictions such as the 1-2-3 agreement[9] with the USA[10]. This agreement roots in weapons proliferation concerns and essentially excludes domestic fuel cycle activities in the partner country and revokes the 'inalienable right' as stated in Article 4 of the Non-Proliferation Treaty (NPT).

Proliferation concerns

There are also views that expressively link the peaceful nuclear power ambitions in the region to Iran's potential acquisition of a nuclear weapon (Luomi, 2012).

Most countries in the region interested in the adoption of nuclear energy have declared that they are not interested in any domestic fuel cycle activities (except uranium extraction) and that they

FIGURE 6 **FINAL ELECTRICITY DEMAND GROWTH, 1995 TO 2010**



Source: IEA (2012B)

will be fully compliant with their national safeguards obligations. While all Arab countries are part of the NPT regime and have in place comprehensive safeguards agreements with the IAEA, not all have joined the 'Additional Protocol'.[11]

National position and stakeholder involvement

A decision to embark on a nuclear power programme should be based upon a national position, with a sound and long term non-partisan energy policy and the fully understandings of the long term (100 years plus) commitments required for a nuclear power programme. Developing a national policy should be based on transparency, accountability and full stakeholder involvement, especially the general public. The risks and benefits of nuclear power versus the risks and benefits of non-nuclear alternatives must be presented in a neutral and transparent manner. Only then public acceptance can be accomplished. Stakeholder involvement, however, is not general practice in most Arab countries.

V. CURRENT AND PLANNED NP PROGRAMMES IN THE ARAB COUNTRIES

In one way or another, almost all Arab countries, large and small, have expressed at least some interest in nuclear power. Starting around 2005, smaller countries like Bahrain, Kuwait, Oman and Qatar without any nuclear infrastructure or nuclear engineering expertise carried out energy studies, signed international nuclear cooperation agreements, gathered information on prerequisite nuclear infrastructure requirements or adhered to international nuclear treaties, protocols and conventions, etc. After the Fukushima Daiichi accident, however, these countries have dropped or suspended their national nuclear plans.

Another group of countries started developing national nuclear infrastructure programmes as early as the 1970s; this list includes Algeria, Libya, Morocco, Syria and Tunisia. These countries have maintained modest nuclear research and education programmes often centred on small research reactors for training purposes, materials testing and radioisotope production. Initial ambitions towards adding nuclear power to their national electricity systems were dampened after the mid-1980s by the Chernobyl accident, low oil and gas prices and economic development below expectation.

All these countries stepped up their national nuclear infrastructure preparations after 2005 - very much in line with the rising expectations of a global nuclear renaissance. The justifications have been rising energy prices, energy security concerns, an expanding economy thus growing demands for electricity and desalination and environmental considerations. All five countries entered into various international nuclear cooperation agreements with the objective of enhancing their nuclear infrastructures, especially

human resource development as well as the creation of nuclear oversight institutions and regulations. Countries with known uranium resources are exploring their eventual extraction usually as integral parts of international nuclear cooperation agreements.

The Fukushima Daiichi accident has had no profound impact on these countries except perhaps a better appreciation of the need for thorough nuclear infrastructure development and implementation. All signs point to an undeterred continuation of planning towards the introduction of a first NPP.

- **Algeria's** current plans are to have a first NPP in operation by 2022 (Sidi Ali 2012) and adding one NPP every five years thereafter. The development of its uranium resources is under consideration.

- **Morocco** has had plans for building its first NPP at the Sidi Boulbra site located on the Atlantic coast and intends to open negotiations with vendors next year. Grid connection is expected between 2022 and 2024. The country has enormous amounts of uranium contained in phosphates estimated at about 6.9 million tonnes uranium (tU) which is larger than currently known global conventional uranium resources (NEA/IAEA 2010, 2012). The feasibility of recovery of uranium as a by-product from phosphoric acid is under investigation with support from France.

- **Tunisia's** nuclear cooperation with France focuses on nuclear electricity generation and desalination. Initial targets of having a first NPP operational by 2020 are no longer publicly maintained, 2025 currently seems more likely. Tunisia's phosphate resources are estimated at higher than 1 billion tonnes of which 100 million tonnes are reserves containing some 50,000 tU. The construction of a pilot plant for the extraction of uranium is in an early planning stage.

- **Libya's** peaceful nuclear technology development intentions were seriously questioned when it declared in 2003 to abandon a clandestine uranium enrichment programme. It regained its nuclear credentials when it signed the Additional Protocol one year later. Since then, numerous nuclear cooperation agreements on the peaceful use of nuclear energy with Libya were signed.

- **Syria -** Between the late 1970s and 1990, Syria undertook several unsuccessful attempts towards the construction of a NPP. It later pursued plans with support from Russia for a NPP and a nuclear seawater desalination facility (Sharp 2007) for operation by 2020. Syria's peaceful nuclear power programme has been seriously contested following an Israeli air strike in 2007 that destroyed Dair Alzour, a facility alleged by U.S. and Israeli intelligence to have been a partially completed 25 MWth gas-cooled graphitemoderated nuclear reactor. Syria claims the site was an unused military building. Lack of resources, the on-going controversy concerning the Dair Alzour site and the civil war make the implementation of a civil nuclear power programme quite unlikely for the foreseeable future.

The final group includes countries either with the most advanced national nuclear infrastructures already in place (Egypt, Jordan and the UAE) or with firm intentions to adopt nuclear power (Saudi Arabia).

- **Egypt** - The nuclear energy program in Egypt is the oldest in the Arab region and dates back to the mid-1950s with the creation of the Atomic Energy Commission. The first research reactor started operation in 1961 followed by the establishment of the Nuclear Power Plant Authority (NPPA) in 1976. Ambitious nuclear energy development plans for both electricity generation and desalination started in the late 1960s and culminated with a target of ten reactors operating before the close of the 20th century (WNA, 2013). However, international cooperation was hampered until 1981 by Egypt's reluctance to ratifying the NPT. After ratification, several projects were tendered with EL-Dabaa as the preferred site for NPPs. The Chernobyl accident of 1986 and collapsing oil and gas prices halted Egypt's quest for nuclear power. In 2008 the NPPA awarded a preconstruction contract for the planning and preparation of a 1200 MW NPP for commercial operation in 2017. By 2010 the entry into operation was pushed back to 2019 while the number of plants online by 2025 was raised to four. Egypt persistently advanced the development of its nuclear infrastructure through international cooperation in the area of human resource development including training in facilities abroad. It also continues to seek to

develop the expertise to maximize the local participation in NPP projects. However, with the onset of the "Arab Spring", all plans are put on hold until the political situation stabilises again. The new government has yet to state its position on nuclear energy, foreign participation and finance (Abou Elhassan, 2012).

- **Jordan** - Jordan imports over 95 percent of its energy needs at considerable expense and adverse impact on it current accounts, making a strong case for the nuclear power option. In addition to energy supply security concerns, Jordan also faces serious shortages in fresh water supplies.

In the early 2000s', Jordan began to aggressively prepare its nuclear infrastructure following IAEA guidelines and in 2007 established the Jordan Atomic Energy Commission (JAEC) and the Jordan Nuclear Regulatory Commission (JNRC), and initiated comprehensive energy analyses with the aim to plan the introduction of nuclear power at the earliest point in time feasible. Jordan's nuclear strategy called for nuclear power to supply 30 percent of Jordan's electricity demand by 2030, as well as to provide for exports to neighbouring countries.

In 2009 it contracted a 5 MW Korean research and test reactor as an integral part of its nuclear technology infrastructure (science, education and research) development. In the same year JAEC contracted an international consultancy for a comprehensive pre-construction phase of a 1000 MW nuclear power plant including finding a strategic partner for the finance and operation of the plant.

After discarding the initially preferred site near the Gulf of Aqaba's coastline for reasons of heightened seismic activity, the new proposed location is the Majdal area some 40 km north of Amman. Cooling water at this inland site far away from the coast or rivers would be provided by a waste water treatment plant using the Palo Verde nuclear generating station in Arizona, USA as a template.

In May 2012, after evaluating several bids from various vendors, the JAEC announced it had selected two bidders or rather consortiums — Russia's Atomstroyexport (AES-92 VVER-1000 MW) and the Franco-Japanese joint venture Areva-Mitsubishi (1,100 MW Atmea-1) — for further negotiations to build Jordan's first nuclear power plant.

In early June 2012, Jordan's parliament voted to suspend the country's nuclear power and uranium mining programme pending the completion of further economic feasibility and environmental surveys. In March 2013, JAEC announced that the government would decide the following month which of the two competing consortiums would be selected to build two 1000 MW nuclear reactors at an estimated cost of €12 billion. Possible delays in construction start associated with Syrian civil war are acknowledged.

A key factor in the selection process will be the financial package offered by the consortiums. The JAEC anticipates a limited recourse arrangement with a debt-equity ratio in the order of least 75-25 with government guarantees on part of the debt and long-term power purchase arrangements. A build-own-operate (BOO) scheme modelled on the Akkuyu nuclear power plant project in Turkey is also considered.

Jordan's undeveloped uranium resources could help finance its nuclear power program. The countries uranium resources are estimated at 33,800 tU of conventional uranium and up to 120,000 tU unconventional uranium in phosphate rocks (NEA/IAEA, 2012). In order to maximize the value added of uranium extraction, this could eventually also include domestic uranium enrichment. Consequently, Jordan has expressed a preference to keep its enrichment and reprocessing options open. Jordan has signed nuclear cooperation agreements with more than a dozen countries covering nuclear power and desalination, uranium mining and nuclear infrastructure development. It had initialled but not signed a 1-2-3 agreement with the USA. The USA wants Jordan to agree to the "gold standard" precedent set with the USA-UAE 1-2-3 agreement, not to pursue indigenous uranium enrichment or plutonium reprocessing capabilities. The absence of a full nuclear cooperation agreement with the USA prevents Jordan access to US nuclear technology. The Jordanian government maintains that the NPT affords it the right to all capabilities associated with the peaceful nuclear fuel cycle, and is therefore on principle disinclined to sign an agreement holding it to a different standard than most other treaty members (Grossman2013). Jordan has a safeguards agreement with the IAEA and has also ratified the Additional Protocol.

- **Saudi Arabia** - In August 2009, the Saudi government announced that it was considering a national nuclear power programme. The government immediately signed a safeguards agreement with the IAEA but has not ratified the Additional Protocol.

  The King Abdullah City for Atomic and Renewable Energy (KA-CARE) was established in 2010 to advance nuclear and renewable energy. KA-CARE is tasked with the development of all aspects of the nuclear power programme and infrastructure. KA-CARE contracted various international consultancies to help define a national strategy and action plan for the introduction of nuclear power including an operation model, identification of potential sites and the development of technical specifications for a future tender.

  According to KA-CARE, although "hydrocarbons will remain a prime element in the likely electricity mix in 2032" (KA-CARE, 2013), the future supply structure for meeting the expected electricity demand of more than 120 GW in 2032 includes supplies of 17.6 GW of nuclear power and 54 GW of various renewable generating capacities. Nuclear power would then account for about 20 percent of the Kingdom's electricity supply. KA-CARE literature states that the first two NPPs are planned to be on line by 2023/4, to be followed by 2 more per year up to 2032.
  Saudi Arabia has little in terms of a nuclear infrastructure, but is working with the IAEA and other countries to develop human resources in nuclear sciences and research. Although a nuclear regulatory authority has been set up, due to a lack of local regulatory expertise this new institution still falls within the King Abdulaziz City for Science and Technology (KACST), currently responsible for nuclear regulation.

  Saudi Arabia has entered into several international cooperation agreements, especially with France, the Republic of Korea, China and Argentina, covering nuclear infrastructure development, R&D and nuclear power plant construction, maintenance and nuclear fuel supply. KA-CARE continues negotiations with other nuclear technology holders, especially the USA, regarding such agreements. An agreement with the USA (so called 1-2-3 agreement) would most likely need to include the nuclear trade "gold standard", i.e., a verifiable Saudi Arabia pledge not to enrich uranium or reprocess plutonium domestically, similar to what the UAE had agreed to.

- **UAE -** The UAE published its "Roadmap to Success for the UAE Nuclear Power Program" in 2008 which envisaged ten NPPs by 2030. The Emirates Nuclear Energy Corporation (ENEC) became the organization charged with implementing the UAE nuclear energy programme while the Federal Authority for Nuclear Regulation (FANR) was established as the national nuclear regulator.

  In December 2009, ENEC announced that it had selected a consortium led by the Korea Electric Power Corporation (KEPCO) to design, build and assist in the operation and maintenance of four 1,400 MW nuclear power units. One year later ENEC submitted licence applications for units 1 & 2 to FANR which subsequently issued construction licenses in July 2012. Construction of the first two units was subsequently started, with commercial operation expected by 2017. The other three units are scheduled to be completed by 2020.

  As regards nuclear waste management, the UAE pursues a "dual track" strategy

that involves developing a national storage and disposal programme in parallel with exploring regional cooperation options. This also includes the option of fuel leasing and shipping spent nuclear fuel to other countries for reprocessing or storage outside the region.

Rather than following the slow path of first establishing indigenous expertise, the UAE implements and manages its nuclear power programme by outsourcing and contracting services from abroad. Otherwise this fast-track approach of four years between the political decision to go nuclear and the shuffle hitting the ground would have been impossible. The contract with KEPCO provides for extensive training, human resource development, and education programs as the UAE builds the capacity to eventually staff the vast majority of the nuclear energy programme with UAE nationals (IAEA, 2011). While international experts staff FANR and ENEC as well as other key organizations, Emirati nationals are shadowing important positions, and over time, the staffing of these organizations will be taken over by Emirati nationals.

Thanks to the early and transparent communication of its nuclear intentions, the UAE has enjoyed solid international support from technology holding countries. Key was the quick ratification of the Additional Protocol and the USA-UAE 123 agreement in which the UAE explicitly forswears domestic enrichment and reprocessing. This agreement and the high reliance on expertise from abroad in the implementation of the national nuclear programme has been declared as the 'model for the world' by Western policymakers, commonly referred to as the 'gold standard' for newcomers (Kamrava, 2012). Many potential newcomers are not necessarily agreeing to the 'gold standard' as it carries the danger of perpetuating the dependence on foreign expertise and services.

VI. CONCLUSION

Is there a solid case for nuclear power in the Arab countries? While there are many promising benefits, there are also demanding challenges and daunting obstacles to overcome on the road to introducing nuclear power. The answer to this question can only be given in comparison with the alternatives to nuclear power. Dismissing one energy option without specifying its replacement on a level playing field is of no avail. There is no perfect technology without risks and interaction with the environment. Moreover, as much as sustainable development is a dynamic process, technology is also subject to change. Innovation and technology change improve most performance aspects of a technology from the current to the next generation or investment cycle.

From today's perspective, nuclear power advantages include: competitive economics; low life-cycle GHG emissions; energy security, especially during periods of price volatility; stable and predictable generation costs; most externalities are already internalized; small and managed waste volumes; productive use of a resource with no competing uses; firm base load electricity supplies and synergies with intermittent energy sources (EU, 2003; NRC, 2009; Markandya et al, 2011) For the oil and gas exporting countries of the Middle East, the nuclear power option appears to be competitive economically if the average price of oil over the long term is firmly above 50 US$/bbl and long term LNG export price is above 8 US$/GJ.

Nuclear power is a highly complex technology along many dimensions. Mastering these to reap its benefits is an even more challenging task. Nuclear power is less forgiving than other energy technologies, requiring persistent discipline in operation and maintenance, especially with regard to strict adherence to safety standards and regulatory requirements. Equally important is competent and effective regulatory oversight. The Fukushima Daiichi accident is testimony that even technologically advanced countries can have serious weaknesses in their national nuclear programs. In technologically less advanced countries without a well-developed safety culture, e.g., the Arab region, the introduction of nuclear power needs to balance the added risk with the benefits. Therefore, the development of a successful, safe and secure nuclear power program requires a strong and unwavering long term national commitment, with high initial efforts to develop the required infrastructure, especially human resources and an effective and disciplined management system for all components of the nuclear fuel cycle and related organizations, which is a cumbersome and time-intensive process.

Other aspects of the nuclear power option that need continuous attention are (a) the permanent and safe disposal of HLW - here regional approaches, fuel leasing and take back arrangements are potential alternatives for the region; (b) risks of nuclear weapons proliferation; (c) the physical security of nuclear material and facilities; (d) ensuring highest level of safety in technology design and facilities operation; (e) lower construction costs; and (f) public acceptance of the technology. The current benefits of nuclear power may fade away without further advances ranging from technology innovation and international institutional arrangements to a participatory civil society in nuclear matters. While there is consensus with the nuclear community that technical solutions do exist for the safe and secure ultimate disposal of HLW, lingering doubts will continue in segments of the public mind and decision makers until experience has been accumulated from waste disposal facilities under construction in Sweden and Finland.

Clearly, the Arab countries are also endowed with enormous renewable energy potentials, especially solar energy. Costs of PV and CSP have been declining substantially in recent years - a trend that is expected to continue. Still intermittency of supply remains to be a principal issue. Solar energy needs a companion and nuclear power can, in principle, play that role. Given the diurnal cycle of electricity demand and solar energy insolation, nuclear power might supply base load demand and solar energy the daily intermediate and peak loads which largely match its daily availability. Moreover, electricity is difficult to store, water is not. With reverse osmosis (RO)[12] becoming the desalination technology of choice, nuclear electricity can be used for RO desalination whenever electricity is not required to meet non-desalination demand.

Yet for most Arab countries, the low lying fruit of demand management to curb the wasteful part of current high energy demand and future demand growth is technically easier and more economic. Enhancing energy efficiency and replacing wasteful energy subsidy policies, in particular in GCC countries, with more rational approaches to wealth sharing policies, can reduce by as much as 50 percent of the business-as-usual power capacity growth projected for the 2-3 decades to come. It is truly the low lying fruit that must be implemented first, ahead of increasing supply from any source. The political cost of making unpopular changes to the irrational part of the prevailing energy subsidy policies is far less costly than the costs associated with development of new electricity generation capacity from any source.

Finally, one size does not fit all. Countries differ with respect to their energy needs, their national endowment with energy resources, their energy system infrastructure, technology alternatives, financing options, preferences and risk perceptions. How countries trade off among various specific considerations- e.g., air pollution, dammed rivers, jobs in the mining industry or in the home insulation industry, the risks of a nuclear accident or gas explosion or an oil tanker sinking at its shores or coal mining accidents, the dependency on foreign fuel supplies, and the benefits of affordable electricity – is at least partly a matter of national preference, and thus an area of legitimate disagreement even if everyone were to agree precisely on all the facts. The Arab countries face additional challenges that need to be tackled ranging from a weak R&D capacity, lack of human resources, absent emergency preparedness, non-participating civil society, and a fragile peace and security situation.

All countries use a mix of energy sources, and nearly all countries generate electricity from a mix of technologies. Partly that reflects the march of history, where new technologies replace older ones, but more usually in fits and starts over time, not in one sudden, instantaneous and complete replacement. It reflects the fact that investors disagree about what will prove most profitable, and it reflects the fact that a portfolio of sources reduces risk and vulnerability. Local conditions determine the optimal supply and technology mix which may or may not include nuclear power.

Nuclear power is not for everyone and one size does not fit all. But it will remain or become part of the energy mix in many countries. What is right for the Arab countries also depends partly on the regions' national preferences and priorities as expressed in national politics. For now, there is no doubt that the unfolding changes in the region are pointing to delays in planning and implementation of nuclear power programs in several Arab countries.

Nuclear power is a long-term commitment (on the order of centuries not decades) and will require solid social and-political support. Stable and mature participatory political systems are considered essential to assure such long term national commitment. In the short-run it means committing several billions of US$ for infrastructure, human resource development, and plant construction. It is a commitment to maintaining highest operating safety and security standards. In the longer run it is not only a commitment to safekeeping of nuclear waste and effective nuclear proliferation control schemes, but also the development and implementation of advanced proliferation-resistant fuel cycles and fuel supply assurances MNA schemes. Societies need to understand these commitments as well as the risks and benefits associated with nuclear power, and may as well decide that the benefits are not worth the risks.

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NOTES

1. Nuclear was not the only technology affected by low oil and gas prices: Numerous coal-fired plants suffered a similar fate of construction delays and cancellations.

2. The vastly improved utilization of existing capacities worldwide corresponds to a virtual construction of about thirty-five 1,000 MW nuclear power plants.

3. In 2002, the German government, consisting of the Sozialdemokratische Partei Deutschlands (SPD) and Alliance '90/The Greens introduced legislation that mandated the phase out the use of nuclear energy. This phase-out was revoked by the current coalition government six months before the Fukushima Daiichi accident. In the wake of the accident the same government ruled a new phase-out by 2022.

4. Note: The estimated absolute number of radiation induced fatalities for all but the three most exposed groups is only calculable, not measurable or attributable to the accident.

5. Tsunamis exceeding the 5.7 meter high seawall have been historically reported for the site and surrounding region by considered too unlikely despite recent studies suggesting otherwise.

6. The USA has a repository for transuranic wastes - the Waste Isolation Pilot Plant (WIPP) in New Mexico - in operation for more than a decade. It receives wastes including Plutonium, Americium etc. from the military weapons programme.

7. The UAE and Kuwait contributed US$ 10 million each in support of another US led international LEU Fuel Bank to be managed by the IAEA.

8. Iran is the first country in the Middle East with a nuclear power plant in operation (since 2011).

9. Section 123 of the United States Atomic Energy Act of 1954 defines the principles for cooperation in the area of nuclear energy between the US and any other nation. It requires a bilateral agreement between the USA and the recipient country - a so-called 1-2-3 Agreement. Without such an agreement U.S. firms are not allow engage in nuclear technology transfer to that country.

10. The International Fuel Bank (see Section 3.3) was established to mitigate potential access to nuclear fuel supply concerns.

11. While the NPT foresees IAEA verification in 'declared' (by the Member State) nuclear activities, the Additional Protocol (AP) permits IAEA inspectors access to all parts of a State's nuclear fuel cycle - including uranium mines, fuel fabrication and enrichment plants, and nuclear waste sites - as well as to any other location where nuclear material is or may be present. The AP increases the likelihood of detecting a clandestine nuclear weapons program and to build confidence that States are abiding by their international commitments.

12. RO is electricity operated. The standard multi-stage flush process uses heat often decoupled from co-generation plants which limits the flexibility between heat and electricity.

OPINION

THE NUCLEAR POWER OPTION IN ARAB COUNTRIES

Najib Saab

The earthquake that struck the Iranian Bushehr province in April 2013 reminded us of the nuclear reactor at Bushehr, and raised concerns about possible radioactive leakages. Such fears were to be expected, just two years after the nuclear disaster caused by the tsunami in Fukushima. These concerns had not yet subsided when another more violent quake hit East Iran with tremors felt in the Arabian countries across the Gulf. Scenes of residents fleeing high-rise buildings and taking to the streets in panic in Doha, Dubai and Abu Dhabi were abounding in media.

Fears of radioactive leakage, whether caused by an operational accident, like in Chernobyl and Three Mile Island, or a natural disaster such as Fukushima's, are justified. Accidents do happen in all stages of the energy industry, upstream and downstream. But due to the complex nature of nuclear plants the impacts of any accident would be far deeper and wider than an oil spill incident or an explosion in a gas or oil plant. While the latter can be brought to a closure, consequences of nuclear accidents continue over an unforeseen period. So the residents of the Arabian cities of the Gulf were not to blame for being terrified of the possibility of an accident at the Bushehr reactor on the opposite side, that would transmit radioactive material to the Arab cities through water and air.

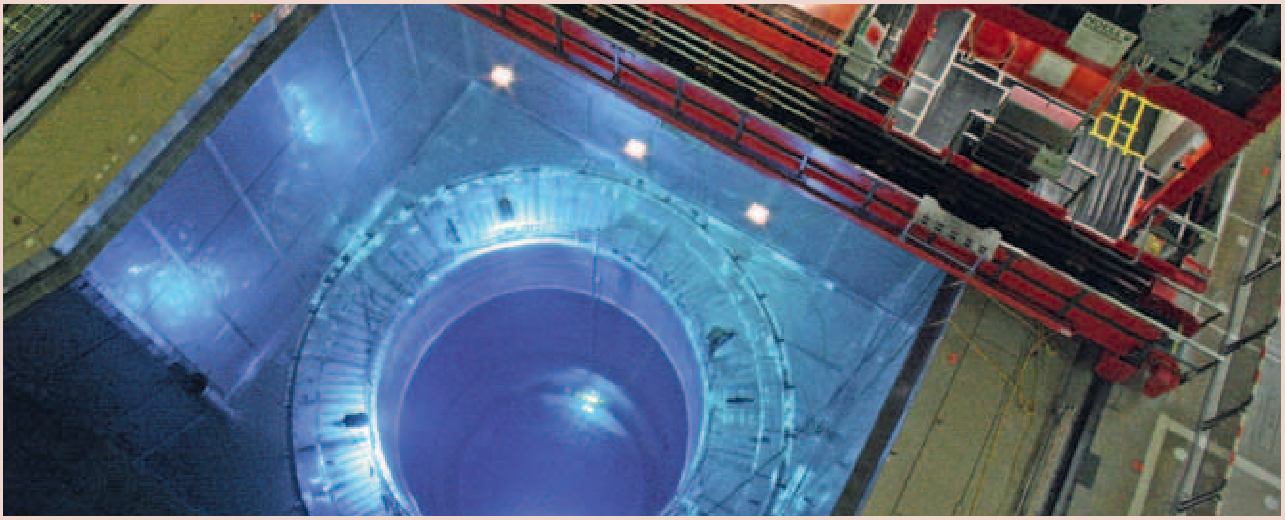
These events revived the debate about nuclear energy in the Arab world. Most Arab countries have shown interest in acquiring nuclear power, at various levels, and belong to two categories. The first group constitutes oil-exporting countries, such as the UAE, Saudi Arabia and Algeria. These countries consider the nuclear option an opportunity for diversifying income sources and enriching the energy mix. It should be noted that as much as 40 percent of oil production in these countries is used locally for power generation and seawater desalination. Using nuclear power for electricity generation will allow them to increase export of oil and secure better positions in the energy markets, long after fossil fuels. On the other hand, non-oil producing countries that aspire to have nuclear energy, such as Jordan and Morocco, consider the nuclear option as a way out of their energy crisis, especially since some of these countries have stocks of uranium, though mostly low-grade. Both groups similarly believe that the possession of nuclear technology promotes scientific research and secures a sort of prestige and higher standing in the international arena.

It is worth mentioning that the Arab states with the highest nuclear commitments, such as Saudi Arabia, Egypt, Morocco and Algeria, have at the same time the highest commitments with respect to renewable energy sources, notably solar energy targets. Saudi Arabia announced a plan to produce 41 Gigawatts from solar energy by 2032, the most ambitious renewable energy target ever. The UAE is investing billions in renewable energy through MASDAR. Morocco and Algeria are at the heart of DESERTEC, the initiative designed to generate solar electricity not only for domestic use but also for export to Europe. These countries believe that the incorporation of nuclear technology into the energy mix provides an additional measure of energy security alongside stabilizing supplies. Proponents say that storage of solar electric power to use overnight, for example, is still an expensive process that can be supported by nuclear energy.

Energy security, in the context of nuclear power, varies among different groups of countries. While countries that have the right to enrich uranium locally can claim a certain level of supply security, the same does not apply to others, including Arab countries. There are restrictions that prevent those from enriching uranium locally, and impose bans on importing it enriched, even if they have uranium ores as in Jordan, Morocco and Algeria. It should be noted, in this respect, that the United States has warned that it would prevent Jordan from using American nuclear technology and would impose wide-ranging sanctions if the country opted to enrich uranium locally.

Investing in nuclear technology to promote scientific research and support development requires as a prerequisite the development of national capabilities for scientific research, particularly local human resources. But some Arab countries have actually chosen the easy path to save time, by outsourcing the whole process, from design, construction, supply of equipment and material, to the manpower needed to operate and maintain security of plants. Although these countries have included in their nuclear plans training programs for national manpower, it is to be seen how fast this could be implemented.

Scientific research, industrial development and security of



energy supplies are justifiable arguments for looking into nuclear energy options. However, the most prominent argument for supporting nuclear energy options in recent years has been that it helps in controlling climate change, because it does not discharge greenhouse gases (GHGs). Proponents of nuclear power say that the world may well find no other alternative to drastically reduce emissions and curb climate change- even just for a bridging period until renewable energy gains more solid grounds. But environmental impacts of nuclear power are not limited to climate change. There has not yet been developed any permanent solution for the ultimate safe disposal of wastes of nuclear reactors. Although the nuclear industry is confident a solution should be found sometime, the operative word to explain the situation is still temporary storage, with the risks of radioactive leakages due to natural disasters and / or human errors. The same applies for calamities in nuclear reactors, resulting from earthquakes, floods and operating errors, noting that the bigger the reactors the greater the related risks. A key question is how prepared Arab countries are for such a scale of disasters? Therefore, all phases of the nuclear cycle should be taken into consideration: construction and operation of reactors, storage and disposal of wastes, and impacts of possible catastrophes.

Fast and immense increase in demand on electricity is often cited as an immediate reason which justifies the nuclear power drive. Prior to funding considerable investments for the construction of new power plants, regardless of the technology to be adopted, be it based on fossil fuels, renewable energy or nuclear, Arab countries must first manage energy demand and improve efficiency. The per capita energy intensity in the Arab Region is twice the world average; energy consumption per capita reaches six times the world average in some GCC countries. The main causes of this situation are the low efficiency levels and the lack of incentives that should encourage saving, mainly as a result of subsidies. After all, increasing production, as the only response to waste and over-consumption, is like supplying an addict with more drugs rather than helping him to quit the damaging habit.

Renewable sources, particularly solar energy, remain the cheapest and most secure option for the Arab countries. The cost of solar power generation is rapidly decreasing and shall be almost equivalent to the costs of fossil fuel-based power generation if subsidies are lifted. Arabs do have solar resources even in much bigger and more sustainable reserves than oil. Both oil and sun can be under national control, and do not have to be imported with restrictions, like enriched uranium. As for hurdles facing the storage of solar electricity for night use, proponents of renewable energy say that a portion of the electricity generated during day can be used to produce hydrogen through electrolysis of seawater, which can in turn be used to obtain electricity, night and day.

Serious analysis of the cost, risk and safety of nuclear power generation relative to conventional and alternative sources should inform government decisions and long-term commitments.

Najib Saab is Secretary General of Arab Forum for Environment and Development (AFED) and Editor-in-Chief of Al-BiaWal-Tanmia (Environment & Development) magazine. This commentary, which was the editorial of the May 2013 issue of the magazine, was simultaneously published in 10 regional newspapers.