CHAPTER 9

Nuclear Technology Transfers

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INTRODUCTION

Nuclear technology transfers are different from the other technology transfers examined by OTA because some nuclear technologies can be used to supply the materials necessary to construct nuclear weapons. Since the 1950's, when it first began to be developed for peaceful purposes, nuclear technology has become the epitome of "dual use" technologies—those that have both civilian and military applications.

On the one hand, developing nations—particularly those not well endowed with oil and other natural energy resources—see in commercial nuclear power a way to meet their rapidly growing demand for electricity. In addition, many developing countries view nuclear research as a means to build their national technical and scientific infrastructures. On the other hand, because of their potential weapons applications, some nuclear technology transfers raise critical military and foreign policy questions. Nuclear technology transfers to the Middle East, a region that has experienced major wars and changes of regime, as well as growing oil revenues during the last decade, thus raise important technological, commercial, and strategic questions for countries in the region. Nuclear technology transfers to the Middle East are also of central importance to U.S. nuclear nonproliferation policies.

In contrast to the other technology transfer sectors examined in this report, commercial nuclear power is currently at a very early stage of development in the Middle East. Nevertheless, decisions taken now about nuclear technology transfers can directly affect the political, military, and economic future of the region. There is today no commercial nuclear facility in operation in the region, but there are a number of nuclear research facilities, and a few nations have plans for commercial nuclear power development. The Islamic countries of the Middle East[1] have widely differing plans for nuclear technology. Before its revolution, Iran had the most extensive plans for such development. In Egypt the rationale for commercial nuclear power is comparatively strong, and planning for a commercial program is under way. Saudi Arabia and Kuwait have not committed themselves to nuclear power. Libya has clearly expressed an interest in nuclear weapons applications, as well as nuclear power.

OTA's analysis indicates that no Islamic country in the region will be capable of acquiring a nuclear explosive device on a wholly indigenous basis within this decade, and most would find it impossible to do so before the turn of the century. Egypt has the strongest technical infrastructure, but would not be able to produce nuclear weapons independently before the late 1990's. With assistance from foreign scientists and engineers and suppliers of critical items, however, these constraints posed by weak indigneous technical infrastructures could be reduced or eliminated, depending on the extent and type of assistance.

While it is unlikely that any of these nations will acquire large enrichment and reprocessing facilities that could supply very large, dedicated weapons programs,[2] smaller-scale nu-

[1]This report deals with the countries of the Islamic Middle East. Because Israel has attained a much higher level of technological development, it is not included as a major focus of study. However, Israel's nuclear capabilities are discussed in this chapter as necessary for an understanding of nuclear technology transfers to the region. The term "Islamic countries is used here simply to indicate that sizable proportions of the populations of these countries are Muslims, or followers of Islam. As discussed in ch. 3, there are many groups in *these* countries and the role of Islam in political, economic, and social affairs varies widely.

[2]Enrichment and reprocessing technologies are referred to as "sensitive" technologies because of their applicability to weapons programs.

clear technology transfers (involving research reactors and laboratory-scale sensitive facilities) are expected to increase. These small-scale sensitive facilities are required for peaceful research, but they can also be used (albeit with difficulty) for production of nuclear weapons materials. Therefore, the prospects for nuclear weapons proliferation in the Middle East will increase in the years ahead as these facilities are introduced, as new supplier nations not parties to the Nonproliferation Treaty (NPT) enter the market, and as Middle Eastern countries improve their technical capabilities.

During the next decade a number of Middle Eastern countries could begin operation of commercial power reactors. By themselves power reactors do not pose a significant direct proliferation risk.[3] It is technically impossible to use a light-water power reactor (LWR) or a Canadian Deuterium Reactor (CANDU) to produce plutonium for a nuclear explosive without access to enrichment in the case of LWRs, and to reprocessing for both.

[3]The risk of a nation's using either fuel or spent fuel from such power reactors in the production of nuclear weapons is minimal when safeguards are effectively enforced, and nonexistent when no sensitive facilities (open or clandestine) are present. However, it is technically possible to support a significant nuclear weapons program by using a reprocessing facility of moderate size to reprocess spent fuel from the power reactor. In the case of a safeguarded power reactor, spent fuel would have to be diverted to a clandestine reprocessing facility or utilized in a reprocessing facility acquired for the ostensible purpose of peaceful research.

Despite the contribution that nuclear power could make to meeting anticipated rapid growth in the demand for electricity, a number of factors limit the attraction of nuclear power to many Middle Eastern nations. These include the high costs of nuclear plants, limited interconnected grids, and the availability of hydrocarbon and other energy sources, including solar energy. Of all the Middle Eastern countries, Egypt has the most extensive current plans for commercial nuclear power but will be able to acquire reactors only with subsidized foreign financing.

This chapter describes the constraints and opportunities for nuclear technology transfers to the Middle East, paying special attention to both commercial and military applications, and identifies the implications for U.S. policy. The issues discussed are of particular concern because the spread of nuclear weapons in the Middle East would not only threaten the national survival of Middle Eastern countries but also substantially reduce the ability of the United States to influence events there.

In addition to the six nations of primary consideration in the report, this chapter deals peripherally with a number of other countries that must be considered in an analysis of nuclear technology transfers to the Middle East. One goal is to identify major factors recipients must consider as they make choices about nuclear technology transfers; another is to clarify trends important for U.S. policies in the years ahead.

NUCLEAR FACILITIES IN THE MIDDLE EAST

Developing countries account for only a minor part of commercial nuclear capacity worldwide. At the end of 1980, there were 256 nuclear power reactors operating around the world, with an installed capacity of 136 gigawatts electric (GWe), or about 7 percent of installed world electrical generation capacity. About 98 percent of this capacity was located in the Organization for Economic Cooperation and Development (OECD) nations,[4] and the Soviet Union and Eastern Europe.

For nuclear power or nuclear weapons, certain types of nuclear technologies, fuel or material, technically trained manpower, systems for delivering either electricity or weapons,

[4]OECD nations include the United States, Japan, Australia, New Zealand, and major West European nations.

and political commitments are necessary. The requirements are different for commercial power production and weapons production, but some facilities can be used for both. The discussion that follows briefly identifies various types of nuclear technologies that have been or maybe transferred to Middle Eastern nations, and then evaluates their significance for both commercial power and weapons programs.

COMMERCIAL NUCLEAR POWER REACTORS

Commercial power facilities include a number of reactor types currently in operation, such as LWRs, including pressurized water and boiling water types, and CANDU. Most of these reactors were developed for use in industrial nations and are comparatively large scale, or more than 600 MWe in capacity.

Iran and Egypt: Countries With Current or Previous Nuclear Power Plans

Most of the major countries in the region have at some point studied the feasibility of nuclear power for generation of electricity and desalination. Iran under the Shah developed the most ambitious program for nuclear power development of any of the Middle Eastern countries. Iran's program, which came to a halt after the revolution, called for building 23 reactors in 20 years to generate 23,000 megawatts of electricity (MWe) by 1994.[5]

Iran carried out negotiations with a number of suppliers during the 1970's, and the West German firm Kraftwerk Union began construction of two 1,300-MWe pressurized light-water reactors near Bushehr on the Persian Gulf. When work stopped on these reactors in late 1978 with the mass exit of German technicians during a nationwide Iranian labor strike, the two reactors were 75 percent and 65 percent complete. In the past year, some official Iranian spokesmen have indicated interest in a renewed nuclear program, but construction has not been resumed on the two reactors, although a feasibility study was under way in May 1984.[6]

Egypt today has more extensive plans for commercial nuclear power development than any other Middle Eastern country under study. By 2000, its official plan is to have 8 reactors in operation, with a total generation capacity of 8,000 MWe, amounting to 40 percent of its electricity. However, Egypt's nuclear plans have been quite volatile over the years, with activity in the mid-1960's, followed by inactivity until 1973-76, followed by more delay. The Egyptian program is stimulated by insufficient alternative power sources and a comparatively large nuclear manpower pool, but owing primarily to financing problems, construction has not begun on any of these reactors. Negotiations with France progressed to an advanced stage, and that nation signed preliminary agreements to supply two 950-MWe turnkey reactors to be located at El Daba'a, northwest of Cairo. French spokesmen continue to state that final agreements are imminent and that the reactors will go online in the early 1990' s.'

Egypt selected the Swiss firm Motor Columbus to work 011 an 18-month contract as the consulting engineer for the first two reactors and to help prepare the tenders for the bids for the second two reactors. In early 1983 the Egyptian Government called for bids on four reactor units, and by the end of the year the French firm Framatome. the West German

'Daniel Poneman, *Nuclear Power in the Developing World* (London: Allen and Unwin, 1982); Bihan Mossavar-Rahmani, *Energy Policy in Iran I New* York: Pergamon Press, 19811, p. 105.

[6]Kraftwerk Union and the Atomic Energy Organization of Iran signed a contract under which Kraftwerk Union will carry out an inspection of the Bushehr site in order to determine the feasibility of completing one of the reactors: the same report claims that site maintenance has been good, See ''Kraftwerk Inspects Nuclear Plant," Middle East *Economic Digest. Dec.* 9, 1983, p. 12. See also "Official Comments on Iranian Nuclear Research, " *Iranian News Agency,* Mar. 16, 1982. Kraftwerk Union spokesmen confirmed that 40 engineers were carrying out a feasibility study on site in May 1984.

[7]''According to the Current Timetable, Egypt and France Should Come to Terms, " *Nucleonics Week*, June 10, 1982, p. 7; '' In Brief, ' *Middle East Economic Digest*, vol. 26, No. 51, 1982.

firm Kraftwerk Union, and U.S. firms Westinghouse and Bechtel had submitted bids.[8] Thus, negotiations continue with firms from various nations for supply of reactors, but Egypt has reached no firm agreements, and technical assessment of the bids continues.

Middle Eastern Countries Considering Nuclear Power

A number of other Middle Eastern countries have shown interest in developing commercial nuclear power, but none of them is as far along as Egypt. Libya has plans to acquire four nuclear reactors by 2000 and is negotiating with the Soviet Union to purchase a 440-MWe reactor from the Soviet export organization Atomenergoexport.[9]

The Syrian government has plans for two to six reactors, but has done little to carry out these plans. In 1981 the Minister of Electricity announced that feasibility studies had been initiated. The French firm Sofratome was selected to carry out a feasibility study in the summer of 1982, but the study was delayed through the end of that year. Discussion in Syria has focused on two power reactors, each with a capacity of 660 MWe.[10] Iraq has expressed interest in a commercial nuclear program, and at the Second Arab Energy Conference in 1982, it was forecast that Iraq will have an installed capacity of 1,400 MWe by 2000. Negotiations with France for the purchase of a 900-MWe pressurized-water reactor were mentioned.[11] More recently, it was reported that the Iraqi nuclear energy organization signed an agreement with the Soviet firm Atomenergoeksport to carry out the first phase of a study to choose a site for a nuclear power station.[12]

Algeria has made no firm commitment to nuclear power development, but government planning organizations have considered nuclear power in medium- to long-term development plans. In 1976, for example, a special decree was issued which called for establishment of nuclear reactors as a stimulus to industrial development.[13] Similarly, Kuwait has no formal plans for a nuclear power program, but a number of feasibility studies have been carried out, some regarding use of nuclear reactors in desalination. More recently, the Kuwaiti Government discussed the possible purchase of four CANDU reactors with Canadian officials in 1982, but these discussions were not continued.[14]

Thus, while Middle Eastern nations have considered nuclear power programs, few have carried these plans very far, and those that have, have experienced delays–Iran's program came to a stalemate during the revolution, and Egypt is still negotiating for the purchase of its first commercial reactor. It is unlikely that any Middle Eastern nation will

[8] See "Egypt: Nuclear Bids In–Will Financing Follow?, " *Middle East Economic Digest,* Dec. 2, 1983. See also, Paul Taylor, "U.S. and Japanese Groups Link in Egyptian Nuclear Power Bid, " *Financial Times,* Sept. 1, 1983, p. 1; "Consultant's Bid to Egypt Show Huge Gap; EDF Leads French Reactor Offer, " *Nucleonics Week,* vol. 23, No. 4, Jan. 28, 1982, p. 1.

[9] Robin Miller, "Nuclear Power Plans Outlined, " *Jamahiriyah Review,* No. 22, March 1982, p. 17. See also, James Everett Katz and Onkar S. Marwah, *Nuclear Power in Developing Countries* (Lexington, Mass.: D. C. Heath, 1982), p. 8. Press reports indicate that the Belgian firm Belgonucleaire may also participate in the project. See "Libya-Belgian Firm to Supply Plants, Paris International Press Service, 1245 GMT, May 23, 1984, reported in FBIS, May 23, 1984

[10] Rob Laufer, "Syria Plans Nuclear Power Unit by 1991, " *Nucleonics Week,* vol. 22, No. 24, June 18, 1981, p. 1.

[11] Adnan Shihab-Eldin and Yusef Rashid, "Cooperative Development of Nuclear Energy in the Arab World, " paper presented at the Second Arab Energy Conference, Mar. 6-11, 1982, sponsored by the League of Arab States, the Arab Fund for Economic and Social Development, Arab Industrial Development Organization, and Organization of Arab Petroleum Exporting Countries, pp. 10 and 20.

[12] "Contract with USSR to Study Nuclear Power Site, " JN071201 Baghdad INA in Arabic 1052 GMT 7 March 84, reported in FBIS, *Daily Report.- Middle East and Africa,* Mar. 7, 1984, vol. v., No. 046, annex No. 016.

[13] See Adnan Mustafa, "Nuclear Fuel Resources in the Arab World, " paper presented at Second Arab Energy Conference, ibid.; see also "Interministerial Committee Set Up to Define Nuclear Energy Policy, " *El Moudjahid* (Algerie), Nov. 1, 1980, p. 5.

[14] Canadian officials reported that they would not sell the reactors unless Kuwait became a party to the NPT. See "Offer to Sell Reactors Denied, " *Canadian Radio,* in FBIS Jan. 28, 1982. Kuwait has signed but not ratified the NPT,

have an operating commercial reactor before the mid-1990's.

RESEARCH REACTORS

A second type of nuclear facility currently in operation in the Middle East, the research reactor, is used in conjunction with nuclear research at several training centers in the Middle East. Research reactors provide a source of neutrons and/or gamma radiation for physics, biology, chemistry, and metallurgy research; for investigation of the effects of radiation on many types of materials; and for production of isotopes used in medicine, industry, agriculture, and training and teaching. There are more than 350 research reactors worldwide.

Israel was the first Middle Eastern country to build a research reactor; in 1960 it completed a 5-MWt[15] IRR-1 research reactor using highly enriched uranium (HEU) and a few years later, a 26-MWt research reactor at Dimona.[16]

Egypt is the Islamic nation with the oldest research reactor in the Middle East. Built with Soviet assistance in the early 1960's, Egypt's 2-MWt research reactor using 10 percent enriched uranium is located at the Inchass Nuclear Research Center. It has been operated since 1972 by Egyptians without foreign assistance. In addition, West Germany has agreed to sell Egypt a l-MWt research reactor.[17]

Iraq has constructed the largest number of research reactors. One is a small pool-type research reactor supplied by the Soviets, which was upgraded to 5 MWt in 1978 and is located at the Tuwaitha Nuclear Research Center. This IRT-2000 reactor is suitable for small-scale medical and civilian research applications and can be fueled with uranium of various enrichments. Two other research reactors were supplied by the French in the 1970's. Isis (or Tamuz 2) is a small 800-kilowatt critical assembly, which has a negligible annual fuel utilization. Osirak, as the French called it, or Tamuz 1 was a research reactor before it was destroyed by Israel in 1981. According to the IAEA, this reactor had a capacity of 40 MWt. Iraq has discussed rebuilding the reactor with the French, but this has not occurred. Among the points of controversy was the suggestion that medium-enriched uranium (MEU) fuel be used in a rebuilt reactor, which was opposed by Iraq. '8

It is not clear whether Iran's 5-MWt reactor provided by the United States in the 1960's and located at the Teheran University Nuclear Center is still in operation.[19] Finally, Libya has a 10-MWt Soviet-built (WWR-C) research reactor fueled by 80 percent enriched uranium.[20]

A number of nations have plans for or are considering building research reactors. Algeria, for example, has a nuclear research institute and has carried out some discussions with the U.S. firm General Atomics concerning construction of a research reactor, but no purchase has been announced.[21] Morocco has purchased a 100-kilowatt TRIGA Mark I research reactor from General Atomics, but the facility has not yet been constructed.[22] Saudi Ara-

[15] 1 MWt would produce approximately 0.3 Mwe. Unless otherwise noted, MW indicates megawatts (electric). Thermal megawatts (MWt) is used to refer to capacity of reactors not used for production of electricity.

"No U.S. observers have inspected the Dimona facility since 1969, and Israel says that it has no nuclear weapons. However, informed opinion is that Israel does have nuclear weapons capability. Some claim that the Dimona reactor was upgraded to 70 MWt capacity in the 1970's. See George H. Quester, "Nuclear Weapons and Israel, *The Middle East Journal,* vol. **37,** No. **4,** autumn 1983, p. 548.

"'' German Minister Seeks Trade Increase, " *Middle East Economic Digest, vol. 26, No.* 13, 1982,

[18] See "France, Iraq Unveil Secret Nuclear Accord, " *Energy Daily,* June 19, 1981; "Mideast Nuclear, " *Reuters Report, Mar.* 19, 1982. The U.S. Department of Energy cited a **70** MWt capacity, but the French said that the reactor had a **40** MWt capacity. Due to limitations of the heat rejection system, the reactor would have been operated at 40 MWt, according to the IAEA. See IAEA, Background Briefing Paper, "Safeguards and the Iraq Nuclear Centre," December 1981.

[19] Zivia A. Wurtele, Gergory S. Jones, Beverly C. Rowen, and Marcy Agmon, *Nuclear Proliferation Prospects for the Middle East and South Asia* (Marina del Rey: Pan Heuristics, 1981), p. A-18.

"'' Development of Nuclear Capability' Reviewed, " *The Arab World Weekly* (Jan. **24,** 1981), reprinted in JPRS *Nuclear Development and Proliferation Worldwide Report #84, Mar. 3, 1981.*

"''Algeria To Go Nuclear, " *8 Days.* Feb. *28, 1981,* pp. 46-47.

[22] "Extraction of Uranium from Arab Phosphate: The Arab World Decides to Turn to the Nuclear Alternative, " *Al Duster* (London), No. 231, Apr. 26, 1982.

bia has plans to build a nuclear research center, but no research reactor has yet been built, although feasibility studies have been carried out.[23] In Kuwait, similarly, discussions about research reactors have been pursued, but those organizations interested in purchasing one have not appropriated funding for fiscal year 1984 to proceed. Likewise, Syria and Tunisia have also considered research reactors, but in neither case have negotiations been finalized.

ENRICHMENT AND REPROCESSING FACILITIES

No Middle Eastern nation currently has such facilities on a commercial scale, nor is it likely that any of these nations will have commercial-scale enrichment and reprocessing facilities in this century. However, a number of countries are reported to have small-scale reprocessing facilities. (There is, however, no authoritative source identifying all small reprocessing facilities worldwide.)

Only a few Middle Eastern nations are reported to have small-scale reprocessing facilities in operation. At the Inshass Center, Egypt has a small complex of hot cells which were supplied by the French. Iraq contracted with the Italian firm SNIA in 1976 for a radiochemistry laboratory. Construction on the facility was completed in 1978. The lab consisted of a hot cell complex. Such hot cells are used to manipulate radioactive substances and have many potential peaceful uses, but also could be used to separate small quantities of plutonium from dissolved uranium in the Osirak reactor.

Italy also reportedly agreed to provide Iraq with four additional labs designed to give the Iraqis "mastery of the fuel cycle, " in the words of Dr. Umberto Colombo, head of the firm CNIEN. These labs are said to have included a fuel fabrication lab, a chemical engineering lab, and a radioisotope lab. The exact status of these projects is not clear.[24]

The only other laboratory-scale sensitive research reported in the Middle East are efforts in Israel and prerevolutionary Iran. Iran acquired experimental laser enrichment technology in late 1978 from a U.S. firm. The fate of this equipment is unknown. Observers believe that separation facilities in the form of hot cells exist at two Israeli reactor facilities.[25]

PATHS TO NUCLEAR WEAPONS

A number of Middle Eastern nations do possess research reactors and laboratory-scale sensitive facilities, and a few have plans for nuclear power programs. A key question is whether these facilities now in place, or those planned, could result in proliferation of nuclear weapons in the Middle East. The term "proliferation' is used hereto refer not only to the manufacture or acquisition of nuclear weapons by nations that do not now possess them, but also to programs that prepare for the construction or testing of a weapon and that would allow nations to produce a nuclear device in a very short period of time.[26]

Israel, for example, is generally credited with the capability to produce nuclear weapons in a very short period of time. Just as commercial nuclear power development promises to enhance the electricity-generating capacity of Middle Eastern nations, nuclear weapons

~ 'Between 1976 and 1982 General Atomics attempted to Persuade King Saud University to purchase a small Triga Mark 1 reactor, but was unsuccessful. The Saudis signed a memorandum of understanding with Great Britain in late 1981 to facilitate nuclear research and training. The physics department at the University of Petroleum and Minerals has ordered a 14-MeV neutron generator, and has plans for a linear accelerator. The University of Riyadh is acquiring a 2.5-MeV Van de Graaf generator for its physics department. Thus, the Saudis are initiating a low-level research program.

"For the most detailed published account, see Richard Wilson, "A Visit to the Bombed Nuclear Reactor at Tuwaitha, Iraq, *Nature*, vol. 302, Mar. 31, 1983, pp. 373-376. The report is based on observations made onsite in early 1983. More recent reports of onsite conditions are not available. According to information provided by Dr. Wilson in July 1984, about 30 scientists and 100 others (non-military), as well as 100 soldiers are onsite at Tuwaitha; French and Italian technicians are not present.

'⁵Roger F. Pajak, *Nuclear Proliferation in the Middle East* (Washington, D. C.: National Defense University, 1982), p. 38.

[26]This definition, and a more detailed explanation of the weapons applications of various nuclear technologies, can be found in *Nuclear Proliferation and Safeguards* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-48, 1977) and appendix vol. 11.

proliferation would have significant implications for the balance of power in the region, including not only tension between Israel and its Arab neighbors but also rivalries among Islamic states, and for the strategic interests of the superpowers.

Commercial power reactors cannot, by themselves, be used to manufacture nuclear weapons, To make nuclear weapons, plutonium or highly enriched uranium is needed. Low-enriched uranium is used as fuel for light-water nuclear power reactors. Such fuel would have to be "enriched" in an enrichment plant to boost the concentration of uranium 235 to the level required for weapons production. OTA's study, *Nuclear Proliferation and Safeguards,* stated that "it is *impossible,* not merely impractical, to use light-water reactor or CANDU reactor uranium fuel in a nuclear fission explosive without an expensive and technologically advanced enrichment facility."[27]

Another method of producing weapons involves plutonium. Plutonium is produced when uranium atoms in reactor fuel are bombarded by neutrons during the normal operation of a nuclear reactor. Such plutonium, however, must be separated from used ("spent") fuel through a process called reprocessing. Therefore, in addition to a light-water reactor, either an enrichment facility or a reprocessing facility would be required to produce suitable uranium or plutonium for weapons production.

All of the nations that now have nuclear weapons have obtained them through "dedicated" programs devoted to military purposes, but there is at least a conceptual possibility that a country might use commercial nuclear facilities, specifically reactors, in conjunction with an enrichment or reprocessing facility, to acquire or produce weapons materials-plutonium and/or highly enriched uranium. Diversion of materials needed for weapons production from a commercial reactor could occur through evasion of safeguards or through use of unsafeguarded facilities.

[27]F'or analysis of diversion potential from light-water reactor and other nuclear power systems, see Nuclear *Proliferation and Safeguards,* op. cit., pp. 23, 154-189.

Because light-water reactors require considerable time for removing "spent fuel assemblies and replacing them with new fuel assemblies, it is unlikely that spent fuel could be diverted to a reprocessing plant for weapons use without considerable economic and power penalties, except at a normal discharge and loading operation or from the spent fuel storage pool. This would make clandestine evasion of safeguards difficult.

Use of commercial reactors without associated enrichment or reprocessing facilities constitutes at best a very indirect path to nuclear weapons production from the standpoint of the manpower involved as well. There is a limited overlap between personnel requirements for a commercial nuclear program and a nuclear weapons program. About a quarter of the personnel normally involved in operating a commercial reactor require specialized nuclear training. A weapons program would also require personnel with specialized training, some of it in different areas. Therefore, some personnel working in a commercial program could be used for a weapons program (assuming that many were retrained) along with personnel possessing specialized skills in areas such as nuclear engineering, physics, and the handling of high (nonnuclear) explosives.[28]

In Egypt, the Middle Eastern nation most likely to acquire a new commercial power plant in the next decade, policy makers have indicated their preference for turnkey plants. With a turnkey contract, indigenous personnel are gradually trained either in the host country or abroad, and the contractor may also be responsible for operations. Thus, the turnkey approach implies a delay in development of indigenous capabilities. For a nation that wants to keep its nuclear weapons option open, commercial power plants (particularly turnkey plants) raise no direct proliferation considerations. Indirectly and over a long time, how-

[28]The total number of personnel required to operate a nuclear plant in the United States is 600 to 800, including both onsite and off site personnel. See Glenn A. Whan and Robert L. Long, "Nuclear Power: Manpower and Training Requirements, paper presented at the Workshop on Nuclear-Electric Power in the Asia-Pacific Region, Honolulu, Hawaii, Jan. 24, 1983.

ever, such facilities could contribute to the creation and maintenance of a technical infrastructure that would be useful if the nation later decided to develop nuclear weapons.

In contrast to commercial power reactors, which do not pose proliferation risks by themselves, are small-scale sensitive facilities which can be used in conjunction with research or power reactors to extract small quantities of weapons materials if facilities are unsafeguarded or safeguards are evaded.

During the next decade, it is quite likely that more research reactors will be supplied to contribute to the creation of a local science and technology infrastructure in developing countries. However, research reactors can also be used, at least theoretically, as components of programs oriented toward weapons production. The critical considerations are: 1) the size of the reactor, with those over 10 MWt of particular concern; 2) the use of very highly enriched uranium as a fuel; 3) the presence of reprocessing technology; 4) the strength of safeguards to monitor fuel and spent fuel stockpiled within the country; and 5) the operation of such reactors.[29]

One concern is that HEU could be diverted and used in weapons production, although this would entail considerable effort to obtain sufficient quantities. Most safeguarded research reactors fueled by HEU contain less than 25 kg of U^{235} in inventory. During 1981, the International Atomic Energy Agency (IAEA) conducted inspections at 176 research reactors and critical assemblies, of which about 43 contained more than one significant quantity (SQ)[30] of highly enriched uranium or plutonium.

Another concern is that more powerful research reactors might be modified to produce plutonium through irradiation of uranium targets in the core or the use of a uranium blanket around the core.[31] Small, but significant, quantities of plutonium could be produced in reactors with a capacity of more than 10 MWt. (If such a reactor were fueled with HEU, the uranium inventory would probably be of more proliferation concern than would potential plutonium production.) IAEA inspections would detect activity involving modifications in safeguarded facilites, but some plutonium could at least theoretically be produced between inspections.

In the event that quantities of plutonium could be produced through such means, ability to produce nuclear weapons would depend on the presence of a reprocessing facility. Hot cells, such as those in the small radiochemistry lab provided by the Italians to Iraq, are generally limited to gram-scale reprocessing—therefore limiting the amount of plutonium that could be produced annually to several kilograms, at most.

Research reactors larger than 10 MWt and fueled by very highly enriched uranium (VHEU) thus raise proliferation concerns. These include reactors constructed in the 1960's to the late 1970's. More recently, the United States, France, and other nations initiated efforts to encourage the use of low enriched uranium (LEU) in order to reduce the potential for nuclear weapons proliferation from diversion of HEU fuel. There have been few U.S. research reactor exports in recent years; the United States exercises restraints over research reactors abroad through decisions about supply of enriched uranium fuel. Libya is the only Islamic nation with a research reactor having a capacity of 10 M Wt.[32] The Israeli 26-thermal megawatt (MWt) Di-

[29]The discussion on research reactors draws from the work of Marvin M. Miller and Carol Ann Eberhard, "The Potential for Upgrading Safeguards Procedures at Research Reactors Fueled with Highly Enriched Uranium," for the U.S. Arms Control and Disarmament Agency, contract No. AC2NC104, November 1982.

[30]One SQ = 25 kg of U^{235}. Most of the proliferation concern regarding civlian applications has been with the use of very highly enriched uranium (VHE U) containing 93 percent U^{235} used in research reactors. Smaller quantities of about 5 kg U^{235} or between 2 and 8 kg Pu are also of proliferation concern. See Miller and Eberhard, "The Potential for Upgrading Procedures, " op. cit.

[31]See Hans Gruemm, "Safeguards and Tamuz: Setting the Record Straight, " *IAEA Bulletin, vol. 23,* No. 4, December 1981.

[32]Richard Wilson confirmed in August 1984 that the Soviet WWR C reactor at Tuwaitha, Iraq, has a 5-MWt capacity.

mona reactor is estimated to be capable of producing 8 kilograms of plutonium (kg Pu) annually. [33]

For nations wishing to produce weapons covertly, it is at least possible for research reactors to provide an avenue, albeit one much less convenient than acquisition of large-scale sensitive facilities. However, diverting enough HEU or plutonium from these small reactors to support a weapons program (especially one geared to the production of more than one experimental device) would take some time; during that time, a strong safeguards program would probably detect diversion, or at least suspicious circumstances.

The nuclear technologies raising greatest concern in terms of proliferation are enrichment and reprocessing technologies. Because Iraq has purchased laboratory-scale reprocessing equipment, concerns arose about whether or not that country was attempting to produce nuclear weapons, a subject which will be discussed in more detail in the section that follows. Sensitive facilities raise proliferation concerns because they could be used in a weapons program if safeguards were inadequate or circumvented. Requiring only a modest sum of money and a modest construction effort in comparison to large-scale facilities, smaller-scale reprocessing facilities could be used to produce clandestinely the material for a small number of bombs annually if the spent fuel were available. Although time-consuming, such an operation is not technically difficult.

Construction of either unsafeguarded enrichment or reprocessing facilities would constitute a violation of the Nuclear Nonproliferation Treaty (NPT), which all Middle Eastern nations except Algeria, Israel, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) have ratified or signed. Dedicated weapons programs could potentially use some safeguarded facilities: e.g., in theory low-enriched uranium could be diverted from a safeguarded reactor and boosted in a dedicated enrichment plant, However, this would be a time-consuming and difficult process if safeguards were in place.

As OTA's study of *Nuclear Proliferation and Safeguards* outlined, the path to weapons production most accessible to developing countries with modest technical infrastructure is one involving construction of a 25-MWt plutonium production reactor (which would produce enough plutonium for one or two explosives per year) and a small reprocessing plant. The two facilities together would require 10 to 20 professional engineers for operation. The reprocessing plant requires more expertise in remote control, the handling of very radioactive materials, and chemical engineering procedures, but the equipment and supplies needed are generally available on world markets. [34]

A more demanding route would be the use of centrifuge enrichment facilities. In either case, the facilities would have to be constructed and operated without detection. Five years is the estimated time between the point when a nation begins discussion of a dedicated route and the point when the weapons material could be in hand. In addition to these two dedicated routes, the next decade could see progress in advanced isotope separation technologies such as laser isotope separation, which could greatly accentuate proliferation problems.

It must be emphasized that in the Middle East, where manpower is a major constraint on transfer of advanced technologies, it would be difficult to assemble a team with the appropriate specialized skills. Even in newly industrializing countries, such as India, with much larger pools of scientific and engineering manpower, construction of reactors has required more skilled workers than are needed in industrial countries. A small national program designed to produce weapons clandestinely without testing would require a core group of more than a dozen well-trained and very competent people experienced in many fields of science and engineering, and access to open technical literature.

[33] Miller and Eberhard, op. cit., p. 21.

[34] See *Nuclear Proliferation and Safeguards,* op. cit., pp. 174-79.

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In addition, a staff of technicians, diverse laboratory facilities, a field-test facility for handling experiments with large-scale (nonnuclear) explosives, and financial and organizational resources to purchase or fabricate items required for the assembly mechanism would be needed.[35] Any one of these components might be easy to acquire, but Middle Eastern countries face strong obstacles to assembling the entire package of skills needed and to retraining personnel over a long period of time. More important than the sophistication of the facilities is the competence of the individuals involved in the program. Manpower is thus a critical constraint to nuclear technology transfer in the Islamic Middle East.

A final route to nuclear weapons is theft or purchase of nuclear material or weapons on the black market. This would eliminate the need for the expensive and demanding technologies described above. Libya has reportedly attempted to purchase not only sensitive nuclear technologies (reprocessing and enrichment) but also a nuclear bomb.[36] While there is no evidence that such a black market now exists, one may develop if second-tier suppliers enter the market to sell unsafeguarded facilities and if plutonium recycle becomes more extensive. The black market is the least technically demanding route to nuclear weapons.

This discussion indicates an ascending order of proliferation problems, with commercial reactors at the bottom and sensitive facilities at the top of the list. In the case of power reactors, the commercial applications are most important for these Middle Eastern nations, particularly where the recipient possesses none of the more sophisticated reprocessing or enrichment equipment. For commercial powerplants, particularly those built through turnkey contracts, there is no direct proliferation risk if reprocessing and enrichment facilities are not present.

The most worrisome path to a weapons capability would be one that involves acquisition of small-scale fuel cycle facilities that could be rationalized, more or less reasonably, as logical components of an orderly long-term effort to develop a broad capability for using nuclear power. Such facilities, designed with great flexibility of operation in mind, maybe capable of producing materials adequate for one to a f'ew weapons per year. However, it must be emphasized that such facilities would have to operate over considerable periods of time and escape safeguards in order to be used for weapons production.

If a nation were to succeed in this covert weapons production path, it might produce a few small-scale, untested nuclear weapons. Some observers believe that in the Islamic Middle East a number of nations–Iraq, Libya, Egypt, Syria, and Iran[37]-might by the turn of the century be in a position to develop such "small nuclear forces" (comprising 5 to 10 deliverable and militarily serviceable fission bombs or warheads).

If present nuclear supplier policies remain in force and are accepted by new suppliers, the Islamic nations of the Middle East will not be able by themselves to produce weapons for many years, unless they abrogate or violate safeguarding agreements. In that case, production of weapons would be difficult, and because the separation of plutonium required for a single weapon would take many months (depending on the type of reprocessing facility), detection of the program would be probable.

However, if new suppliers enter the market who are willing to provide sensitive facilities and assistance, and if recipients abrogate safeguards, the possibility of nuclear weapons proliferation would increase dramatically. Table 84 outlines the nuclear proliferation implications of policies of supplier and recipient countries, in their current form and under theoretical modifications.

The section that follows explores the plans of these and other Middle Eastern countries for nuclear power development. The technical capabilities of these nations to utilize nuclear technologies are evaluated in the light of stated policy toward commercial power development and toward weapons programs.

[35] Ibid., p. 140.

[36] Steven J. Rosen, *Nuclear Proliferation and the Near-Nuclear Countries*, (Cambridge, Mass.: Ballinger, 1975), p. 178.

[37] Center for Strategic and International Studies, *Proliferation of Small Nuclear Forces* (Washington: CSIS, 1983), p. i.

Table 84.—implications of Technology Transfer Policies for Proliferation of Nuclear Weapons

Recipient policies	Suppler policies	Implications for weapons programs
	No changes i policy, no new suppliers	1. Recipients could obtain reactors but no capability for obtaining plutonium or HEU, except through facilities of an undeclared or clandestine nature (although abrogation of safeguards would allow for Pu path) Weapons capability would be limited several years for a single weapon
Acceptance of full-scope safeguards (party to NPT or equivalent)	Suppliers, possibly new ones, willing to provide sensitive facilities (as well as reactors), with, however, Insistence on safeguards on facilities they provide	2 Could obtain everything necessary for a fairly large-scale weapons program. but weapons could be obtained only after abrogation or violation of safeguarding agreements
	Suppliers, possibly new ones, willing to provide anything without safeguards	3. Same as 2. above
	No change in policy, no new suppliers	4. Same as 1
Acceptance of safeguards only as required by individual suppliers	Suppliers willing to provide sensitive facilities (as well as reactors), with insistence on safeguards at least on facilities they provide	5 Same as 2
	Suppliers willing to provide anything without safeguards	6 Recipients could acquire essentially unlimited weapons potential
	No changes in policy. no new suppliers	7 Weapons capability for recipients confined to currently existing facilities Recipient might not be able to obtain additional shipments of HEU; therefore, proliferation potential remote
Unwilling to accept safeguards on anything	Suppliers willing to provide sensitive facilities (as well as reactors), with insistence on safeguards on at least facilities they provide	8 Same as 7, above
	Suppliers willing to provide anything	9 Same as 6 above

SOURCE: Office of Technology Assessment

PERSPECTIVES OF RECIPIENT COUNTRIES ON NUCLEAR TECHNOLOGY TRANSFERS

A number of economic, political, and manpower-related considerations restrict the ability of Middle Eastern nations to develop nuclear power and pursue a nuclear weapons option. Despite the growing awareness of the problems associated with nuclear power—including waste management, potential for accidents, and economic costs—some developing nations see nuclear power as essential for their economic development. Likewise, despite the potentially destabilizing effects of nuclear weapons acquisition, some developing nations have apparently invested considerable resources in attempting to keep a nuclear weapons option open.

This section explores the various types of constraints on nuclear technology acquisition in the Middle East, with reference to specific countries and programs. One important theme is that the manpower required for indigenous technology development is a significant constraint for all of these nations. Also, the volatility and early stage of nuclear programs in the Middle East reflect an absence in most of these countries of the political agreement and leadership needed to support a large-scale nuclear program.

ECONOMIC AND ENERGY CONSIDERATIONS

In deciding whether to promote commercial nuclear power, developing nations face significant constraints related to the following requirements: financing, validity of projected energy demand, electricity grid size, political agreement concerning the appropriateness of nuclear power in view of overall development strategies, and competing requirements for resources. OTA analysis leads to the conclusion that, despite the potential which nuclear power holds for meeting anticipated rapid growth in electricity demand, only a few developing Middle Eastern nations are likely to have operating power reactors within this century. Egypt, the Middle Eastern nation with the most extensive program for nuclear power development, is likely to obtain nuclear reactors only with subsidized financing.

Financial Requirements

In developing countries, where financial resources are scarce and demand for central power station electricity comparatively small, coal, oil, and hydropower have commonly been used to meet electrical demand. For Middle Eastern nations, particularly those with abundant hydrocarbon resources, the rationale for commercial nuclear power is far from clear. Herein lies the central question: What changes in the incentives and disincentives for nuclear power which heretofore weighed against nuclear power in the Middle East might "tip the logic" in its favor?

Cost and financing terms for the purchase of nuclear reactors severely constrain the ability of many developing nations to acquire reactors. While costs of reactors vary, depending on a variety of factors such as reactor types, safety standards, and construction delays, a 1,000-MWe reactor costs a minimum of about $1 billion in industrial countries, and could run double or triple that amount elsewhere. Including indirect costs (interest, manpower training, administration), a 600-MWe reactor alone has been estimated at $1.5-$2 billion (in 1981 dollars) for developing nations."

Financial constraints have been particularly salient for Egypt. Despite Egypt signed letter of intent to buy a 626-MWe pressurized-water reactor from Westinghouse in 1976, financing of $1.2 billion in loans was never resolved and the sale was never completed.[39] In 1981, Egypt set up a alternative energy fund whereby oil revenues were to have been set aside at the rate of $500 million annually. As of December 1983, Egyptian Government officials stated that $800 million had been deposited in this fund,[40] and that another $300 million would be added in 1984. Financing continues to be a major factor influencing Egypt nuclear power plans.

The reluctance of the U.S. Export-Import Bank to grant loans and congressional opposition to loans to finance U.S. nuclear reactor exports has been a continuing issue in negotiations carried out by U.S. firms." Similarly, financing has been the sticking point in Egyptian negotiations with the French for two 950-Mwe pressurized-water reactors valued at $2 billion. Egypt announced plans to finance 20 percent of the project itself and sought financing for 80 percent of the project at 8 percent interest rates. For the last 2 years, the pro-

[38] In Taiwan, where labor costs are very low and skilled manpower exists, two 950-MWe reactors were built at a total cost of $1.7 billion in 1983, This low cost reflects the lack of public hearings and very limited backfitting, conditions not present in the United States. See "Nuclear Costs, " *Engineering News-Record,* May 26, 1983, pp. 27-28. See Ian Smart, "The Consideration of Nuclear Power, " in James Everett Katz and Onkar Marwah (Marwah) *Nuclear Power in Developing Countries: An* Analysis of *Decision* Making (Lexington, Mass.: Lexington Books, 1982), p. 28.

[39] See U.S. Department of Energy, *Joint Egypt-United States Report on Egypt- United States Cooperative Energy Assess*ment, 5 vols. (Washington, D. C.: U.S. Government Printing Office, 1979).

[40] See "Seminar Discusses Nuclear Safety, " London Al-Sharq Al-Awsat in Arabic, Nov. 24, 1983, p. 7 reported in JPRS TWD 84-002; see also Charles Richards, "Four Bids Expected for Egypt N-Plant, " *Financial Times, Nov.* **24,** 1983.

[41] " Egypt Seeking Direct U.S. Aid for Nuclear Plant Purchase, ' *Nucleonics Week,* vol. 21, Feb. 14, 1980, p. 2.

jected date for beginning construction of the two reactors has been continually postponed.

For a country like Egypt, which has limited oil resources, a rising demand for food imports, and growing government expenditures, the viability of its nuclear program has been strongly affected by financing problems. With declining oil prices, remittances from Egyptian workers abroad initially fell, as did income from the Suez Canal. Egypt's current account deficit increased from $820 million in fiscal year 1979-80 to $1,406 million in fiscal year 1982-83.[42]

The nation's changed financial position is illustrated by its modified requests for external financing of nuclear reactor construction: In 1980, Egypt was negotiating to finance 50 percent of the reactor project at 8 percent interest; in 1982, 80 percent financing was requested at the same interest rate. Meanwhile, contributions to the alternative energy fund fell from the $500 million per annum announced in 1981 to $150 million in 1982.[43] All of these factors suggest that unless Egypt is offered a nuclear reactor at highly subsidized rates, its current nuclear plans are unlikely to come to fruition.

The history of Iran's nuclear program illustrates that even in oil-rich developing nations, political difficulties may arise from excessive costs accompanying a rapidly developing nuclear program. In 1975, the Canadian consulting firm Monenco (Montreal Engineering Co. Ltd.) estimated nuclear construction costs in Iran at $690 per kilowatt installed capacity. At the time, this estimate made nuclear power appear very attractive; cost estimates compared favorably with an average $700 to $1,000 per kilowatt for developed countries. However, the installed costs approached $3,000 per kilowatt, as construction neared completion before termination of construction following the revolution.[44]

The cost discrepancies were due largely to inflation, cost overruns, large infrastructure expenditures for associated road and port construction, the system of commissions paid to royal family members, and the government's mismanagement of the bidding process. Critics charged that Iran's hasty drive to develop nuclear power met with such difficulties because, among other factors, decisionmakers lacked sufficient technical expertise.

Determinants of Electricity Demand

In addition to costs and financing terms, expectations about future demand for electricity are key considerations for planners in developing nations. The demand for energy, and specifically for electricity, is determined by a variety of factors, including population growth, economic growth, energy intensity of economic growth, energy prices, and technological change.

Population growth is a major factor affecting energy demand in developing countries. Based on current trends, population growth in all the Middle Eastern countries will remain high, at least until the end of the century. While population growth may eventually decline under the impact of urbanization, increases in education, income levels and standards of living will tend to lower mortality rates. Population growth in all of these nations is expected to average well above 2 percent annually until the turn of the century. The Persian Gulf States, as a group, are projected to experience the world's highest levels of population growth, averaging 2.6 percent annually, according to World Bank estimates.[45]

Expansion of Middle Eastern economies depends strongly on the rate of oil income. As chapter 14 explains, it is extremely difficult

[42] In 1982, Egypt's financial situation improved somewhat as earnings from the Suez Canal and remittances increased. See *Middle East Economic Digest,* Egypt Special Report, July 1983, p. 9. See also "Egypt's Economy on the Right Track'?" *Middle East Economic Digest,* Dec. 2, 1983, p. 11.

[43] "In Brief," *Middle East Economic Digest,* vol. 26, No. 45, 1982. By early 1984, it was estimated that a total of $700 million to $900 million had been set aside under the fund.

[44] "Nuclear Still Wrong for Iran, But Events May Dictate Otherwise, Analyst Says," Nucleonics Week, Oct. 16, 1980, p. 6.

[45] World Bank, *World Development Report 1983,* p. 185. Population growth for Saudi Arabia for the period 1960-2000 is projected at 3.4 percent annually, 2.6 percent for Kuwait, and 2.0 percent for the UAE.

to predict economic growth rates for various Middle Eastern nations. However, if the current trend in slack oil prices continues, economic growth rates could fall far below those achieved by Middle Eastern nations during the 1973-74 and 1979-80 periods of dramatic expansion. Since many countries already have a large amount of electrical generating capacity in place or under construction, if economic growth proceeds at rates well below those of the 1970's, demand for additional generating capacity will be dampened. Therefore, as countries complete their conventional powerplants now under construction, there could even be overcapacity by the mid-1980's if Middle Eastern economies grow at a slower rate than anticipated in the early 1980's.

The structure of economic growth also has an important bearing on energy demand. Development strategies favoring industrialization and urbanization are more energy-intensive than strategies stressing agriculture and service sector development. Generally speaking, during the early stages of industrialization, increasing rates of growth in energy consumption occur. Those Middle Eastern nations where diversified heavy industrialization is under way will thus experience a more rapidly rising demand for electricity.

Demand for energy is also affected by prices. Governments in the Middle East tend to set oil-based fuel prices lower than the opportunity cost to the economy. In Egypt, for example, the price of kerosene used in home heating and cooking was 15 percent of the world market price in 1980.[46] Subsidized energy prices, which are politically popular but reduce incentives to conserve oil and to diversify to other energy sources, have probably contributed to acceleration of growth rates of energy consumption. During the period 1974-76, these rates averaged over 20 percent in Saudi Arabia, Libya, Algeria, and Egypt. Although some fuel efficiency improvements will take place through import of energy-efficient goods from nations where energy costs are high, significant energy savings are unlikely to occur in the presence of continued subsidization of energy prices.

All of these factors help influence the pattern of growth in demand for energy. Historically, the pattern has been that electricity consumption has risen more rapidly than energy consumption. Fifty years ago, for example, electricity represented only 4 percent of total primary energy consumption worldwide; today the figure is 27 percent. The proportion of commercial primary energy transformed into electricity is projected to rise in developing countries from 25 percent in 1980 to 31 percent in 1990.[47]

Annual growth rates of electricity consumption in the Middle Eastern countries during the past decade have been dramatic, in many countries approaching 15 percent. At this rate, consumption doubles in less than 5 years. In the late 1970's, Iran, Egypt, Algeria, and Saudi Arabia all ranked among the 20 largest consumers of commercial energy among developing countries.[48] Table 85 presents a summary of data relating to electricity demand in the region in the year 1980. Growth in electricity demand was, during the last decade, strikingly high in Gulf States such as Saudi Arabia and the UAE. During 1980, Egypt, Iran, and Saudi Arabia were the countries with the highest levels of electricity generation.

Interconnected Electricity Grids

There is a wide diversity in projections of electricity consumption for the next decade. Planners must consider regional and sectoral demand in their analysis of the relative costs of various electricity-generating systems. National projections of electricity demand and installed, connected, electrical grid, however, provide a general context for evaluating the rationale for nuclear power in specific countries.

[46] World Bank figures, cited by R. Mabro, "Factors Affecting Future Energy Demand in Arab Countries, Second Arab Energy Conference, March 1982, Qatar.

[47] World Bank, *Energy in Developing Countries* (Washington, D. C.: World Bank, 1980), p, 63.

[48] Joy Dunkerley, William Ramsay, Lincoln Gordon, and Elizabeth Cecelski, *Energy Strategies for Developing Nations* (Washington, D. C.: Resources for the Future, 1981), p. 41.

Table 85.— Electrical Demand in the Middle East and North Africa

Country	Growth in demand for electricity 1971-80 (percent)	1980 Installed capacity (GWe)	1980 Installed connected grid	1980 electricity generated (GWh)[a]
Algeria .	112	18	1,4	6,400
Egypt	8.7	4.5	4,5	18,500
Iran	7,5	53	53	17,000
Iraq	134	12	12	8,000
Jordan	166	0.4	04	1,100
Kuwait	134	28	26	9,300
Lebanon	27	07	0.7	1,800
Libya	17,0	12	0.9	3,100
Morocco	80	12	10	4,800
Oman	220	04	04	800
Qatar	165	0.5	0.5	1,500
Saudi Arabia[b]	400	62	30	17,000
Syria	125	11	0.9	3,400
Tunisia	107	09	08	2,800
UAE	360	11	11	4,500
AR Yemen[c]	180	002	002	70
PDR Yemen	00	007	0,07	200

[a]GWh gigawatt-hours.
[b]1975-80
[c]1971-77
NOTE: There ia a wide disparity in data provided by the United Nations. the Central Intelligence Agency, and other sources concerning current electricity production as well as future growth projections. This compliation is based on U.N. data which are gathered from government sources, but uses other estimates as well.

SOURCE: United Nations. Statistical Yearbooks 1970-79: Central Intelligence Agency, National Basic Intelligence Factbook. 1974-82 additional materials used for each country estimate.

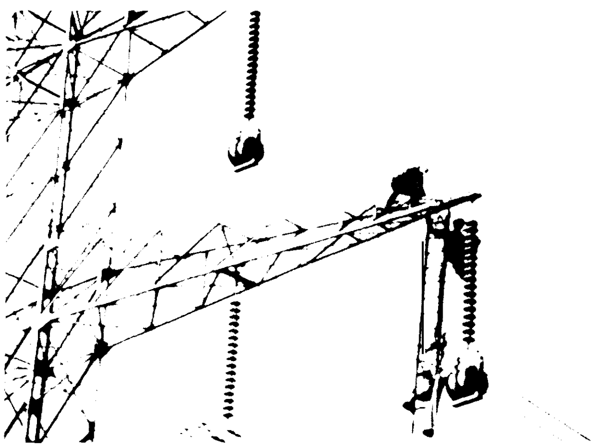


Photo credit: Aramco World Magazine

Power workmen string line on the Saudi Consolidated Electric Company's 230 kw power distribution network

A rule of thumb is that no single generating plant should constitute more than 10 percent of the system's total installed interconnected grid. This criterion is based on considerations of system reliability, reserve capacity, and economics. For example, if a power station in an electrical grid fails, reserve capacity must be brought online or portions of the load must be shed if the operating frequency of the system is not to be reduced by the added load of the remaining generators. To prevent this, some fraction of the installed electrical capacity is usually kept spinning in synchronization with the grid ("spinning reserve' '), ready to take over in seconds until other components of the reserve capacity such as quick-start turbines can be brought online. Requirements for spinning reserve are smaller if load can be shed. Although load shedding is not a normal practice in industrialized countries, many developing countries shed load during peak hours. The smaller the size of the largest plant, the less reserve margin is needed to achieve a given system reliability.

Developing nations such as India, South Korea, Argentina, and Brazil all have had nuclear powerplants constituting less than 10 percent (and as low as 6 percent) of their grids at various times. On the other hand, in 1978 when Taiwan's Chin-shan 600-MWe reactor went critical, it represented 10 percent of a basically integrated national grid estimated at 6.5 GWe, and Pakistan's 125-MWe KANUPP reactor was designed with a capacity to make up 17 percent of Karachi's interconnected grid, although it has apparently rarely been operated at that level.

The 10 percent rule of thumb has been more common for industrialized countries than for developing countries, but it does help to indentify situations where addition of a nuclear reactor might not be clearly warrented. In practice, the upper limit may be higher or lower, depending on analysis of the nature of the grid, its load, and acceptable outages and load shedding. The rule of thumb points out cases where the installation of a power reactor might be questionable in terms of energy and economic considerations.

Applying the 10 percent rule to projections for electricity grids in various Middle Eastern nations indicates that most of them would not be in a position to install a 900-MWe reactor in this decade. Morocco, Tunisia, Jordan, Lebanon, Oman, Qatar, and North and South Yemen would not be in a position to do so until after the year 2000. Algeria, Iraq, Libya, Syria, and the UAE (only under high-growth assumptions) would have the installed grid to accept a 900-MWe reactor by the year 2000, but not as early as 1990. As table 86 indicates, only Egypt, Iran, Kuwait, and Saudi Arabia would be able to accommodate a 900-MWe reactor at 10 percent of grid size by the year 1990. These projections are based on assumptions that interconnected grids will be expanded rapidly. If Middle Eastern countries move to link their electricity grids, an option which has been discussed, power reactors might be accommodated earlier without violating the 10 percent rule.[49]

Small Reactors

The feasibility of nuclear power reactors could change substantially if small nuclear reactors (less than 600 MWe) were as readily available as large reactors on world markets. While a few older, small reactors are in operation, the Soviet 440-MWe reactor is the only small reactor currently available on the international market. According to U.S. industry, a major reason why such small reactors are not available is that there are marked differences in economies of scale for smaller units.

[49]The Gulf 'Cooperation Council (GCC) nations are considering the feasibility of linking national grids in a regional power grid, but there is some doubt that these countries will be willing to contribute the massive capital costs that would be necessary. See "The Pros and Cons of Regional Power Grid, " Middle East *Economic* Digest, vol. 27, No, 43, Oct. 28, 1983, p. 19. Interconnection of grids was discussed at the 2nd Arab Energy Conference, Mar. 6-11, 1982, held in Doha, Qatar.

Table 86.— Potential for Nuclear Reactor Installation, 1990, 2000

	1980 Actual grid capacity in GWe	Size of hypothetical reactor	Demand assumptions 1990 Low	1990 High	2000 Low	2000 High
Algeria	(1.4)	440 MWe				x
		900 MWe			x	x
Egypt	(4.5)	440	x	x	x	x
		900		x	x	x
Iran	(53)	440	x	x	x	x
		900	x	x	x	x
Iraq	(1.2)	440			x	x
		900				x
Kuwait	(2.6)	440	x	x	x	x
		900		x	x	x
Saudi Arabia	(3.0)	440	x	x	x	x
		900	x	x	x	x

X reactor could be installed and not exceed 10 percent of projected grid

NOTES Other countries *able* to install a 900-MWe reactor by 2000 under 10 percent assumptions Libya, Syria, UAE under high electricity growth assumptions

Other countries *unable* to install a 900-MWe reactor until *after 2000* under the same assumptions Morocco Tunisia Jordan Lebanon Oman Qatar North and South Yemen

SOURCES Computed from table 91 World Bank Energy in the Development Countries (World Bank Paper August 1980) background Information prepared for the paper and energy analyses, Joseph Egan. Small Power *Reactors in Less Developing Countries:* Histroical *Analysis and* Preliminary *Market Survey* (Westmont, *Ill,:* ETA Engineering Inc., 1981) additional sources for individual countries (For example the high demand estimate for Egypt is based on U S Department of Energy, and the low demand estimate is based on Shuli, as indicated in table 93

For reactors larger than 600-MWe, a 0.7 scaling law is normally applied to direct construction costs. Therefore, a 1,200-MWe reactor would cost only about 60 percent more to build than would a 600-MWe reactor. The standard unit built by major reactor vendors increased to the 900- 1,200-MWe range typical today; these larger reactors are more appropriate for industrialized nations where grid size is not a major constraint. A second factor is research and development (R&D) costs of several hundred million dollars, which firms must take into account when considering commercial development of small reactors. Industry experts believe that only if a firm could anticipate 5 to 10 orders for such reactors would it be reasonable to proceed with the necessary R&D.

Despite these factors, which some believe weigh against small reactors, some factors are in their favor. Smaller units may require less construction time, and therefore reduce prospects of cost overruns. It is not clear whether small reactors are more reliable than large reactors.[50] While some older, smaller reactors, such as the 220-MWe Rapp 1 heavy-water reactor in India, have poor reliability records, others such as the 325-MWe Atucha 1 heavy-water reactor, built by the German firm Kraftwerk Union in Argentina, have been worldwide leaders in uninterrupted operation. The Argentine reactor has had a capacity factor of 90 percent since it began operation in 1974. Small reactors have several potential features, such as compatibility with shop fabrication and barge transportation, that might tend to compensate for higher direct construction costs per kilowatt installed. To summarize, scale issues are complex. In the face of uncertain demand and limited resources, developing countries may see small reactors as attractive because of the possible reduced risk involved in building several short lead-time plants rather than one large unit.

Availability of small reactors would enhance the feasibility of nuclear power for developing nations with comparatively small grids. For example, if demand for electricity grows at a high rate, Iraq could be in a position by 1990 to install a 440-M We reactor that would meet the 10 percent rule of thumb. Similarly, Egypt would be able to meet this criterion even under low electricity demand growth assumptions by 1990. Flexibility would be increased further if large reactors could be derated (operated at lower capacities) during initial stages of operation and still be operated efficiently.

Two factors could significantly change the prospects for small-reactor sales. The Soviet Union has exported a few 440-MWe power reactors. If the Soviet-designed VVER 440-MWe reactor can be manufactured and sold at attractive prices, Middle Eastern nations may be interested in importing it. In 1980, there were five such reactors operating in the Soviet Union, and plans exist for installing a few additional reactors. However, since Soviet construction facilities are pressed to meet construction deadlines for larger reactors now at the center of Soviet nuclear plans, construction of the smaller reactors has been shifted to the Skoda Works in Czechoslovakia.

VVER 440 reactors, reported to be reasonably reliable and economical, will be installed in East European nations. The question is whether the Czech works will have the capacity for exports, and whether small reactors produced there will gain a reputation for reliability.[51] In addition, India has built a 235-MWe heavy-water reactor for domestic use, but it is not attractive for export.

The second possibility is that some of the Western firms with design concepts for small power reactors would decide on a commercialization strategy. A handful of companies in Western nations have such design concepts, and if such small reactor designs embodying inherent rather than engineered safety were commercialized, developing countries more

[50] C. Komonoff, *Power Plant Cost Escalation* (New York: Komonoff Energy Associates, 1981). See also, *Nuclear Power in an Age of Uncertainty* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-216, 1984), pp. 106-107.

[51] See *Technology and Soviet Energy Availability* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-ISC-153, 1979), pp. 116, 130, 295.

concerned with safety in the post-Three Mile Island era might find them attractive. Kraftwerk Union of Germany, for example, has a design for a 400-MWe boiling water reactor that features uncomplicated safety technology. In all cases, however, these designs have not advanced beyond the drawing board, and a major R&D effort would be required in the country of origin to produce an attractive export product.[52] Nevertheless, if small reactors could be marketed near the turn of the century, that could change the prospects for nuclear power in some Middle Eastern countries.

Other Incentives for Commercial Nuclear Power

Nuclear power plants have two other civilian applications—to supply process heat for desalination of sea water and in stimulating heavy oil production—which Middle Eastern nations may wish to develop in addition to generating electricity. Nuclear desalination is currently economically feasible only in conjunction with nuclear generation of electricity. While the UAE, Qatar, and Oman conventionally desalt large amounts of water, their electricity grids are too small and poorly integrated for introduction of nuclear desalination plants at the present time. In contrast, nuclear desalination appears more feasible for Saudi Arabia and Kuwait. The only commercially available option for nuclear desalination involves the use of light-water reactors, using backpressure steam or extracted steam. Other specially designed reactors, such as the French Thermos, the Swedish Secure, or Soviet designs, are not currently commercially available.

Economic tests of the feasibility of nuclear desalination depend on capital and fuel costs of the nuclear plants versus conventional plants, as well as on water demand and electricity requirements. As a general rule, if nuclear electricity is economically feasible, then the cogeneration of low-temperature steam[53]

Photo credit: Saudi Arabian Ministry of Information

Al-Khobar Desalination Plant

(used in desalination) makes the system more attractive. Small reactors have not been viewed as particularly attractive for desalination. Kuwait, for example, drafted specifications in 1977 for a 40 MWt water desalination and research reactor, but owing to the small scale of the reactor and to its multipurpose usage, the project was canceled when it was determined that the costs per kilowatt would have been extremely high.[54]

Use of heat produced in nuclear powerplants for stimulating heavy oil[55] production does not appear to be a major option for Middle Eastern nations. Heavy oils sufficiently viscous to profit from enhanced steam recovery have been discovered in Kuwait and Libya, but they are of only marginal interest for these nations, given the large quantity of proved reserves of conventional oil. Nor would standard reactor designs produce steam of appropriate pressure and temperature to drive the large Middle Eastern oil reservoirs.

Uranium Resources

Presence of uranium deposits does not provide sufficient economic justification for a nuclear program. The mining and refining are expensive and enrichment is a complex and

[52] See Joseph R. Egan, *Small Power Reactors in Less Developed Countries: Historical Analysis and Preliminary Market Survey* (Westmont, Ill.: ETA Engineering, Inc., 1981).

[53] Excess steam used in the production of electricity that can be used for other purposes.

[54] Power produced in this reactor would have cost $15,000 per kW. See Egan, op. cit., p. 5-1.

[55] Heavy oil is a term used to apply generally to any crude oil of less than 20 percent API (or with a specific gravity of 0.934 or more).

technically demanding operation; thus, most developing nations with commercial nuclear programs contract for supplies of enriched uranium.

Algeria and Morocco illustrate this point. Algeria has the richest reserves of uranium of any Middle Eastern nation. These reserves have been estimated at 26,000 tonnes at a recovery price of $80/kg.[56] Algeria has been exploring for uranium since 1969; the state mining company, Sonorem, is building a uranium mine in Algeria that is expected to open in 1985 and produce 1,000 tonnes annually. Algeria could also produce uranium as a byproduct of phosphate mining, although no plans have been announced to do so. But while Algeria has emphasized its uranium reserves as an asset in nuclear planning, the nation has no commercial or research reactor.

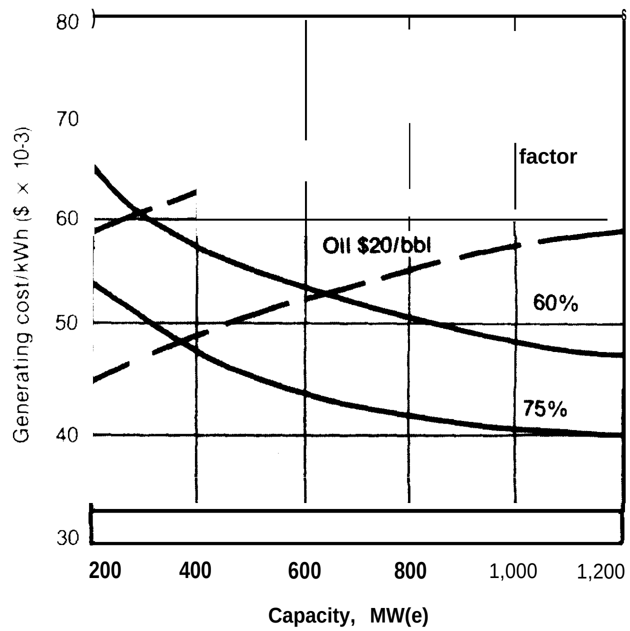
Morocco also has considerable uranium deposits, and uranium will be extracted in conjunction with fertilizer production. One plant is being modified for uranium production. When it begins operation in 1985, Morocco will be in a position to export 200 tonnes of uranium annually. Like Algeria, Morocco is also considering nuclear development, but the presence of uranium deposits has apparently not been a major factor- in this regard.

Total world production of uranium is well in advance of demand, and this situation is expected to continue into the future.[57] Therefore, the attraction of uranium production is not great for developing nations not already exporting. Indeed, since all light-water reactors require enriched uranium for fuel, the purchase of enrichment services from abroad would still be a requirement, even for nations producing uranium.[58] However, uranium production by nations such as Algeria and Niger, which are not parties to the NPT, raises proliferation concerns, since they are not covered by safeguards and could theoretically export to nations having clandestine weapons programs.

Alternative Energy Sources

-Judgments about nuclear power focus more on the alternative means of meeting electricity requirements than on the presence of uranium or the other commercial applications of nuclear power mentioned above. (The use of nuclear technologies in civilian research programs important for building a science and technology infrastructure will be discussed later in the context of technical manpower considerations.) In the Middle East the obvious alternatives to nuclear power are oil and gas. Cost comparisons between oil and nuclear energy are sensitive to the assumed price of oil, capital costs of oil and nuclear plants, costs of financing, and load factors. Figure 15 illustrates the cost of nuclear power as a function of plant size and load factor.

Figure 15.— Kilowatthour Cost as a Function of Plant Capacity and Load Factor



Note.-This figure is based on the following assumptions 30 year design (depreciation) life for both oil and nuclear plants starting from the date of plant start up with a cost of financing of 5 percent per year (in constant dollars) installed capital cost for oil plants of $1 000/k W(e) and for nuclear $2 × 104 S ', /kW(e) where S is plant capacity in megawatts(e), fuel cost for nuclear of $0 /01 kWh operations and maintainence costs of $75{ kW(capacity) yr and $40 for nuclear and oil respectively This figure should be regarded as illustrative only considering the very great uncertainties that must attach to some of these parameters particularly installed capital costs

[56] OECD Nuclear Energy Agency and IAEA, *Uranium: Resources, Production, and Demand* (Paris: OECD, 1982).

[57] See U.S. Department of Energy, *World Uranium Supply and Demand: Impact on Federal Policies* (Washington, D.C.: U.S. Government Printing Office, 1983), p. 36.

[58] The CANDU reactor operates on natural uranium, eliminating the need for enrichment.

The oil-nuclear indifference curve (in dashes) illustrates the relationship between load factor and break-even size for oil versus nuclear plants at two different assumed oil prices. Under the assumptions used, there will bean advantage for nuclear power for conditions to the right and below the oil-nuclear indifference curves. While this figure is merely illustrative, it suggests that if oil is priced at $25 per barrel, oil and nuclear-generated power will be about equally costly if nuclear powerplants of 630-MWe are used at a load factor of 45 percent. As the price of oil declines, the advantages of nuclear power are reduced, but such power is still attractive under reasonable load factors. However, if the oil price drops significantly, as it did in 1983, it will be more difficult to raise the capital to build nuclear plants, and the incentives for developing nuclear power will be further reduced.

Comparing gas and nuclear power is a more complex issue because up until 1979 most gas in the Middle East was flared. This occurred because the costs of collecting and transporting gas in the Middle East were extremely high in comparison to its market value in the Middle East. After the oil price increases, however, gas became more attractive in industrial operations such as petrochemical and fertilizer plants. Gas-fired generating capacity is being built while nuclear is not, and in many situations it will have an edge over nuclear power.

In addition to cost advantages, gas-fired plants can be installed more quickly, require lower investment, are available in small sizes, demand fewer highly skilled operating personnel, and raise fewer waste disposal and safety concerns. Some experts believe that associated gas may be more profitably used in industrial applications than in electricity generation, since the amount of gas available depends on the level of oil production.[59] The attraction of gas for electricity production is strongest in countries such as Saudi Arabia that have flared gas. There are, however, other potential uses for gas: in petrochemical production, and (for Algeria) exports.

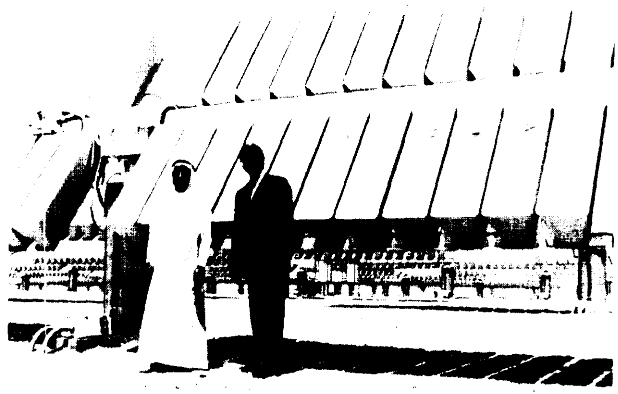


Photo credit *Saudi Arabian United States Joint Commission on Economic Cooperation*

Solar collector panels of the SOLERAS project, focusing on solar energy research and development

In addition, there is an extensive list of renewable energy resources—including solar energy–-for Middle Eastern policymakers to consider. For many developing nations, including those in the Middle East, there is insufficient understanding of the potential role that these sources of energy might play. In the Middle East, some countries such as Iran and Iraq may be able to develop hydroelectric power more extensively.[60] Likewise, some believe Iran, Algeria, and Egypt could use biomass as an energy source.[61] Direct use of solar energy in areas such as the Sahel offers potential for crop drying and other agricultural uses.

Other technologies, such as solar photovaltaic systems, are under development, but are comparatively costly. The United States and Saudi Arabia jointly fund a $100 million solar energy research program through the U. S.-Saudi Joint Commission; the program includes establishment of a 350-kW power station in a "solar village." In Egypt, AID has sponsored research on solar energy for rural development. However, solar energy for rural electrification is a longer term option.

[59] See T. Stauffer, "Oil Exporting Countries Need Nuclear Power," paper delivered at the Uranium Institute, London, September 1982.

[60] Dunkerley, et al., op. cit., pp. 160-161.

[61] Ibid., p. 178.

Nevertheless, technical assistance programs that help clarify all energy options make an important contribution.

The Economic Rationale for Nuclear Power in Egypt

Of all the nations in the Middle East, Egypt currently has the most extensive official plans for commercial nuclear power development. Its electricity grid is one of the largest in the Middle East, and electricity demand grew rapidly during the 1970's. By 1980, the installed grid capacity reached 4.5 GWe. The Egyptian Government has estimated that demand for electricity will grow at an annual rate of 9.9 percent from 1975 to 2000–to 12 GWe by 1990 and 26 GWe 2000.” Egypt's leaders believe that there is a strong economic rationale for nuclear power, based on these projections.

Egyptian officials have plans to develop a system for monitoring electricity flows throughout the connected grid at the National Energy Center. When the center is complete, it will have the capacity to accommodate planned nuclear plants, as well as thermal and hydroelectric facilities.

Alternative energy sources may be insufficient to meet projected rise in demand. Much of Egypt's hydroelectric energy potential is already exploited by the Aswan High Dam (2,100 MWe) and the Aswan Low Dam (345 MWe). The only options for expansion of hydroelectricity include installing additional turbines at the Aswan Dam and constructing three low dams and four barrages (for a total of about 500 MWe).[63] In addition, pumped storage with a potential of 4,300 MWe capacity could be added at seven locations along the Nile.[64] Finally, the Qattara Depression Project,

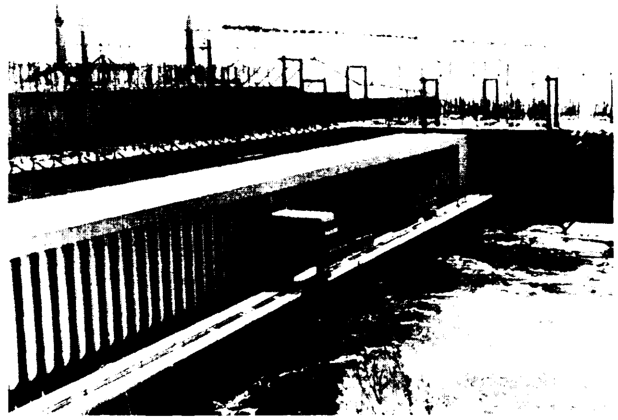


Photo credit: Agency for International Development

Aswan High Dam

which would involve excavating a canal and generating electricity from the flow of water from the Mediterranean into the depression, could produce 670 MWe by the year 2000.[65]

Solar energy and other alternative energy sources can contribute to Egypt energy supply in the years ahead. U.S. AID funding supports a project sponsored by the National Science Foundation on solar energy in the development of an Egyptian village, mentioned above. Nevertheless, while alternative energy sources appear promising for small-scale rural applications, costly large-scale solar programs involving technology now under development would be required to contribute significantly to electricity requirements.

Egypt has limited hydrocarbon reserves. Oil exports have been used for export earnings. Production increased from ***450,000*** barrels in 1977 to 775,000 in 1983. Oil will probably not be used to provide a large amount of new electricity production because it is the mainstay of Egyptian export earnings. Accounting for 37 percent of export revenues in 1978 and 65 percent in 1980, it made up a remarkable 70 percent in 1981. In addition, domestic consumption of oil at highly subsidized prices is increasing at about 12 to 15 percent annually. The nation's small coal reserves, estimated at 50 million tonnes, are to be used to replace

“Cited in U.S. Department of Energy, *Joint Egypt-U.S. Report*, vol. 1, op. cit., p. 42. The Egyptian Ministry of Electricity and Energy cites a total capacity of 4.7 GWe for 1980, in *Annual Report of Electric Statistics*, 1980, p. 8. For 1981-82, a figure of 5.0 GWe total electricity;' generating capacity is cited in Arab Republic of Egypt, *Electricity and Energy in the Arab Republic of Egypt, 1983*, p. 20.

[63]The three low dams could be located at Esna, Nag Hammadi, and Assiut. The four additional barrages could be located at Silsila, Qift, Sohag, and Deirot.

[64]One pump storage facility was under construction at Port Suez. K.E. A. F: ffat, H, Sirry, M, F. El-Fouly, E. El-Sharkawy, and A. F, El-Saiedi, *Projected Role of Nuclear Power in Egypt and Problems Encountered in Implementing the First Nuclear Plant* (Vienna: International Atomic Energy Agency, 1977).

[65]This project is being evaluated by the Swedish firm Sweco and is estimated to cost $1.2 billion, or approximately the amount Egypt plans to spend on its oil and natural gas program from 1982 to 1987.

coke in the Helwan Iron and Steel Works and to fuel a 1,200-MWe power station planned in the Sinai. Coal mines at Maghara in the Sinai are also being developed to fuel a 1,200-MWe powerplant at El Arish.

Egypt has 203 billion cubic meters of gas reserves, which are expected to increase substantially in the next 10 years. A substantial amount of gas could be utilized for electricity generation if the 88 percent of associated gas which is currently being flared were piped to and used in thermal power plants. However, Egypt's ability to use this natural gas is severely constrained by a lack of facilities to collect and transport the gas. If Egypt's total gas production in 1980 were dedicated to the generation of electricity, about 20 percent of electricity demand for that year could be met. The Egyptians intend to use this gas for other industrial purposes, especially steel production. Egypt situation thus contrasts sharply with that of other Middle Eastern countries where gas production is sufficient to meet all immediate and even near-term projected electrical generation needs. Gas, nevertheless, represents an important energy source, and additional gas-fired plants are planned for upper Egypt.

Even if all of the nonnuclear sources are utilized, if the Egyptian Government projected growth rates for electricity hold, nuclear power may be used to provide a substantial fraction of generating capacity. A joint U.S.-Egyptian study completed in 1979 concluded that 40 percent of Egyptian electricity could be generated by nuclear reactors by 2000.[66] Under high electricity growth rate "assumptions, Egypt could accommodate a 900-MWe reactor by 1990. Under low-growth assumptions, which appear more realistic, such a reactor could be installed and not make up more than 10 percent of the grid by 1995. Table 87 presents a summary of the range of projections

[66] U.S. Department of Energy, *Joint Egypt-U. S. Report,* op. cit.

Table 87.— Range of Projected Electricity Demand in Egypt

Author	1980	1985	1990	1995	2000
Shulli (1)					
Capacity (GWe)	4.460	—	8.815	—	15,480
Production (GWh)	15,518	23,338	34,424	47,847	61,744
Egan (2)					
Capacity (GWe)	4.595	7.36	10.103	13,392	16,769
World Bank (3)					
Capacity (GWe)	3,915	6.734	9.708	13.168	(17,870)a
Production (GWh)	18,430	28,350	39,770	55,780	(78,234)[a]
U.S. DOE (4)					
Capacity (GWe)	–	6.954	—	—	22.036
Production (GWh)	–	27,520	—	—	88,000

[a]Calculated using the same growth rate as the Previous period

NOTE Assumptions of Electricity Growth—Shulli: 1 By 2000 the gross domestic product (GDP) will be divided with 14 per cent from agriculture, 30 percent industry, 2 percent building, 12 percent transportation, 16 percent commerce and 26 percent services (In 1977 it was 29 percent agriculture, 25 percent Industry, 4 percent building, 7 percent transportation 13 percent commerce and 20 percent services), 2 Population growth will be 24 percent from 1980 to 1985 and 23 percent from 1986 to 2000, 3 GDP growth will be 82 percent from 1981 to 1985, 7 percent from 1986 to 1990.6 percent from 1991 to 1999, and 47 percent from 1996 to 2000, 4 Electrical consumption by 2000 will be divided, with industry requiring 56 percent, housing 21 percent; transportation, 8 percent agriculture 8 percent, and other, 6 per cent (1975 Industry, 49 percent, household, 20 percent transportation, 2 percent, agriculture, 8 percent, and other 21 percent) 5. Natural **gas will** provide 52 percent of electrical production by 2000, 6 Nuclear power wilt provide 2500 MWe by 2000

Egan: *Electricity growth assumptions 17* percent 1979-80; 9.2 percent, 1981-85.72 percent, 1986-9058 percent. 1991-95, 46 percent, 1996-2000,

World Bank: Electrical *growth assumptions* 11.4 percent 1980-85 75 percent 1985-90 63 percent 199195

U.S. DOE: 1 Electricity *consumption by the year 2000 will be* 54 percent industry 6 percent agriculture 7 percent transportation, 7 percent public utilities, 22 percent residential 4 percent other, 2 Electrical growth *assumptions* 1975-85127 percent, 1986.20008 percent

SOURCES 1) Abdul Rahman Shunt A , "Energy Consumption Forecast for Egypt and Sudan til the Year 2000 a paper presented at the Second Arab Energy Conference, Qatar, Mar 6, 1982, 2) Joseph R Egan, *Small* Reactors in Less Developing *Countries Historical Analysis and Preliminary Market Survey* (Westmont Ill ETA Engineering Inc , 1981) 3) World Bank, *Energy in the Developing Countries* (World Bank Paper August 1980), background {n formation prepared for the paper and energy **analyses 4)** U S Department of Energy, *Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment 5 vols* (Washington, D.C. U.S. Government Printing Off Ice, 1979) of Egyptian electricity demand. Even if Egyptian electricity demand rises at a low rate, it appears that the rationale for nuclear power may remain comparatively strong in Egypt. Lower oil prices, however, enhance the attractiveness of oil and reduce the ability of the Egyptian Government to finance these projects.

In the final analysis, the ability of Egypt to develop nuclear power depends on its ability to obtain subsidized financing. Indeed, it is precisely the reluctance of the U.S. Export-Import Bank and financing agencies in other Western supplier nations that has repeatedly delayed the project. As a result, U.S. and Japanese firms teamed up in 1983 to bid jointly. Practically speaking, the politics of export financing[67] may influence Egypt nuclear program more than the various energy-economic considerations mentioned above.

Iran's Prerevolutionary Nuclear Program

Iran's experience with nuclear power development prior to its revolution illustrates the susceptibility of a large nuclear program to being criticized as unsound for economic, political, and infrastructure reasons.[68] While the ambitious nuclear program initiated under the Shah was ended by the new revolutionary government, criticism of the program had already begun. Iran's nuclear program was viewed by critics as grandiose and wasteful, indicating that nuclear power development is a critical choice even for oil-rich developing countries.

Iran's 1974 program called for rapid construction of nuclear plants so that 23 reactors would generate 40 percent of the nation's electricity by 2000. The Atomic Energy Organization of Iran saw its budget grow from $30 million in 1975 to $1 billion in 1976. By the end of the 1970 's, the Shah's nuclear program came under direct attack by the revolutionary opposition on a number of grounds. Some criticisms focused on political factors. A small group of energy specialists and economists (from both the government and the university community) charged that a small group of foreign businessmen and advisors close to the Shah who were not competent to make technical judgments had spearheaded the nuclear program. The royal family, they said, had reaped huge commissions amounting to 20 percent of the total contracts, or several hundred million dollars per reactor.

Other criticisms, on economic grounds, highlighted the exorbitant cost overruns in the construction program. Construction costs on two planned French-built reactors grew 90 percent, interest payments included. Additional costs for consultants' fees, training, and installing reserve capacity and high-voltage transmission lines could have added several billion dollars to the cost of the first four reactors, according to some estimates. At a time when oil export revenues declined and budget trimming was required, the costs of the nuclear program became a problem, Construction by the West German firm Kraftwerk Union, however, progressed on two power reactors at Bushehr to the point where the steel dome was complete on one reactor and partially complete on the other when construction was interrupted after the revolution,

Part of the cost problem stemmed from Iran's underdeveloped infrastructure. With a shortage of reserve capacity and problems with brownouts, the additional reserve capacity to back up shutdowns of the 1,000-MWe reactors would have been extremely costly. In addition, critics worried that the Bushehr plants were not designed for a region with seismic activity. Furthermore, the water temperature and salinity of the Persian Gulf created additional design problems relating to cooling capacity and increased erosion.

Most important, perhaps, was the long distance from the Persian Gulf to the main centers of industrial electricity consumption and the inadequacy of the national grid. Enormous

[67] Italy reportedly promised to contribute 40 percent of the cost of building a nuclear power station. according to a protocol with Egypt signed in early 1984,

[68] This discussion of Iran debates about nuclear power is based on Bijan Mossarvar-Rahmani, *Energy Policy in Iran: Domestic Choices and International Implications* (New York: Pergarnon Press, 1981). p. 105.

costs to build high-voltage lines, and inevitable transmission losses, reduced the attractiveness of plants sited along the Persian Gulf when these factors were taken into consideration. The Ministry of Power, not the Atomic Energy Organization, was responsible for transmission lines. At the end of 1977, Tavanir, the company contracted by the Ministry of Power to build the transmission and distribution network, had not yet begun construction on the 400,000-volt lines to carry power from Bushehr to other parts of Iran.[69]

Despite statements by Iranian leaders, such as Rafsanjani in 1982, that Iran must promote "technical independence" and reinvigorate the Bushehr reactors, only limited budgetary allocations have been made under the revolutionary government to support these statements. The case for nuclear power in Iran has not rested on strong economic arguments in the past, nor is it likely to in the future.

The Iran-Iraq war may determine the future of the Bushehr reactors. Energy resources have been targets of Iraqi air strikes. If Iran's large hydroelectric Karun River and Dex plants were hit, the case for nuclear power might be stronger. On the other hand, the Bushehr plants might also be damaged. Most certainly any revived Iranian nuclear program would be smaller than that envisioned under the Shah. The West German firm Kraftwerk Union agreed in 1984 to conduct a feasibility study of the Bushehr site, but announced that it would not complete construction until the end of the war with Iraq.[70]

Other Nations

Prospects for nuclear power in Saudi Arabia are very uncertain. The nation has abundant oil and gas deposits, and large infrastructure projects have been scaled back in order to promote manpower development and completion of current projects. While estimates of installed electrical capacity differ widely, production of electricity has grown rapidly during the last decade. By 1985 the Saudi Arabian Government expects to have 12.4 GWe of installed capacity, not including considerable additional capacity of at least 4 GWe under the Saline Water Conversion Corporation.

Currently, there are three major disconnected load centers and several smaller disconnected regional centers. However, the Eastern Province alone has a large grid system with an installed capacity of approximately 3 GWe, and another 4 GWe under construction. (The 1980 installed capacity figure for Saudi Arabia in table 85 reflects this capacity.) Because most of this electricity in the Eastern Province is generated to desalinate water, it is possible that a nuclear reactor of 900 M We could be accommodated by 1990. However, no firm nuclear plans have been made in Saudi Arabia.

Algeria also has no firm plans for nuclear power. The nation has a grid that connects the main population centers along the Mediterranean coast. Algeria's primary near-term option for production of electricity rests on the use of its large natural gas reserves and large existing natural gas collection and distribution system. Algeria's production of natural gas in 1980, for example, could have generated five times as much electricity as was consumed during that year. Algeria could have 4.3 GWe of installed capacity by 1990 and 10 GWe by 2000; this would be sufficient to accommodate a 900-MWe reactor not exceeding 10 percent of the grid by 2000, but not before.

Given the current financial constraints facing Algeria, the availability of electricity generation from use of its abundant gas, and the results of preliminary studies by the IAEA and SONEGAZ which indicated that nuclear power was not an economic solution for generating electricity, it is not likely that Algeria will have an operating nuclear power reactor prior to 2000.

Kuwait has a relatively large electricity grid and could theoretically accommodate a 900 MWe reactor by 1990. Despite the fact that

[69] *Nucleonics* Week, Feb. 2, 1978, p. 10.

[70] It was reported in December 1983 that Kraftwerk Union had signed a contract to inspect the Bushehr site. See *Middle East Economic Digest,* Dec. 9, 1983, p. 12. Kraftwerk Union spokesmen reiterated intentions to delay resumption of construction until the end of the war in communication with OTA, May 1984.

a number of feasibility studies have been carried out, Kuwait has no definite plans for a nuclear power program. Anticipated declines in the historic rate of growth in electricity consumption and budgetary constraints indicate that Kuwait is not likely to have a power reactor until the mid-1990's, at the earliest.

For Iraq, even more than Iran, the Iran-Iraq War provides a strong constraint on nuclear power development. Iraq's grid is much less extensive. Faced with a severe fiscal crisis and planning uncertainty due to the war effort, it appears highly unlikely that Iraq will acquire a nuclear power reactor until the war is concluded or the level of conflict significantly reduced. In contrast to the situation in Iran, Iraq's gas resources are not sufficient to provide a large portion of electricity generation.

TECHNICAL MANPOWER CONSIDERATIONS: TECHNOLOGY ABSORPTION

For all the countries of the Middle East, lack of technical manpower is a major constraint on indigenous development of nuclear power. The dilemma for developing nations is that while nuclear power often is viewed as a means to reduce dependence on foreign supplies of energy, a nuclear program inevitably increases dependence on foreign suppliers for materials, equipment, technology, and skilled manpower.

IAEA has taken the position that a systematic program for developing requisite personnel, both engineers and technicians, must precede construction of nuclear powerplants. This approach implies a long lead-time, since qualified personnel are scarce in the Middle East. Developing countries likewise have emphasized building their indigenous nuclear technological base as a means to raise the general level of scientific and technological development.

An alternative approach is to have foreign contractors build complete turnkey plants. In this case, the vendor is fully responsible for design and construction of the facility, which is operated by the vendor or by an experienced foreign firm, such as Electricité de France (EdF), working in conjunction with the vendor. The turnkey approach normally involves a degree of technology transfer, even though the buyer's staff may participate in training programs to only a limited extent during construction work. Technicians continue on-the-job training when the plant is operating. Over time, more host country personnel are trained, partly in the vendor country and partly onsite.

In sectors such as national airlines and petroleum refining there is a precedent for such a turnkey approach in the Middle East. While some argue it may limit the training of indigenous personnel, others view it as a means to eliminate manpower as a constraint on nuclear power in developing nations. The indigenous approach is more costly in the shortrun—in terms of time and human resources—than the turnkey strategy. Over the long run, however, the developing nation that has invested in building a technical manpower base is in the best position to adapt and master advanced technologies.

The discussion that follows examines the technical manpower availability and political/administrative resources of Middle East nations. These factors, in addition to the choice of an indigenous or extended turnkey strategy, determine the ability of Middle Eastern countries to absorb or fully utilize nuclear technology.

Manpower Requirements for a Nuclear Program

The nuclear industry in Western nations involves an unusually high proportion of scientific, engineering and technical workers.[71] Few

[71]In 1975, 49 percent of the U.S. work force in the nuclear industry was made up of scientists, engineers, and technicians. See H. Miessner, ' 'Manpower- Sources for Nuclear Power Programmes," in International Atomic Energy Agency, *Manpower Requirements and Development for Nuclear Power Programmes: Proceedings of a Symposium, Saclay, April 1979* (Vienna: IAEA, 1980). Another source indicates that the occupational distribution for [J. S. nuclear powerplant workers in 197'7 included 17,4 percent engineer-s, 35 percent technicians, and 2.8 percent scientists, See J. S. Chewning, D. L. Couchman, and G. H. Katz, "Meeting the M anpower Challenge in the Transfer of Nuclear Technology\' to Developing Countries." in IAEA, *Nuclear Power and Its Fuel Cycle*, Proceedings of an International Conference, Salzburg, Austria, May 2-13, 1977, vol. 6, pp. 259-272.

countries in the Middle East have even a limited technical manpower base necessary to support a nuclear program. The exceptions are Egypt, Algeria, Iran, and Iraq–which have limited technical manpower pools.

In examining the technical base, two kinds of considerations are pertinent. One is the quantity and quality of scientists and engineers (high-level manpower), and the other is the quantity and quality of supervisors and skilled craft laborers (technical manpower). Many developing countries in other parts of the world have found that while their scientific base is limited but adequate to support nuclear programs, the scarcity of administrative, technical and craft labor places significant constraints on the operation and maintenance of nuclear powerplants.

Leaving aside for a moment the issue of scientists and engineers, the requirements for technical laborers and supervisors are particularly great during construction of a nuclear powerplant. Construction of one 600-to 1,200-MWe light-water reactor requires 12 million to 15 million man-hours, including 10 million to 12 million man-hours of skilled labor such as welders, electricians, operating engineers, and quality control specialists. Iran imported the required manpower from the supplier country for its nuclear power construction program. There, the vendor, Kraftwerk Union, brought in most of the skilled labor and practically all of the managerial personnel from West Germany.

The bulk of technical labor requirements come during the 5 years before the start of commercial operations. For a plant of 600 to 1,300-MWe capacity, a peak work force of about 5,000 is required for plant construction and manufacture of equipment and components. Utility officials experienced in nuclear powerplant construction in developing countries conclude that first-level supervisors who have 5 to 20 years of experience are particularly important during the construction phase. In the view of U.S. officials working in an international division of a major vendor company:

> An adequate craft labor force is not a controlling factor in developing countries becoming self-sufficient, but the development of an adequate first-line supervision is. The needed skilled labor can be drawn from existing resources or by recruiting and training the available and often highly motivated resources. Single skills are quickly and readily acquired, [However,] experience has shown that nuclear power plant construction requires a significantly larger ratio of first-level supervisors to craft than is needed on other heavy construction projects.[72]

After the plant is built, about 300 to 400 workers may be needed to operate it, depending on the type of reactor.[73] IAEA spokesmen emphasize that developing nations often underestimate the requirements for highly skilled manpower needed to ensure safety and reliability in nuclear plant operations. Even for turnkey plants, there is a need for a "core of indigenous qualified manpower from the beginning of the planning for a nuclear power project. "[74] In addition to requirements for scientists and engineers, about one-quarter of the operating personnel require specialized training specific to nuclear plants in areas such as radiation protection, nuclear chemistry, and operations.

The types of other personnel required are similar to those needed for an oil-fired plant, but the general capabilty of all technicians, especially the maintenance personnel, must be higher in order to ensure safety and reliability of operations. In most developing countries, additional personnel must be trained to allow for back-up and attrition, meaning that the first powerplant may demand twice as many technical personnel as a conventional power-

[72]David R. Zaccari, Francois R. Martel, and Eric L. Westberg, "Establishing a Nuclear Program: Some Perspectives, " a paper presented at Montevideo, Uruguay, May 12, 1980.

[73]When offsite personnel are taken into account, 600 to 900 personnel may be required to operate a nuclear plant in the United States. The Connecticut Yankee 580-MWe pressurized-water reactor in 1981 had a staff of 387 onsite and 187 off site personnel. See Lelan F. Sillin, "Management Initiatives–Manpower, " Chief Executive Workshop, Institute of Nuclear Power Operations (INPO), Sept. 1, 1981.

[74]F. Mautner-Markhof, "Manpower Development for Nuclear Power, " in *Manpower Requirements,* op. cit., p. 359.

plant of the same size. Many of those in the specialized technical category must be grounded in the basics of engineering, including computer science, while those in the second category can often be trained on the job.

The importance of supervisory and skilled craft labor to the operation of a nuclear powerplant cannot be overemphasized. South Korea, for example, found that it had the core group of nuclear physicists needed for scientific research but lacked the welders and specialized technicians needed to build reactors. Major suppliers of reactors provide training as well as services to deal with special problems as they occur in the operation of a reactor. In a typical reactor sale, training is provided during the 6- or 7-year period between the signing of the contract and the startup of a turnkey facility.

During this period, a large number of people are trained in a wide range of skills, from graduate engineer to nondegree-holding operators. Westinghouse, for example, typically brings hundreds of local engineers who must be fluent in English to the United States for training, While the recipient may purchase simulators at a cost of $7 million to $10 million to train personnel in the host country, it is generally believed that a country should have more than one power reactor in operation to justify such an investment.

Eventually, such training programs may evolve into a means for more extensive technology transfer. Recipients wishing to acquire the ability to design and fabricate equipment and construct facilities may seek to purchase the technology itself. If the supplier agrees, licensing agreements could be worked out with the respective nuclear organizations in the host countries, and design groups from the host country might work alongside supplier firm personnel in the United States. This level of technology transfer normally occurs only after the recipient has built up considerable experience in operations and maintenance.

Based on experience in the United States, once a nuclear powerplant is built, most of the operating staff have practical training and experience but not necessarily a professional scientific education. While a developing country may have a relatively large pool of technical labor, operating and maintaining a nuclear plant requires considerable additional training in specialized areas such as health and safety, instrument calibration and repair, quality assurance, and nuclear records. As noted earlier, at least a quarter of the technical work force require specialized training in an engineering-based curriculum.

Requirements for back-up staff, and the need to bring together individuals who can work together as a team, mean that relying on indigenous labor would be viable for Middle Eastern nations only over a long-term period. All the Islamic nations of the Middle East that seek to develop nuclear power will have to depend on foreign vendors for a considerable period of time after startup of facilities for training of personnel, spare parts, and repair. Egypt's decision to purchase its first nuclear reactors on a turnkey basis reflects a recognition that it would now be impossible to construct and operate such a facility with only indigenous personnel.

Operating a nuclear power reactor does not require a pool of research scientists trained in fields such as nuclear physics.[75] However, scientists and engineers are needed to run the regulatory and planning organizations that administer nuclear programs in developing nations. In addition, without a scientific and engineering research sector, it is unlikely that a developing nation would be able to surmount the turnkey stage of comparatively low-level nuclear technology transfer and move into independent large-scale design and fabrication of equipment, including both commercial and military applications.

Because nuclear programs require long lead-times, and because they imply a trend toward electricity-based industrialization, the ability of highly trained scientists and engineers to

[75]See Ian Smart. "The Consideration of Nuclear Power, " in James Evert Katz and Onkar S. Marwah, *Nuclear Power in Developing Countries: An Analysis of Decision-Making* (Lexington, Mass,: Lexington Books, 1982), p. 152.

work with political leaders in establishing nuclear program stability and continuity is a key requirement for developing nations. It is not enough that a country possess a large pool of academic research scientists: even more critical are individuals with specialized advanced education who can act as planners and managers. The highly trained scientists and engineers play key roles in assuring the political/administrative success of nuclear programs.

Middle Eastern Nations With Comparatively Large Technical infrastructures

In contrast to Israel, the nations of the Islamic Middle East have limited technical manpower infrastructures. Israeli scientists, engineers, and technicians are among the best in the world, and Israel has the technical capability to support the most advanced nuclear technologies. Israel, then, is in a situation completely different from the countries of the Islamic Middle East.

Egypt.–Of all the Islamic nations in the Middle East, Egypt has the largest pool of scientists and engineers. The Egyptian Atomic Energy Establishment was formed in 1955, almost three decades ago. Even so, a lack of appropriately trained technicians precludes the possibility of Egypt developing commercial nuclear power on its own for some time. Egypt's experience is especially significant, since other nations in the region face even more severe manpower problems.

The 2,000 Egyptians at the nation's nuclear research center are far fewer than the 18,000 people included in the scientific and technical staff of the Indian Department of Atomic Energy.[76] It has been estimated that Egypt has almost 1,000 nuclear physicists with doctor's or master's degrees.[77] In 1980, the Inshas Nuclear Research Center employed approximately 2,200 people, including 500 physicists and engineers, 200 of whom held doctorates.[78] However, these scientists have been criticized for their strong academic orientation by those who would prefer that they contribute more directly to the establishment of a nuclear power program.

The Egyptian nuclear scientific community is neither well-integrated nor supported with financial resources adequate for the large nuclear program envisaged. Faced with a lack of adequate research facilities, Egyptian scientists have been forced to accept teaching positions in Egyptian or other Arab universities. The Minister of Electricity called on those scientists working abroad to return home to take part in the nuclear program, but apparently few have done so.[79]

Major decisions about nuclear power in Egypt have been taken at the highest political levels. The Higher Council for Nuclear Energy (HCNE), formed in 1975, is the formal decisionmaking body, composed primarily of politicians. President Sadat himself, in consultation with the HCNE, made the decision in 1975 to pursue a commercial nuclear power program. Critics of the program, however, include university professors and politicians from opposition parties such as the Socialist Labor Party.[80] Three state corporations possess the major responsibilities for carrying out the program, but they have been periodically reorganized, and the advice of the technical experts in these agencies has not always been heeded by politicians in making decisions. Some observers say that the Egyptian Atomic Energy Corporation, one of these three, was not fully consulted about a plan to store Austrian nuclear waste in Egypt, which was later abandoned.[81]

On rare but significant occasions, such as the opposition of people in the Alexandria area

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[76] See Richard P. Cronin, "Prospects for Nuclear Proliferation in South Asia, *The Middle East Journal, vol. 37, No. 4,* autumn, 1983, p. 597, for figures on Indian personnel.

[77] Mohammad El-Sayed Selim, "Egypt," in Katz and Marwah, op. cit., p. 152.

[78] Louise Lief, "Egypt Reviews its Stance as MidEast Nuclear Arms Swell, " *Christian Science Monitor,* Aug. 18, 1980. See also U.S. DOE, *Joint Egypt-United States,* vol. *5,* op. cit., p. *17.*

[79] *See* Selim, op. cit., p. 153 and Abdel-Gawad Sayed, "The Reality of the Arab Nuclear Capability, " *Al-Mustabkbal Al-Arabi,* January 1980, p. 162, (translated and quoted in Selim).

[80] Ibid., p. 148.

[81] Ibid., p. 147.

to proposed local siting of a nuclear plant, nuclear policy choices have become matters of public debate. In that case, President Sadat himself ordered suspension of siting plans after the Alexandria council passed a resolution rejecting the plant. In Egypt, where professional engineering and scientific authority has long been politically suspect, scientists and engineers have played a much less important role in giving technical advice than their numbers might suggest.[82]

Iran.– In comparison to Egypt, other Middle Eastern countries face even more severe constraints on nuclear technology transfer by virtue of their small technical manpower pools. In Iran, where the Institute of Nuclear Science was established in Teheran in 1958, it is doubtful that the revolutionary government will be able to launch a new nuclear program based on "indigenous technical expertise, " as the head of the Isfahan Nuclear Technology Center has advocated.[83] Owing to political, social, and economic dislocations of the revolution and the war with Iraq, a revised Iranian nuclear program would have to start off with only a fraction of the prerevolutionary technical base.

In the 1970's, hundreds of Iranian students were trained in the United States and Europe in nuclear-related fields, but many of these technicians and scientists fled from Iran during the revolution. The revolutionary government has passed legislation encouraging them to return, offering the incentive that their property holdings will be guaranteed. However, there is no evidence that this group has returned. Iran's technical manpower base is thus currently weaker than it was prior to the revolution. Therefore, despite recent indications that Iran's leaders have begun to consider completing the Bushehr power reactors, it appears that inadequate local manpower will remain a constraint, particularly if Iran should emphasize a program based on independent development of nuclear power.

Iraq.—Iraq has committed itself to a nuclear research program and has acquired a number of operating research reactors and a laboratory-scale reprocessing facility. It is impossible to gauge precisely the number of Iraqi nuclear scientists and engineers, but they number far fewer than those in Egypt. Currently, education and training in nuclear fields is limited to undergraduate studies in Iraq, and for the foreseeable future Iraq will depend on foreign countries such as France and Italy for training.

Italy agreed to train 100 Iraqis in the fuel cycle labs they provided, and the French agreed to set up a "nuclear university' at Tuwaitha to train 600 scientists and technicians. While information concerning the quality of current programs is not available, these assistance programs have not been officially discontinued in the post-Osirak period. The combined impacts of the Iran-Iraq War and Saddam Hussein's imprisonment of members of the nuclear community have resulted in a setback to the nation's nuclear program.[84]

Iraq, through a technical cooperation agreement with Brazil, is acquiring training, uranium exploration technology, and engineering services. Because Brazil is not a signatory to the NPT and the country has received nuclear technology from West Germany, West Germany negotiated a bilateral nonproliferation provision with Brazil which extended safeguards over West German technology retransferred by Brazil. While it appears that Brazil did not transfer any West German know-how, Brazil's position as an importer of Iraqi oil raised concerns about the possibility that Iraq might receive sensitive technologies from Brazil not covered in the Brazil-West Germany accords.[85]

[82]For a discussion of the limited role technical advisors played in the decision to build the Aswan Dam see Clement Henry Moore, "The Politics of Technical Consultation, " *Images of Development: Egyptian Engineers in Search of Industry* (Cambridge, Mass.: MIT Press, 1980), pp. 156-165.

[83]See "Es sfahan Nuclear Technology Center Reactivated, " reported in JPRS, *Nuclear Development and Proliferation, No.* 138, Apr. 14, 1982, pp. 26-27.

[84]See [J. S. Congress, Senate, *Analysis of Six Issues About Nuclear Capabilities of India, Iraq, Libya and Pakistan* (Washington, 1). ('.: U.S. Government Printing office, 1982); and *New Scientist*, Aug. 28, 1980), p. 635. See also Richard Wilson, op. cit., for a report on a visit to Tuwaitha in early 1983.

[85]See "Brazil and Iraq Signed a Nuclear Cooperation Agreemerit, " *Nucleonics Week*, vol. 21, Jan. 17, 1980, p. 10.

Other nations such as West Germany and Sweden have agreements with Iraq that include training; however, it appears that far fewer Iraqi students have studied nuclear engineering in Western countries than have Egyptians and Iranians. In 1981-82, for example, the Institute for International Education Survey showed that five Iraqi students were studying nuclear engineering in U.S. universities, four at the graduate level.[86] Iraq's cooperative agreements with the Soviet Union are still valid, and the number of Iraqis trained in the Soviet Union is considered to be significant.

Algeria. -In Algeria a nuclear research organization was set up in the mid-1960's, and education in physics, chemistry, and nuclear engineering is available through the undergraduate level. Algeria's Center for Nuclear Technology and Science (CNST) is developing a broad-based nuclear science research program that provides Algeria with the fourth largest pool of nuclear manpower in the Middle East. The center has research divisions working on uranium ore processing, fuel fabrication, reactor engineering, nuclear physics, applied nuclear research, and health physics. It employs 170 scientists and has a total staff of 500. CSTN spends an estimated $9 million annually and operates two Van de Graaf accelerators (3 Mev and 2 Mev).[87]

Algeria has tentative plans to build a nuclear research center at Ain Oussera, but no announced plans to expand graduate-level education at the new technical universities that are to be built. As a result, most advanced training in nuclear fields takes place outside Algeria, in Western nations. The nation has technical cooperation agreements with Belgium, Brazil, and France.

In years past, the Soviet Union provided some limited nuclear assistance, but there is no indication that significant cooperation still occurs. Given the extreme limitations to training programs for advanced technicians and the absence of a formal decision by Algeria to emphasize nuclear technology acquisition, it appears that Algeria might develop the manpower 'base required to operate nuclear reactors built on a turnkey basis and the skills needed to support limited uranium mining-all by the turn of the century. However, advanced training will entail foreign study for the next 20 years.

Limited Technical Infrastructures in Other Middle East Nations.–In contrast to Egypt, Iran, Iraq, and Algeria where a small technical infrastructure exists, Libya and other Middle Eastern nations have much more limited technical manpower bases. In Libya, despite a high-level political decision to acquire nuclear technology, mixed results have been achieved-owing primarily to the reluctance of foreign suppliers to involve themselves and to Libya's comparatively late start in the early 1970's. Unable to acquire technology from many Western nations, Libya has relied primarily on the Soviet Union and Belgium.

The Tagiura Nuclear Center near Tripoli was built with Soviet assistance and a 10-MWt research reactor, fueled with approximately 3 kg of 80 percent enriched uranium, was provided. This reactor went critical in late 1981 or early 1982, but reportedly experienced some start-up difficulties.[88] Libya has received assistance from the Belgian firms Union Mirac and Belgonucleaire for uranium exploration and fuel fabrication. It is also negotiating with the Soviet Union for a 440-MWe reactor, which would probably be imported on a turnkey basis using skilled labor from Bulgaria and Yugoslavia. As mentioned earlier, a Belgian firm may participate in the power reactor project .[89] Given its lack of facilities for advanced study in nuclear fields, Libya will be dependent on study programs abroad, particularly in Eastern bloc nations, for many years to come.

'Institute of International Education, "Detailed Cluster Report on Nuclear Engineering, ' correspondence, Feb. 1, 1983.

[87]See "Cooperation is the Key to Arab Nuclear Development, " *Nuclear Engineering International,* January 1982, p. 14. See also, papers by Adnan Mustafa and Adnan Shihab-Eldin for the Second Arab Energy Conference, Doha, Qatar, Mar. 6, 1982.

[88]See Zivia Wurtele, Gregory S. Jones, Beverly C. Rowen, and Marcy Agmon, *Nuclear Proliferation Prospects for the Middle East and South Asia* (Marina Del Ray, Calif.: Pan Heuristics, 1981).

[89]Robin Miller, "Nuclear Plans Outlined, " *Jamahiriyah Review, No. 22,* March 1982, p. 17. See footnote 9.

This discussion underscores the weakness of the nuclear technical manpower base in the Islamic nations of the Middle East. All of them, except Iran under the revolutionary government, have publicly committed themselves to a strategy of near-term reliance on foreign suppliers rather than attempting a purely "indigenous" route. (And in Iran it is doubtful that the rhetoric can be translated into practice.) Because of their limited technical infrastructures, none of these nations can construct, fuel, operate and maintain nuclear powerplants without considerable foreign assistance at this stage.

Bilateral Nuclear Cooperation

Nuclear technology transfer, particularly the training component, has occurred most often in a bilateral context. Normally, governments establish bilateral nuclear cooperation agreements that open the door for commercial sales and training programs. The United States has established bilateral agreements for nuclear cooperation with a number of Middle Eastern nations. A bilateral agreement was signed with Iran in 1957, and a revised agreement was negotiated but not signed prior to the revolution in Iran. The United States provided technical assistance though its Atoms for Peace Program.

Under that program, a total of about 230 people from Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, and Saudi Arabia were trained. More than half were Egyptians, and the total number of trainees was far smaller than that for countries such as India (1,104) or Taiwan (713).90 The United States has a few programs in the nuclear field with Israel; the Nuclear Regulatory Commission (NRC) has a 5-year agreement to exchange nuclear safety and environmental information with Israel. [91]

The most important bilateral agreement in the nuclear field with any country in the Islamic Middle East is the one with Egypt. In 1981, the United States and Egypt signed a full nuclear cooperation agreement that contains strict provisions concerning controls and safeguards. Programs sponsored under this agreement have included special attention to safety issues. Egypt's decision to ratify the NPT and its willingness to accept bilateral controls opened the way for more extensive technology transfers. The bilateral agreement between the United States and Egypt has thus contributed to U.S. nonproliferation policies.

Many other supplier nations have also established nuclear cooperation agreements with Middle East nations. Bilateral cooperation agreements provide the assisting nation with a measure of influence over the nuclear program of the recipient in exchange for helping the recipient develop indigenous technical capabilities. The inability of the U.S. Export-Import Bank to finance Egyptian reactor sales is seen by some as evidence that cooperation is limited, posing a significant problem for Egypt's leadership."

Middle Eastern Students in the United States

As discussed in chapter 13, foreign student enrollment in U.S. educational institutions may be an important channel for technology transfer. To date, comparatively few Middle Eastern students have been enrolled in technical fields, but this pattern is likely to change as those students who first came to the United States in the late 1970's begin to consider advanced graduate training.

An increasing number of engineering graduates from the 30 U.S. institutions which offer degree programs in science and engineering are foreign nationals. The Federal Government has not collected data on the exact numbers of Middle Eastern students by fields of study enrolled in such U.S. programs, but of the almost 62,000 foreign nationals who received science and engineering doctorates between 1960 and 1981, there were 1,600 Ira-

[90]See U.S. Congress, Joint Committee on Atomic Energy, *S. 1439: Export Reorganization Act of 1976,* hearings, 94th Cong., 2d sess.; Mautner-Markoff, op. cit.

"U.S. Congress, Committee on Science and Technology, *Science, Technology and American Diplomacy* (Washington, D. C.: U.S. Government Printing Office, 1982), p. 174.

"See G. Henry M. Schuler, "Will Egypt Be Denied its 'Peace Dividend?' " *American-Arab Affairs, No. 7.* winter 1983-84.

nians, 500 Iraqis, and almost 1,400 Egyptians. About one-third of these degrees were awarded during 1960-81 in engineering, of which about 1,000 were awarded to students from Iran, Iraq, and Egypt. These numbers are far smaller than the numbers of students from the East Asian region (about 15,000) who earned similar degrees during the period.[93]

In 1981 alone, 189 Iranians, 26 Iraqis, and 77 Egyptians were awarded doctorates in all science and engineering fields from U.S. institutions. In the more specialized fields of nuclear engineering and physics, fewer Middle Eastern students received degrees. Table 88 shows numbers of doctoral degree recipients from these nations for 1981. Middle Eastern students make up only a very small percentage of student enrollment and doctoral recipients in science and engineering. According to data collected by the Institute for International Education, during 1981-82 there were about 20 Middle Eastern students enrolled in nuclear engineering programs.[94] These data are inadequate indicators of Middle Eastern study in technical fields, however, because a doctorate is not a prerequisite for an engineer to function effectively in most developing country projects.

The small number of Middle Eastern students enrolled in and receiving Ph.D. in technical fields contrasts sharply with enrollments in all programs. In 1981-82, 326,300 foreign students were enrolled in various programs of education in the United States. Among this group, 74,390 students were from the Middle East. The largest number (35,860) were from Iran, followed by 10,220 from Saudi Arabia, 6,800 from Lebanon, 6,180 from Jordan, and 3,330 from Kuwait.[95] The enrollment of foreign students from the Middle East grew very rapidly during the 1970's. However, only a small number of these students were studying subjects such as nuclear engineering. With the exception of Iran under the Shah, there is little evidence of a directed effort by any Middle Eastern nation to train a large number of students in nuclear engineering or in related disciplines in the United States.

In 1983, the Reagan administration issued an order forbidding Libyan students to study nuclear engineering or aviation in the United States. However, officials in the State Department and the Immigration and Naturalization Service were unable to verify estimates that 2,000 students from Libya were actually enrolled in all U.S. programs, much less how many were pursuing studies in nuclear engineering or civil aviation. In August 1983, deportation hearings began for nine Libyan students whose visas had expired.[96] The only other instance of such restrictions on foreign students from the Middle East occurred during the time of the hostage crisis, when an investigation was conducted to verify the legal status of Iranian students studying in the United States.

Nuclear technology transfer also occurs through the IAEA. U.S. contributions totaling $5 million in 1981 supported the IAEA's Program for Technical Assistance for Safeguards. This organization carries out training programs in nuclear manpower development in a variety of fields. The organization estimates that its programs have trained about 40 percent of the personnel needed by developing countries.[97] During the 4-year period 1975-78, fewer than 100 people from the Middle East were trained in IAEA programs, with the largest numbers coming from Egypt (23) and Iran (27).

IAEA has forecast that no Middle Eastern nation will attain the highest stage of capability ("self-sufficiency") in nuclear technology by the year 2000. Also, even under extremely optimistic assumptions concerning growth in nuclear power, only Egypt and Iran might at-

[93]National Science Foundation, *Science and Engineering Doctorates: 1960-81*, NSF 83-309, p. 68.

[94]Data provided by the Institute for International Education, January 1983.

[95]Institute of International Education, *Open Doors: 198182* (New York: IIE, 1983), p. 18.

[96]"Libyan Students Held as Risks Freed on Bail; Deportation is Expected," *New York Times*, Aug. 14, 1983.

[97]S. B. Hammon, and M. A. Kanter, "Nuclear Power: Project Training for Engineers from Developing Countries, *Engineering Education*, January 1982, p. 316.

Table 88.—Middle Eastern Students Receiving Doctorates in Technical Fields in the United States, 1981

Country of origin	Ph.D.s engineering	Physics and astronomy
Iran	74	13
Iraq	4	1
Jordan	8	1
Kuwait	3	0
Lebanon	8	2
Saudi Arabia	15	0
Syria	1	1
Algeria	4	0
Egypt	41	1
Libya	5	1
Total Middle East	163	20
Total non-U S, citizens	1,241	715
Taiwan	201	37

NOTE It is difficult to determine where these students will go after receiving their degrees data is collected well before graduation. Out of 13 students receiving Ph.D.s in physics and astronomy for example 3 planned to stay in the United States 2 planned to return to West Asia and 8 had not made plans when the survey was taken

SOURCE Data provided by the National Science Foundation August 1983

tain the level of a "confirmed" program with two or more plants in operation.[98] While many of these countries are developing nuclear research programs, the quality of these programs varies, and only Egypt and Algeria have established programs that could be considered indigenously based. Given these factors, it appears highly unlikely that any of these Islamic Middle Eastern nations except Egypt will be a position to undertake a reactor project indigenously before the turn of the century, unless there are dramatic shifts in policy.

[98] B.J. Csik, "Manpower Requirements for Nuclear Power in Developing Countries," in IAEA, *Manpower Requirements*, op. cit., p. 18.

MILITARY APPLICATIONS CONSIDERATIONS

The Middle East is generally viewed as a part of the world where nuclear weapons would be particularly dangerous because of its history of political turbulence and conflict. Tension exists not only between Israel and its Arab neighbors, but also between other states in the region (Iran and Iraq, Egypt and Libya) and within states. The introduction of nuclear weapons could affect the region's balance of power. Moreover, the Middle East is strategically important to the superpowers, whose interests would be affected by the spread of nuclear weapons in the region. U.S. ability to influence events there could be substantially reduced if weapons proliferation reduced the willingness of nations in the region to cooperate with the United States or to exercise restraint in their military programs.

It seems unlikely that nuclear proliferation in the Middle East would be a stabilizing influence. Arguments about stabilization have been based on the assumption that some states would have a second-strike capability, but the possibility that any country in the region except Israel could develop such a capability in the next 20 years appears remote. In addition, given Israel's stated intention not to allow any states in the region to develop a nuclear explosives capability-and its destruction of Iraq's Osirak reactor—the spread of nuclear weapons is almost certain to elicit response by major states in the region.

The analysis that follows leads to the conclusion that because of shortages of skilled manpower and the restrictive export polices of supplier nations, most Middle Eastern nations will be unable by themselves to construct nuclear weapons until well into the next century. Nevertheless, political variables will strongly influence the course of nuclear proliferation in the region. If one nation were to demonstrate its ability to use a nuclear device, other nations might try to catch up. Similarly, if supplier nations (including countries such as India and Argentina that are likely to emerge as suppliers) loosened restrictions on nuclear exports, proliferation would become more likely.

Intentions

While a host of technological, manpower, and financing considerations affect the spread of nuclear weapons, political considerations are paramount. Political factors that stimulate proliferation include the perception that Israel has the technical capability to produce nuclear weapons in a short period of time. It is likely that, barring a lasting peace settlement, the major motivation for weapons acquisition by other countries in the region will be as a deterrent to Israel.

A second factor involves concern that a country's weapons capability is on a par with that of other Islamic countries in the region. Syria's increased interest in nuclear technology may, for example, be due in part to concern about Iraq's program. If Libya acquires a militarily significant nuclear weapons capability, Egypt might reevaluate the direction of its nuclear program.

Nuclear cooperation among nations in the region could, under certain conditions, accelerate weapons proliferation. Reported contributions by Middle Eastern nations to Pakistan's nuclear program could be motivated by a desire to obtain nuclear technology or by the wish to ensure that the other contributors will not obtain an advantage. Overt proliferation by any state in the region would undoubtedly stimulate activity by others. Finally, if the export policies of supplier nations (including smaller nuclear states likely to become suppliers) become more lenient, the incentives for weapons acquisition will increase.

Pace and Nature of Nuclear Proliferation in the Middle East

Despite incentives for weapons acquisition, overt proliferation has not occurred. Inhibiting political factors include safeguards and the reluctance of major supplier states to provide sensitive technologies. The perceived fear of the consequences of weapons proliferation, especially for small states and those dependent on geographically clustered industrial or oil facilities, has most certainly acted to limit nuclear weapons acquisition.

Another major factor limiting nuclear weapons programs has been the domestic politics of Middle Eastern nations: political leadership has not been strong enough to sustain steady development of commercial nuclear programs, much less to launch highly focused crash weapons programs. Nevertheless, the persistence of deep and costly conflicts such as the Iran-Iraq War might propel leaders to attempt to steal or fabricate unsophisticated nuclear weapons.

While the existing nuclear weapons states developed their weapons in programs dedicated wholly or substantially to military purposes, and while these nations proved their capability through testing, it appears that latent proliferation in conjunction with small research-scale facilities is the most likely path for nations in the region. (Indeed, Israel's assumed capability is based on comparatively small-scale facilities.) This is the case because, as mentioned earlier, most of these countries are not likely to acquire commercial-scale sensitive facilties and because of the nonproliferation controls of supplier nations.

While it is theoretically possible for a state to purchase nuclear-grade graphite or heavy water and attempt to design and build its own plutonium production reactor and a facility for extracting the plutonium, such a project would be difficult for nations with such weak technical infrastructures. In addition, a weapons program that includes facilities such as those listed above would involve substantial importation of equipment and, for all nations except Egypt, of technical personnel; it would be apparent to outside observers that a program was under way.

Given these factors, the most worrisome path to weapons capability is the acquisition of small-scale fuel cycle facilities that can be rationalized, more or less reasonably, as logical components of an orderly long-term effort to develop a broad capability for using nuclear power.

India represents an extreme example of this path. Some of its power reactors are safeguarded, but not all. India acquired unsafeguarded research and materials-testing reactors, pilot-scale reprocessing plants, and heavy-water production facilities in the 1960's, with substantial assistance from foreign companies and governments. Buying these facilities probably cost considerably less than would have construction of commercial-scale plants. A program of this type, using research reactors, could be comparatively inexpensive—on the order of $300 million.[99]

Libya.—Among the Islamic nations of the Middle East, only Libya has made an overt effort to acquire nuclear weapons, although there is strong circumstantial evidence that Iraq has attempted to equip itself with necessary facilities. If these nations are categorized as those with "high intentions, most of the Islamic Middle Eastern nations should be viewed as having medium or low intentions, based on nuclear technology trade patterns and policy positions.

Despite Libya's well-advertised intentions to acquire nuclear explosives and its willingness to use oil money to purchase any type of nuclear technology possible, its nuclear ambitions are severely limited by the weakness of its technical manpower base and lack of coherent planning and research programs. As a result, it is unlikely that Libya will be able to achieve nuclear independence at India's level for 30 years,

Libya's overt designs on nuclear weapons have made supplier nations reluctant to sell, Colonel Qaddafi's request for sensitive nuclear technology, and worldwide concern over Libyan-Pakistani nuclear cooperation, prompted the French government of Giscard d'Estaing to cancel an agreement to sell Libya a 600-MWe reactor in 1975. Libya also failed in its attempt to obtain "tactical' nuclear weapons from China in the early 1970's and to acquire Indian nuclear explosives and production technology in the latter part of the decade.

[99] Vari~~s estimates have been made of the cost of moving to the first nuclear bomb test for a nation with no reactor or nuclear base. These estimates are reviewed in Gordon W. Smith and Ronald Soglio, "Economic Development and Nuclear Proliferation: An Overview, " in Dagobert L. Brito, Michael D. Intriligator, and Adele W. Wilk, *Strategies for Managing Nuclear Proliferation* (Lexington, Mass.: Lexington Books, 1983), pp. 75-76. The authors conclude that the economic costs are less a constraint than the ''policy costs' to less-developed countries of moderate income and population which are determined to acquire nuclear weapons.

Through financial assistance to Pakistan, Libya attempted to obtain sensitive nuclear technology, but relations between the two nations cooled after the fall of Prime Minister Bhutto and under pressure from the United States.

Of greatest current concern are reports that Niger has sold at least 788 tons of uranium to Libya, some of which may have been shipped to Pakistan, thus circumventing IAEA safeguards.[100] These sales apparently were ended in 1981, but the transactions raise a number of problems. The uranium could be stockpiled for use in an undeclared facility located either in Libya or abroad. Currently, Libya's ability to acquire sensitive nuclear technology depends to a great extent on the policies of the Soviet Union. If Soviet exports become less restrictive or new suppliers enter the market, Libya's ability to acquire technology might increase. However, it is striking that the Middle Eastern nation most committed to a nuclear weapons path has been so unsuccessful in acquiring sensitive technology.

Iraq.–The case of Iraq illustrates many of the difficulties in assessing the proliferation potential of individual nations. Although Israel justified destroying the Iraqi Osirak reactor in 1981 on the grounds that " . . . it is intended, despite the camouflage, to create atomic bombs, " U.S. Government officials stated that the U.S. intelligence community had not firmly concluded that Iraq was, in fact, planning to build a weapon.[101]

Public attention has focused on the possibility that Iraq was pursuing a "quick-fix" rapid weapons building effort, when it appears more likely that the primary thrust of Iraq's program was to acquire nuclear facilities and experience needed to produce nuclear weapons some years down the line after expiration of its bilateral accords with the French. The covert and latent nature of the proliferation potential of Iraq underscores the importance of examining the long-term implications of technical infrastructure building.

At the heart of debates about Iraq's ability to produce a nuclear weapon are questions of the effectiveness of safeguards. Because Iraq is a party to the NPT, concern about potential Iraqi nuclear weapons proliferation has highlighted uncertainties about the coverage of safguards, Iraq's record of nuclear technology acquisition has led many to question whether a nation might pursue a weapons program while publicly adhering to the NPT, and later abrogate the NPT when it is convenient to do so.

Evaluation of Iraq's future ability to produce nuclear explosives requires an examination of the proliferation scenarios considered credible prior to the bombing of the Iraqi reactor. One scenario involved Iraq acquiring sufficient highly enriched uranium (HEU) to make a bomb. Using the IAEA definition of a "significant quantity" of uranium needed for a nuclear weapon, Iraq would have had to obtain 25 kg of HEU in order to construct a nuclear device. Concern focused on the HEU supplied to Iraq for its two research reactors. France initially agreed to supply 70 kg of 93 percent HEU. HEU of this type could have been used directly in the production of nuclear weapons. This amount would have been sufficient for production of several nuclear devices, but IAEA safeguards and the presence of French technicians onsite would have made diversion difficult, though not impossible.

Debates ensued within the French Government about whether caramel, or low enriched uranium, should be supplied as a substitute. Such uranium would have to have been further enriched in order to produce HEU. Ultimately, Iraq rejected this caramel option and the French decided on a compromise plan that involved shipments of HEU in consignments of about 12 kg, sufficient for a core-loading reactor but insufficient for weapons manufac-

[100] It is not clear whether shipments planned for 1981 were completed. If they were, the total shipped would have amounted to about 2,000 tons. See "Libya Buys Uranium Secretly, " *The Times*, London, Aug. 29, 1981, p. 4.

[101] See Roger Pajak, op. cit., pp. 53 and 56. For a review of the evidence concerning an Iraqi nuclear weapons program, see Jed C. Snyder, "The Road to Osirak: Bagdad's Quest for the Bomb, " Middle *East Journal,* vol. 37, No. 4, autumn 1983, p. 587.

ture, as the reactor was to be operated contenuously.[102]

After the destruction of Osirak, the French promised to assist Iraq in rebuilding the Osirak reactor but French spokesmen reportedly called for strengthened safeguards and the use of low-enriched uranium fuel in the rebuilt reactor. Iraq opposed this, some believe, on the grounds that it did not meet the conditions of the original contract and that the neutron flux resulting would have been lower and inadequate for certain types of research operations.[103] No agreement has been reached at this point, and fuel shipments from France apparently have not occurred. Nor has the Tammuz 1 Osirak reactor been rebuilt.

The second major diversion scenario involved the production of plutonium for a nuclear device. This diversion path would not be eliminated with the supply of caramel fuel. Osirak could have been used to produce plutonium by irradiation of uranium targets in the reactor core or by installation of a uranium blanket around the core, According to IAEA sources, removing the reflector elements from the reactor and irradiating fertile elements both inside and outside the core could provide up to one or two "significant quantities' of plutonium per year, or approximately 8 kg."" French physicists estimated that the reactor could produce 3.3-10.0 kg per year; however, the actual amount is dependent on the plutonium production scenario.

In a "core" scenario, uranium targets could be placed in the reactor core and irradiated. Tammuz 1 was designed as a materials testing facility; such a facility in industrialized countries is for studying irradiation of power reactor construction materials and fuel elements. Substituting uranium would not have been difficult because of in-core inspection limitations. The procedure might have been difficult to detect given the short irradiation time (weeks) required. However, the core size limits the amount of uranium that can be irradiated, making plutonium production cumbersome. In order to gain 8 kg of weapons-optimal plutonium, 8,000 to 10,000 kg of uranium would have to be irradiated. '05

The IAEA could have detected this activity through existing safeguards techniques, but sufficient time passes between inspections to allow the production of some plutonium. With the presence of French technicians and substantial improvements in IAEA inspection techniques under consideration, detection would have been highly probable.

The second scenario for plutonium production requires a natural or depleted uranium "blanket" to be placed around the reactor core. The length of irradiation is a function of the neutron flux-that is, the density of neutron emission from the reactor core. Since the blanket is outside the core, and therefore farther away from the core, there is less neutron flux and irradiation time is longer. In addition, greater cooling capacity would probably be necessary to remove the excess heat generated by irradiation of the blanket. Despite these constraints, much more uranium could be irradiated at one time. The probability of detection would depend on how easily the blanket was installed and removed. However, once again, with French technicians present and IAEA surveillance cameras operating, this scenario could have been detected with existing safeguards techniques.

If Iraq had succeeded in irradiating uranium, it would have obtained plutonium, but reprocessing limitations would have diminished the prospect of near-term accumulation of significant quantities of plutonium. The small

[102]The French also reportedly irradiated the HEU, making it much more difficult to use in weapons production. irradiated HEU would have to be reprocessed in order to make it usable in nuclear weapons; capabilities to do so would have been limited by the small size of Iraq's reprocessing laboratories.

[103] "France, Iraq Unveil Secret Nuclear Accord, ' *Energy Daily*, June 19, 1981. "More Nuclear Guarantees From Iraq to be Sought, " *Le Monde*, Jan. 18, 1982, p. 7, reported in FBIS: France, See also Andrew Lloyd, '*Can France Stop the Iraqi flomb'?," *New Scientist*, Apr. 2'2, 19H2, p. 201. for a report on French debates on the caramel option.

[104]Hans Gruemm, "Safeguards and Tamuz: Setting the Record Straight, ' *IAEA Bulletin*, vol. 23, No. 4, December 1981.

[105]Less optimal plutonium with 0.2 percent concentration would require irradiation of 4 tonnes (metric tons) of uranium, The light-water reactor design is not a very "convenient path to plutonium production because it does not produce the spare neutrons necessary for a high rate of plutonium production,

laboratory provided by the Italians would have permitted reprocessing on only a small scale.

Both of these plutonium production scenarios are constrained by technical factors and safeguards. For a country with Iraq's limited technical manpower base, indigenous plutonium production would have been difficult. During the nearterm, the presence of the French and the application of safeguards, as well as the international attention focused on Iraq, would have made diversion of HEU or modified usage of the facility unlikely unless Iraq withdrew from the NPT.[106]

However, the thrust of Iraq's program may have been acquisition of nuclear weapons over the longer term. Given the presence of French technicians until 1989, it seems likely that the goal was to buildup a technical capability over the near term, leaving open the option for weapons production after the departure of foreign advisors and the development of a group of highly trained Iraqis. This long-term scenario, requiring 15-20 years, would eventually provide Iraq with the ability to develop a nuclear arsenal rather than a few unsophisticated bombs. While some believe it may have set the program back, Israel's raid on the research reactor thus did not eliminate the long-term possibility of an Iraqi weapons program since technical assistance in reprocessing-related technology continues. More important in diminishing longer term proliferation prospects is the combined effect of the Iran-Iraq War and the reported imprisonment of members of Iraq's nuclear community.

Before the reactor is rebuilt, a number of issues will have to be worked out. The French have expressed their intention to extend safeguards and to "internationalize" the project by insuring that the new administrative scientific director would be a Frenchman or a representative of the IAEA. External Relations Minister Cheysson has stated that French assistance will be resumed only With the "doubling or quadrupling" of safeguards.[107]

The case of Iraq illustrates the possibility that with combined improvements in fuel and facility design and in safeguards, the threat of proliferation could be substantially reduced while retaining a legitimate nuclear program. Three changes could enhance this possibility. First, reduced enrichment fuels (caramel or silicide) now under development might be used in research reactors presently fueled with HEU. The use of low-enriched uranium fuel, if it could be fabricated to maintain the neutron flux of HEU, could serve nonproliferation goals.[108] Second, a new research reactor could be designed to make the installation of a blanket outside the core virtually impossible. Finally, better remote-sensing and inspection techniques could upgrade the quality of safeguards.

Iran.–While it is difficult to ascertain the intentions of the Khomeini regime in Iran concerning nuclear weapons, it appears that the pressures of warfare with Iraq may limit Iran's ability to engage in a crash weapons program. At the same time, its motivations for doing so may be increased. A sudden upbraiding of Iraq's program might stimulate reevaluation by Iran. It appears that the current regime, like that of the Shah, may emphasize acquisition of sophisticated conventional weapons. The acquisition of nuclear weapons would be seen as provocative by the Soviets. In addition, a restart of Iran's nuclear program would be impeded by the flight of scientists and engineers from the country following the revolution.

Syria.–Syria was apparently as concerned about the development of Iraqi and Iranian nuclear capability as Israel was. Syria's approach to nuclear development reflects a de-

[106] If the French had been willing to cover up illegal actions by the Iraqis, a prospect feared by Israel, the possibility of detection would have been significantly reduced.

[107] "Nuclear Supplies to Iraq Dependent on Tougher Safeguards, France Asserts," *Nucleonics Week*, vol. 22, No. 26, July 2, 1981, p. 1.

[108] However, this results in the production of more plutonium. In addition, some experts question whether lower-enriched uranium fuel could be used so as to maintain a high enough neutron flux needed for cutting edge experiments.

sire not to fall too far behind any of the other Islamic nations in the region. Consequently, setbacks to any of the other programs may mitigate Syrian proliferation prospects, particularly if Israeli capability remains undemonstrated. Syria's important step has been to develop plans for commercial reactors and scientific research facilities, and Syria's military expenditures have been concentrated on maintaining the front against Iraq and Israel and on local interventions in Jordan and Lebanon. The Soviet Union, Syria's major military supplier, apparently has not provided Syria with sensitive nuclear technology. Syrian capability to produce a nuclear explosive device indigenously will probably not develop until the turn of the century.

Egypt.–Egypt has a greater technical capability than any other Middle Eastern Islamic nation to develop nuclear weapons if such a political decision were made. However, its nuclear technology purchases indicate that no steps have been taken in this direction, and the nation is generally not considered to be a proliferation threat at present. Egypt rejected a proposal in the early 1960's for a 200-MW natural uranium-fueled, heavy-water reactor that could have produced a large amount of plutonium. The nation currently has no fuel fabrication plans and has concluded that an indigenous enrichment program would not be cost effective. Egypt has little research relating to the front end of the fuel cycle, and no known R&D program related to uranium enrichment.

Although the argument has been made that Israel still may pose a major threat to Egyptian security, Egyptian leaders have said little about Israel's nuclear capability since the Camp David accords. Whether because Egyptians have chosen a strategy of conventional preemptive attack or because the perceived threat has diminished, Egypt acceptance of the NPT indicates an emphasis on a long-term strategy designed to develop the technological foundation for a nuclear power program. After acquiring a large amount of commercial nuclear technology and considerable experience, Egypt could, of course, move toward a nuclear weapons option later if the political choice were made to do so.[109] However, in order to do so Egypt would have to acquire sensitive facilities.

The development of nuclear weapons by Libya, if this were to occur, could seriously alter Egyptian thinking about the nuclear weapons path. Likewise, if Israel demonstrates nuclear capability or is perceived as having expansionist rather than status quo intentions, the pressure to develop nuclear weapons would be increased in many Islamic nations, Egypt probably included.[110]

Algeria.—Algeria's limited nuclear infrastructure precludes indigenous production of a nuclear device until the end of the century. Because Algeria has been moving closer to the West and is unlikely to experience a geopolitical change sufficient to cause it to initiate a crash weapons program, it does not appear that Algeria has made the decision to pursue a weapons path. It could, however, build a broadly based program which could form the foundation for a nuclear explosives program in the 21st century. The nation has not signed the NPT; therefore, in order to import nuclear technology, Algeria may be forced to accede to safeguards. If Algeria exported uranium, it would be under no legal obligation to require safeguards, a situation that could raise proliferation concern in the next century.

Saudi Arabia.–Saudi Arabia currently has no significant nuclear research facilities *or* nuclear power plans. However, since the Saudis have the capacity to finance programs in other nations, they are important in the context of Middle Eastern nuclear weapons proliferation. Saudi Arabia has a strong interest in the stability of the Middle East and therefore is likely to view weapons development programs in other states as alarming. It could support regional and global efforts to reduce Israel's incentives to adopt an overt nuclear stance; for example, participation in the nuclear programs

[109] An editorial written by the editor-in-chief of *Al Abram* advocated ratification of the NPT on precisely these grounds. See Selim in Katz, op. cit., p, 156.

[110] See CSIS, op. cit., p. 56,

of other nations could be directed at enhancing Saudi Arabia's capability to limit the spread of nuclear weapons technology in the region and to ensure the peaceful orientation of such programs.

Some believe that Saudi Arabia may have provided financing for Pakistan's nuclear program in order to preclude exclusive cooperation between Pakistan and either Iraq or Libya. Assistance to Iraq for reconstruction of its reactor could be given in such a way as to restrain Iraq from producing weapons. Another method would be to emphasize regional security interests through organizations such as the Gulf Cooperation Council as a counterbalance to unilateral weapons production programs in individual states.

Other Limiting Factors

For Middle Eastern nations wishing to pursue a nuclear weapons path, gaining sufficient weapon-grade fissionable materials (with all the accompanying technical expertise required) presents a more serious constraint than does weapons design or delivery. As Middle Eastern nations develop the technical manpower and industrial infrastructure to produce independently weapons-grade nuclear materials, the design and fabrication of simple, low-yield (10- to 20-kiloton) fission weapons will also become feasible. Assuming that such weapons would weigh as little as 1,000 pounds—much less than those first produced by the United States–delivery using aircraft already in the region would be possible.

Therefore, if Middle Eastern nations are able to produce nuclear weapons, they will probably also be able to deliver them with a moderately high probability of success, at least against their immediate neighbors. With small air forces, limited numbers of bases, and limited air defense capabilities, such delivery systems are, however, likely to be quite vulnerable to destruction by preemptive attack, either conventional or nuclear. Given the technical difficulty and additional expense required, initial nuclear capabilities are not likely to be of a "secure second-strike" character.

One final issue is the expense of nuclear weapons programs. Based on historical data, a small dedicated nuclear weapons program would cost about $300 million annually.[111] Such an expenditure would, of course, be more feasible for the richer oil-producing nations, but it would not be prohibitive for many countries in the Islamic Middle East. Four countries-Iran, Iraq, Egypt, and Saudi Arabia—could operate such a program over 10 years at a cost less than 3 percent of their annual defense budgets.

Table 89 provides cost estimates of a dedicated program for each of the countries, using average annual defense expenditures for the 1970-79 period as a baseline for calculations. Historically, no nation that has developed a nuclear weapons program has spent more than 3 percent of its annual defense on such a program.[112] Some nations of the region could certainly spend more than this amount, but it is quite possible that bureaucratic infighting among military leaders would result if the program were seen to be jeopardizing improved conventional capabilities. As table 89 indicates, the economic constraints would be much greater for phase 2 and 3 programs, which include dedicated delivery systems and development of a secure second-strike capability.

These conclusions should not, however, be interpreted to indicate that there is little cause for concern about nuclear weapons proliferation in the Middle East. In the years ahead, as new suppliers enter the market it may well be that developing countries determined to obtain nuclear weapons will be able to acquire the required technical assistance and sensitive facilities more easily. This is a major theme of the section which follows. In addition, political variables will continue to weigh heavily in determining the prospects for proliferation. If one nation in the region were to demonstrate its nuclear capability, this would probably

[111]Estimates are based on costs of the Indian Phase 1 program and include costs of heavy-water and nuclear-grade graphite. See Thomas W. Graham, "The Economics of Nuclear Weapons in Nth Countries," in Brito, et al., op. cit., pp. 16-18.

[112]Stephen Meyer, *The Dynamics of Proliferation* (Cambridge, Mass.: Ballinger, 1983).

Table 89.—Hypothetical Cost of Dedicated Nuclear Proliferation Program for Selected Countries

Country	Average annual defense expenditure (1970-79)	Percent of defense budget: Phase 1 ($300 million)	Phase 2 ($2 billion)	Phase 3 ($5 billion)
Algeria	447	6.7	44.7	111
Egypt	1636	1,8	12,2	30
Iran[a]	7596	0.4	2.6	7
Iraq	1811	1,6	11.0	28
Jordan	236	12,7	84.7	212
Kuwait	716	4,1	27.9	69
Lebanon	97	30.8	205.0	514
Libya	418	7,1	47.8	119
Morocco	478	6.2	41.5	105
Oman	530	5,7	37.7	94
Qatar	718	4.1	27.8	70
Saudi Arabia	6802	.5	29	7
Syria	—	—	—	—
Tunisia	67	44.0	297	742
North Yemen	107	27,9	186	465
South Yemen	55	53,7	350	896
USE	187	15,9	106	266
Selected countries *of proliferation concern*				
Argentina	1245	2,4	16,0	40
Brazil	1785	1.6	11.2	28
India	3111	1,0	6.4	16
Israel	3361	0.9	5.9	15
Pakistan	913	3,3	21.9	55
South Africa	1410	2.1	14.1	35
South Korea	1739	1,0	11.4	29

[a]Data for rerevolutlonary Iran.

NOTE Phase 1 Acquisition of a few fission devices based on plutonium (includes both demonstrated and 'bomb In the basement type programs)
Phase 2 Acquisition of a thermonuclear weapons capability with a dedicated aircraft delivery system.
Phase 3 Development of a secure second strike capability

SOURCES US Arms Control and Disarmament Agency *World Military Expenditures* and Arms *Transfers* 19701979 (Washington DC US Government Printing Office, 1982) Thomas W Graham The Economics of Producing Nuclear Weapons in Nth Countries in Strategies for Managing Nuclear *Proliferation,* Brito, et al (eds) (Lexington Mass Lexington Books 1983)

stimulate weapons programs in other states. Military conflict and political disputes in the region thus heighten the danger of proliferation.

Even if a nuclear weapons program were made a matter of highest national priority, no Islamic country in the region is now capable of producing a nuclear device on a wholly indigenous basis within this decade, and most would have difficulty doing so before the turn of the century. Therefore, while political and military conflicts continue in the region, the weak technical capabilities of these nations reduce their ability to obtain weapons-grade materials in domestic facilities and to produce nuclear devices. Egypt, the nation with the strongest technical manpower base, might be in position to independently produce a nuclear weapon by the end of the 1990's if policies were changed to emphasize development of sensitive technologies. With the assistance of foreign experts willing to work in clandestine programs, however, the technical manpower constraints to independent weapons production could be significantly diminished in these Middle Eastern countries.

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SUPPLIER COUNTRY APPRoACHES TO NUCLEAR TECHNOLOGY TRANSFER

Because Middle Eastern countries have limited nuclear infrastructures, the possibility for and rate of proliferation will be strongly influenced by the amount and kind of external assistance provided by supplier nations. The policies of the major nations supplying nuclear technology worldwide—the United States, Great Britain, Canada, France, West Germany, Italy, Belgium, Switzerland, the Soviet Union-range from a reluctance to sell any nuclear materials to countries in the Middle East to a willingness to sell sensitive facilities under IAEA safeguards. It is not likely, because of treaty constraints and domestic political decisions, that any of the current suppliers would sell any type of unsafeguarded nuclear facility to the region.

Nevertheless, the types of small-scale facilities and the nature of training and technical assistance they are willing to provide will affect the rate at which Middle Eastern nations develop indigenous capabilities to absorb nuclear technologies-both for commercial and military purposes. It is much more difficult to anticipate the policies which may be developed by new suppliers such as Argentina, Brazil, and India, which may enter the market in the years ahead. While the "new" supplier nations all have limited capabilities to produce nuclear technologies and are not likely to export until the 1990's, the fact that they are not parties to the NPT, and therefore not under obligation to require safeguards on the export of nuclear materials or equipment, makes their policies of particular concern.

U.S. POLICIES

While different U.S. administrations have placed emphasis on different nuclear nonproliferation policy issues, American policies in practice have precluded the sale of unsafeguarded facilities or even sensitive safeguarded facilities, such as enrichment or reprocessing plants, to any Middle Eastern country. U.S. sales of major nuclear items such as reactors or fuel have generally been made only to countries accepting full-scope safeguards on their facilities. It appears likely that nuclear exports by U.S. firms will remain comparatively limited to fuel, power reactors, or research reactors.[113] It is not only these treaty and legislative obligations but also bipartisan American leadership in international nonlproliferation efforts that indicate continuation and strengthening of policies designed to limit nuclear proliferation. Amendments to the Export Administration Act passed separately by both the U.S. House of Representatives and Senate in 1983 and 1984 would, if enacted, widen the definition of prohibited nuclear export items.

In addition, lower dependence of the United States on Middle Eastern oil nations reduces the possibility that oil leverage could be used to cause serious modification to these policies. U.S. firms such as General Electric and Westinghouse have emphasized sales of fuel cycle services, such as fuel fabrication and spare parts, rather than reactor sales. Therefore, while the subdivisions of these companies producing reactors would obviously benefit from increased reactor exports, the firms are not solely dependent on reactor sales. U.S.-made research reactors are technically and financially competitive on international markets, but in most cases require supplies of 25-percent

"'U.S. policies do not preclude assistance to nations not parties to the NPT, and in recent months nonsensitive spare parts have been provided to such nations in an effort to keep a dialogue open with them, according to administration officials. See, for example, statement by Richard T. Kennedy before the Sub committees on International Security and Scientific Affairs and International Economic Policy and Trade, House Foreign Affairs Committee, Nov. 1, 1983.

One type of proposed legislation would extend export restrictions to a broad variety of dual-use items, primarily computers. This legislation would prohibit sales of any dual-use items to nations not signatories to the NPT. Another type of proposed legislation which gained wider support in the 98th Congress would expressly prohibit sales of nuclear components and technology to nonsignatories. (In the view of proponents of the legislation, the fact that such sales are permitted while sales of major nuclear items are prohibited amounts to a ' 'loophole' which should be closed.)

enriched uranium. In addition, since 1977, Congress has reviewed all nuclear technology sales involving financing by the Export-Import Bank, with the result that exports of nuclear technologies financed by the bank have declined in recent years.[114]

The United States has the most comprehensive export control system covering nuclear equipment and technology of any supplier nation. However, controversy has arisen as to how this system can be strengthened. Recent changes in the policies of the Reagan administration, such as those loosening controls on reprocessing by friendly nations such as Japan, have no significant or direct impact on the nuclear programs of Middle Eastern nations.[115] However, critics worry that this "discriminatory' nuclear export policy represents a general softening in policy and leaves the door open for reclassification of some developing nations as not being proliferation risks and therefore as potential buyers of sensitive U.S. facilities at some time in the future.

On the other hand, under the Reagan administration countries such as Iraq, Libya, and Israel, suspected of developing nuclear weapons, have been added to the list of nations requiring specific U.S. Department of Energy authorization for exports of sensitive nuclear technology by U.S. firms,']' As noted earlier, some advocate widening the scope of exports barred to non-NPT signatories (to additional nuclear items, or to a broad array of dual-use items). In neither case is it clear that the prohibitions would, if enacted, have strong or immediate impacts on the nuclear programs of nations in the Islamic Middle East.[117]

[114] Export-import Bank of the United States, *Report to the U.S. Congress on Export Credit Competition and the Export-Import Bank of the United States,* December 1982, p, 27, In 1981, authorizations for nuclear power-related exports totaled $212 million, out of $1.3 billion for all energy-related exports. The Export-Import Bank supported no authorizations for nuclear exports in 1982. See, *Report to the U.S. Congress,* 1983.

[115] See Harry R.Marshall, Jr., "The Challenge of Nuclear Technology, State *Department Bulletin,* September 1982.

"6"l)OFJ Moves to Expand List of Nations Needing Special (). K. for Nuclear Deals, " *Inside Energy,* July 2,1982, p. 4.

''-l+lffects on (J. S. exports would be more significant. During the July 1981 -,June 1982 period, Israel imported $102 million worth of dual-use equipment, while Saudi Arabia<s imports were valued at $179 million. See General Accounting Office, *Controlling Exports of Dual-Use, Nuclear-Related Equipment,* GAO NSIAD-83-28, Sept. 29, 1983, p. 8,

Currently, about 6 percent of U.S. dual exports go to these nations, and other suppliers are capable of providing both the dual-use and additional nuclear items of concern.[118] U.S. firms are not now major suppliers of nuclear technology to nations of the Islamic Middle East which are nonsignatories to the NPT. On the other hand, in the view of proponents of the proposed legislation, dual-use exports can be critical to nuclear programs and strengthened prohibitions on nuclear and dual-use trade with countries that have not accepted full-scope safeguards and are likely to themselves become suppliers of nuclear technology in the years ahead could contribute to U.S. nuclear nonproliferation policies.

POLICIES OF OTHER WESTERN NATIONS

A number of nations such as Great Britain, Canada, Australia, and Japan, will probably maintain their comparatively restrictive policies on nuclear exports. Great Britain has not sold a nuclear reactor to any country for a number of years, and its longstanding nonproliferation policies preclude sale of unsafeguarded or sensitive nuclear facilities in the Middle East. Canada and Australia are not likely to provide assistance to any Middle Eastern nation that has not accepted full-scope safeguards.

Canada has recently reversed its previous policy of no nuclear sales to any Middle East nation. Therefore, sales of CANDU reactors, heavy-water production plants, and technology to nations covered by safeguards are possible. Canada has ongoing negotiations with Egypt and Kuwait, and is marketing a 600-MWe reactor.

Japan has not yet substantially entered the nuclear export market but has the capacity to do so. However, it does not appear likely that Japan would make its first independent foreign sale in the Middle East. Mitsubishi, in a joint bid with Westinghouse to market in Egypt, may provide nonnuclear equipment.

[118] GAO, Ibid. Israel and Saudi Arabia, both nonsignatories to the NPT, are among the largest single-country importers of dual-use technologies from the United States.

The Japanese Ministry of Trade and Industry initiated a feasibility and design study for a 200 to 300 M We reactor, indicating a potential role for Japanese firms later in the century.

For a number of years, West Germany has opposed the adoption of a blanket requirement for full-scope safeguards by members of the London Suppliers' Group.[119] While West Germany has not sold reprocessing facilities to other countries since 1977, and has announced it will not sell reprocessing plants, it did sell heavy-water production technology to Argentina, a country which has not accepted safeguards on all of its nuclear facilities. West Germany has a strong nuclear power industry, and its firms are likely to remain important competitors in world markets where firms like Kraftwerk Union make large proportions of their sales. Its ban on exports of reprocessing equipment reveals a commitment to nonproliferation policies, but the Germans have carried through with controversial agreements to provide Brazil with sensitive facilities. The Brazil-West Germany agreement does, however, extend comparatively strict safeguards on German technology. The West Germans have adhered to the guidelines of the Nuclear Suppliers Group (NSG),[120] but government spokesmen have also said that the specific situation of each importing country should be taken into account, along with provisions of the NPT in nuclear exports.[121]

In the past, France has exported sensitive facilities; the nation is not a party to the NPT. However, its agreement to the NSG guidelines suggests that it will continue to require IAEA safeguards, but probably not full-scope safeguards, to nations that receive French nuclear assistance. France, like other exporters, is under pressure to export because its reactor production facilities are not utilized to capacity. The most likely Middle Eastern export candidate is Egypt, where negotiations for two reactors are well advanced. French Government and business officials closely coordinate their export negotiation efforts, and talks have been held with nations such as Iraq, Morocco, and Algeria concerning possible reactor sales.

It is not clear whether the French will sell reprocessing facilities to Middle Eastern nations in the future, though they have announced they will not do so and have not signed contracts for export of sensitive facilities in recent years. French commercial considerations have been at least as prominent in French export policies in years past as nonproliferation issues. In certain instances, however, they have exercised restraint: France withdrew from a contract to provide Pakistan with a reprocessing plant owing to concerns about Pakistan's alleged effort to develop nuclear explosives.

France may well refrain from selling commercial-scale sensitive facilities to Middle Eastern nations. In addition, French experience with Iraq's research reactor has led it to move toward more stringent requirements on research reactor exports. However, France's lack of insistence on full-scope safeguards and the commercially oriented nature of its nuclear export policies are issues of concern from a proliferation standpoint.

Belgium and Italy provide nuclear assistance that is not directly required for near-term development of commercial power for peaceful purposes. Both of these nations have supplied such technologies to nations of particular proliferation concern–Libya and Iraq. Belgonucleaire has provided Libya with fuel fabrication technology and is considering supplying technologies that could be of concern if Libya were to obtain centrifuge technology from Pakistan or to develop an indigenous enrichment program.[122] The Italian Nuclear Agency (Comitato Nazionade per l'Energiie) has provided Iraq with considerable nuclear assist-

[119] All of the Western supplier nations discussed here are members of the London Nuclear Suppliers Group, which was set up in the mid- 1970's at U.S. initiative. The members have individually and unilaterally agreed to control exports of nuclear technologies on the "trigger list."

[120] The NSG has made an important contribution to extending IAEA safeguards and to standardizing the conditions for acquisition of sensitive technologies.

[121] Joseph Pilat and Warren Donnelly, "Policies for Nuclear Exports, Cooperation and Non-Proliferation of Seven Nuclear Supplier States," CRS Report No. 82-100 S, May 1982, p. 24.

[122] "Libya and Belgonucleaire of Belgium are in Detailed [Talks]," *Nucleonics Week, vol. 23,* Dec. *2, 1982,* p. 4.

ance, including a range of laboratory-scale reprocessing facilities.

In neither case is the type of assistance being offered "sensitive' in the sense that it can lead directly and quickly to the development of a nuclear weapons capability, but it will provide Libya and Iraq with precursor technology that would make it easier for either nation to take such a step in the future. As noted above, neither Libya nor Iraq is today in a position to develop such technology on an indigenous basis, but the assistance contributes to the development of their technical capabilities. The position taken by Italy and Belgium, both parties to the NPT, is that their assistance is being provided under safeguards, and there is no indication that safeguards are being violated. Given the stated interest of Libya, in particular, in developing nuclear weapons, the United States has viewed this assistance as a matter of concern.

SOVIET POLICIES

The Soviet Union is a party to the NPT and has historically been a strong supporter of a comprehensive nonproliferation regime, to a great extent due to its experience with the spread of nuclear technology to China. It has advocated full-scope safeguards, participates in the London Suppliers Group, has not assisted recipients in developing complete fuel cycle technologies, and has insisted that spent fuel from reactors it has supplied in Eastern Europe be returned to the Soviet Union. The Soviets, for example, strongly encouraged Libya to sign the NPT, which it did.

There are, however, some who argue that Soviet nonproliferation policy may become less unified and strict in the years ahead. The Soviet Union and Eastern European nations that manufacture nuclear equipment may see it as both politically and economically advantageous to expand exports to Middle Eastern developing countries, thus gaining hard currency and perhaps some political leverage. Moreover, a loosening of U.S. nonproliferation resolve might act to diminish that of the Soviets.

The signs of Soviet policy change are far from clear, however. Moscow's dealings with Libya illustrate the point. The Soviet Union concluded its cooperation agreement with Libya only after that nation had ratified the NPT, and waited to expand assistance until full-scope safeguards were instituted. The Soviet Union shipped 11.5 kg of HEU to Libya just before the full-scope safeguards went into effect, a fact that some view as a sign of loosening of controls and that others see as a technicality. In addition, the Soviet Union continues to supply Libya and other nations with HEU instead of developing fuels of lower enrichment. Observers note that it is not yet certain whether or not the Soviet Union will require Libya to return spent fuel rods, but it has done so in other cases thus far.

Some experts worry that Soviet nuclear export policies are in flux and point to the destabilizing effects on the Middle East if Moscow should move toward a more commercially or politically oriented nuclear assistance stance.[123] It does not appear likely that Soviet policies will shift sharply and rapidly, but even a gradual diminution in proliferation resolve would be a matter of serious concern in the context of the Middle East. For Libya and Syria, the Soviet Union is the major force determining the nature and extent of nuclear technology acquisition. However, there is little concrete evidence that Soviet nuclear export policies have changed.

NEW SUPPLIER STATES

While it maybe correct to assume that none of the major suppliers listed above will provide Middle Eastern nations with unsafeguarded sensitive technologies needed for weapons development, a major question is whether the "new" supplier states likely to enter the market in the years ahead will follow the same policy. Several countries such as Ar-

[123] Tyrus W. Cobb, "Small Nuclear Forces: Soviet Political and Military Responses, ' paper prepared for the Georgetown Center for Strategic and International Studies and the Defense Nuclear Agency, September 1982,

gentina, Brazil, India, Pakistan, and South Africa have already engaged in a limited amount of international nuclear commerce or have the potential to do so. None of them have signed international treaty agreements requiring them to place safeguards on their exports.

The People's Republic of China (PRC) refused to give Egypt nuclear weapons technologies in the early 1960's and more recently refused Libya's requests for nuclear weapons or sensitive nuclear technologies. While China reportedly assisted Pakistan with sensitive nuclear technology, it does not appear that any Middle Eastern nation is likely to provide a quid pro quo of advanced conventional military technology, as Pakistanis capable of doing. The PRC has also provided limited amounts of basic nuclear training to countries in the Middle East; however, it has recently joined the IAEA, and its participation in safeguards programs is expected.

Both Brazil and India have been pressured by Iraq and Libya, respectively, to provide nuclear materials and technology, but in both cases no sensitive technology was transferred. Thus new suppliers have exercised some restraints, indicating willingness to support some parts of the nonproliferation regime. It was no coincidence that as Iraq found itself increasingly unable to buy nuclear technologies from major Western suppliers it turned to Brazil, a nation purchasing 40 percent of its oil from Iraq. Brazil's response was measured. The nation diversified its oil imports and concluded an agreement with West Germany ensuring that no retransfer of West German technology to Iraq would occur.

Nevertheless, concern remains that Iraq might receive uranium hexafluoride (a feed material for enrichment) and relatively primitive centrifuge technology from Brazil since they are not covered in the Brazil-West Germany Accord. While Brazilian officials deny that they have supplied Iraq with uranium, the nuclear cooperation agreement signed with Iraq in 1979 calls for a supply of uranium, joint research and experimentation, uranium exploration technology, finished fuel elements, equipment and engineering services for reactor construction.[124] The policies of new supplier nations like Brazil will be extremely important in determining the prospects for Middle Eastern nuclear proliferation.

Libya turned to Pakistan with requests for nuclear technology when France tightened up its policies on nuclear exports. Countries such as Libya and Saudi Arabia have reportedly contributed financially to Pakistan's nuclear program, with Arab credits valued at $1 billion extended to Pakistan for various purposes during the 1974-76 period.[125] Pakistanis high on the list of nations of nuclear proliferation concern. Reports that Pakistan was building a small clandestine reprocessing plant and that the nation had assembled a small enrichment plant through purchases of specialized equipment ostensibly destined for other projects indicate the nation's steps down the path toward nuclear weapons capability.

Some have argued that because of Islamic traditions, as well as growing economic interaction between Pakistan and the oil-producing states of the Gulf, Pakistan is the most likely candidate to retransfer nuclear technology to the Middle East.[126] Despite reports of Arab financial contributions to Pakistan, there is no evidence that Pakistan has transferred sensitive nuclear technologies. It has not been a major supplier of nuclear technologies to any Middle Eastern nation, and has made assurances to the U.S. Government that it will not transfer sensitive nuclear technology. It appears that relations between Libya and Pakistan cooled after the ouster of Prime Minister Bhutto.

The most important potential "new" supplier of nuclear technology to the Middle East may be India. With its comparatively broad nuclear and industrial base, and its expanded foreign policies in the region, India may play a greater role in the years ahead. Indeed, in

[124] "Brazil and Iraq Signed a Nuclear Cooperation Agreement," *Nucleonics Week*, vol. 21, Jan. 17, 1980, p. 10.
[125] Pajak, op. cit., p. 68.
[126] Steve Weismann and Herbert Krosney, *The Islamic Bomb* (New York: Times Books, 1981).

1979 it signed an agreement to provide Libya with sensitive nuclear technology.[127] The Indian nuclear scientists who were to be involved in the transfer objected, and Libya responded by terminating a 2 million-ton oil contract with India. After a period of strained relations, Libyan scientists began training in India in less sensitive areas such as theoretical nuclear studies, reactor operations, and medical applications.

[127] Argonne National Laboratory, *World Energy Data Systems, Country Data: Libya*, vol. 3, 1979.

This incident illustrates that despite considerable oil leverage exerted by Libya, India apparently refrained from transferring sensitive technologies. Thus, it would be a mistake to assume that Third World solidarity (or other factors such as common religious heritage) will necessarily dictate the policies of the new supplier states, Nevertheless, the potential for proliferation increases as new suppliers not parties to the NPT enter the market.

CONCLUSIONS: THE FUTURE OF NUCLEAR TECHNOLOGY TRANSFERS TO THE MIDDLE EAST AND OPTIONS FOR U.S. POLICY

FUTURE PROSPECTS FOR NUCLEAR TECHNOLOGY TRANSFERS

No Islamic Middle Eastern nation is in a position to carry out a commercial reactor program on a wholly indigenous basis during the next decade, and most will not have the capability in the year 2000. The major constraints on commercial nuclear power development in the region include a shortage of appropriately trained scientists, engineers, and skilled craft workers; an absence of interconnected electricity grids; and the disincentive provided by the presence of alternative sources of energy. As indicated in table 86, only Egypt, Iran, Kuwait, and Saudi Arabia might be able to install a 900 MWe power reactor not exceeding 10 percent of their electricity grids by the year 1990.

Nations that choose a turnkey plant strategy can minimize the salience of manpower constraints, but this implies continuing dependence on foreign suppliers. Egypt is the Middle Eastern nation with the strongest rationale for a commercial nuclear program and with the largest technical manpower base to support one, but Egypt has decided to import turnkey plants and to rely on foreign assistance for some years to come.

Developing countries in the Middle East may expand nuclear research programs in the years ahead, even in the absence of commercial nuclear power programs. Such research is viewed by many developing countries as essential for building their indigenous technological infrastructures, permitting more effective use of imported technologies.[128]

Acquisition of commercial light-water reactors without sensitive nuclear facilities poses no direct or significant threat of weapons proliferation. However, even small-scale reprocessing facilities (components of peaceful research programs) could be used (albeit with difficulty) to produce plutonium for nuclear weapons.

The Middle Eastern nation that has most outspokenly stated its ambitions to carry out a nuclear weapons program, Libya, also has an extremely limited technical infrastructure, which will force it to continue to depend on foreign suppliers for many years to come. Egypt, and perhaps Iraq, may have the technical capability needed to produce a nuclear device in the next decade. (In the case of Egypt, the agreement to safeguards and the

[128] See Michael J. Moravcsik, "The Role of Science in Technology Transfer, *Research Policy*, 12 (1983), pp. 287-296, for an elaboration of this point.

emphasis on acquisition of nuclear technologies needed for a peaceful nuclear power program indicate an absence of intention to do so.)

For nations of the Middle East, financing and delivery systems do not present great obstacles to development of small weapons programs. More important are manpower constraints (particularly in the near term) and political factors, including the policies of supplier nations.

Overt proliferation has not occurred in the Middle East. One major explanation is surely that the suppliers have not been willing to transfer sensitive technologies without adequate safeguards. Thus, the nonproliferation regime through which suppliers limit their exports has been the major factor influencing the pace and nature of proliferation in the region. This analysis underscores the critical importance of the "new" supplier states and the need to bring them into the nonproliferation regime. Incentives for latent proliferation can be expected to persist and grow, however, and safeguards cannot fully guarantee that facilities are used for peaceful purposes.

Assuming that the current situation continues and disputes between Israel and its Arab neighbors and among Islamic countries are prolonged, the possibility of nuclear weapons proliferation may increase in the Middle East during the next 20 years. There are two reasons for this pessimistic conclusion: 1) the new supplier states may be more willing to transfer sensitive technologies, and 2) nations in the region will gradually improve the technical manpower and infrastructures required to support weapons programs. Unless a nuclear device is actually used, most of the nations in the region will probably move slowly toward developing expertise and importing facilities needed to start a weapons program. Nevertheless, technological advances such as development of laser isotope separation would increase the potential for nuclear weapons proliferation.

While it is impossible to anticipate the way in which nuclear weapons proliferation might occur, there are a number of possibilities. A new supplier state might provide sensitive and unsafeguarded facilities, perhaps in exchange for oil supply guarantees. The reluctance of both Brazil and India to succumb to such pressure exerted by Iraq and Libya suggests that the new suppliers would probably have to perceive a significant threat to their security interests to do so. Likewise, the policies of one of the major Western nations or the Soviet Union now supplying nuclear technologies might change, permitting freer transfer of sensitive nuclear technologies.

Still another possibility is that nations might accelerate their progress down the path to nuclear weapons production through joint programs, perhaps involving some of the newer supplier states. On the other hand, it is difficult to imagine which nations might forge a political alliance strong enough to support such a joint program over a number of years. In addition, it is not clear which suppliers might be induced to participate, even under the guise of a peaceful program.

A nation or nonstate group might try to purchase or steal a nuclear device. However, nations such as Libya have failed in their attempts to do so. In addition, detonation of a single nuclear device is unlikely to provide the long-term deterrence or defense capability required.

The most likely pattern for nuclear proliferation in the Middle East may, therefore, be a slow and indirect path. Given the technical dependence of most of these nations, they may choose to develop their technical manpower bases and import nuclear technologies that can be justified as parts of a peaceful nuclear program, thus increasing their capabilities to institute a weapons program sometime down the road if they make the political decision to do so. Assuming that suppliers continue to require IAEA safeguards, however, the probability would be high that covert weapons production programs could be detected.

U.S. POLICY OPTIONS

OTA's analysis of nuclear technology transfers to the Middle East indicates that while

U.S. leadership in establishing the nonproliferation regime has been important, only a limited number of policy options are available and even fewer exist that the United States could introduce unilaterally with significant effect.

Options that the United States could adopt unilaterally include an extension of restrictions on Government-supported financing of nuclear exports by the U.S. Export-Import Bank. Export-Import Bank support for nuclear sales has declined sharply in recent years, and this is seen by many as contributing to the reduced overseas sales of reactors by U.S. firms.[129] However, sales of turnkey reactors do not by themselves pose a nuclear weapons proliferation risk, and they contribute only indirectly and over a very long time to building a technical manpower base in developing nations. U.S. firms may form partnerships with foreign firms and seek financing elsewhere. Another possibility might be to selectively subsidize reactor sales to countries that accept stringent nonproliferation restrictions. In this case, nuclear technology would be used as a reward to countries that agree to certain political conditions.

Second, the United States could move to limit the number of foreign students admitted to nuclear physics and engineering programs. However, only in the case of Iran under the Shah have large numbers of Middle Eastern students been enrolled in such U.S. programs. In view of lack of precise information about what foreign students are studying, it would be difficult to implement such restrictions. Moreover, because of the apparently small number of Middle Eastern students currently enrolled in such programs, it appears that U.S. leverage is not strong, Associated questions of the freedom of American academic institutions would certainly be raised, and developing countries in other parts of the world might react negatively. Finally, since foreign students are free to enroll in programs in other supplier nations, U.S. restrictions would not severely restrict their ability to study in these fields unless other supplier nations instituted similar restrictions.

A more positive type of approach that the United States could independently pursue would be an extension of nuclear cooperation agreements with other Middle Eastern nations, similar to that with Egypt. In many respects, the U.S.-Egyptian nuclear accord represents a model by virtue of its detail and the strength of safeguard provisions. One argument in favor of extending such accords is that the offer of assistance to a developing nation might be more persuasive than the threat of denial of U.S. technologies. However, in order for cooperation agreements to be perceived by the recipient as significant, real assistance must be provided, resulting in the recipient developing greater technical capability. Cooperation agreements of this type are most easily negotiated with nations having close relations with the United States. Failure to follow through with cooperative efforts or inconsistent policies (e.g., those limiting financing of U.S. nuclear exports to Egypt) can lead to frictions which may diminish the importance of the agreements.

The United States could also make greater efforts to assist nations in developing alternative energy sources and to help them assess the feasibility of nuclear power. Of the possible alternatives or supplements to nuclear power in the region, the role of indigenous natural gas and the potential for greater efficiencies in energy-use merit further analysis on a country-by-country basis. Such assistance should be viewed as strongly contributing to U.S. nonproliferation policies. Those who oppose U.S. assistance to commercial nuclear power programs would welcome expanded efforts to develop alternative energy sources in these countries.

A number of other policy options would require coordination with other suppliers. One approach would be to continue support for the development of low-enriched uranium fuels in

[129] These restrictions do not prohibit U.S. firms from turning to foreign governments for financing. In late 1983, it was announced that Westinghouse and the Japanese firm Mitsubishi had decided to bid jointly on the Egyptian reactor contract, presumably with financing provided by Japanese banking institutions.

programs such as the Argonne National Laboratory research and test reactor (RERTR) program. In addition, study of the plutonium production potential of research reactors should be promoted so that technical refinements could be introduced that would make it difficult to misuse such reactors. Because risks of proliferation are smaller when research reactors with a capacity of less than 10 MWt and fueled by low-enriched uranium are used, other suppliers could be encouraged to provide such types of research reactors. Nations such as the Soviet Union could also be encouraged to provide only low-enriched uranium fuel.

In addition, a very important contribution would be to clarify the upper bounds on hot cells and other fuel cycle facilities and to establish limits on their export. The United States could also make a major effort to develop and maintain a consensus among suppliers that they not assist in the development of capabilities that will permit Middle Eastern nations to separate kilogram quantities of plutonium per year from irradiated fuel. Similarly, the United States could encourage formation of a consensus not to export enrichment technologies to the region. Such efforts could be combined with a willingness to cooperate with Middle Eastern nations in nuclear power and civilian research programs.

The United States can continue to promote strengthened safeguards, such as the use of remote sensing in reactor cores and more frequent inspections. While critics have pointed out the potential weaknesses of safeguards, the safeguards system contributes to the identification of potential proliferators. It is unlikely that international safeguards can be substantially strengthened outside the IAEA and the NPT. The IAEA is the major international working organization involved in nuclear training and technology transfer, and the U.S. must participate in order to influence its programs.

In the past, the United States has encouraged nations to sign the NPT. In the Middle East, a number of key nations including Algeria, Israel, and Saudi Arabia have not signed the treaty. It maybe difficult to persuade Saudi Arabia to sign the NPT unless equal pressure is placed on Israel. In the case of Algeria, Soviet and French support would be critical, and French nonaccession is a definite liability in this respect. Agreement by the countries of the region to a nuclear test ban treaty could also limit the prospects for detonation of a nuclear device.

Policy options open to the United States are thus limited, and most of those likely to achieve significant results require the cooperation of other nations supplying nuclear technology. It is clear that Middle Eastern countries no longer regard the United States as the world's dominant supplier of nuclear technologies, and that a number of them may develop nuclear power for peaceful purposes in the years ahead. It is therefore essential that U.S. energy and nonproliferation policies stress multilateral efforts to reduce the spread of nuclear weapons.