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Peaceful Nuclear Energy to Saudi Arabia: An Appraisal and Recommendation

by

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Abstract

The argument for and against the application of peaceful nuclear energy in Saudi Arabia is discussed in terms of the country's industrial development and power requirement for electricity and desalination. The discussion leads to the conclusion that due to its large oil reserve, Saudi Arabia may tolerate a considerate approach to nuclear energy up to the year 2000. Beyond this date, nuclear energy should be used in order to achieve the desired industrial maturity in the country. The introduction of nuclear energy, however, will be faced with three constraints, namely (in decending order of importance) man power availability, cooling water requirement, and the size of the electrical grid. The period 1980-2000 is thus most suitable for important preparation steps, among which are the adoption of regulatory provisions, establishment of nuclear facilities with necessary equipments, and staff training for regulatory, organizational, and technical activities. The paper outlines a scheme for the initiation steps and efforts to meet these requirements.

Friedliche Nutzung der Kernenergie in Saudi-Arabien: Bewertung und Empfehlung

Kurzfassung

Die Argumente für und gegen die friedliche Nutzung der Kernenergie in Saudi-Arabien werden unter Berücksichtigung der industriellen Entwicklung des Landes und seines Energiebedarfs für die Stromerzeugung und die Meerwasserentsalzung diskutiert. Die Schlußfolgerung lautet, daß Saudi-Arabien aufgrund seiner großen Ölvorkommen zulassen könnte, daß das Land bis zum Jahre 2000 in wohlüberlegter Weise den Weg in Richtung Kernenergie einschlägt. Nach diesem Zeitpunkt sollte die Kernenergie eingesetzt werden, um das Land zu der gewünschten industriellen Reife zu bringen. Der Einführung der Kernenergie stehen jedoch drei Einschränkungen gegenüber, nämlich (in der Reihenfolge ihrer Bedeutung) Verfügbarkeit von Arbeitskräften, Bedarf an Kühlwasser und Umfang des Stromnetzes. Aus diesem Grund ist der Zeitraum von 1980 - 2000 für wichtige vorbereitende Schritte sehr geeignet. Dazu gehören der Erlaß von Durchführungsbestimmungen, die Errichtung von kerntechnischen Forschungsanlagen und deren notwendige apparative Ausrüstung, die Ausbildung der Mitarbeiter zur Ausarbeitung von Sicherheitsvorschriften, sowie für organisatorische und technische Aufgaben. Der Beitrag gibt ein Schema für die einleitenden Schritte und Bemühungen, die erforderlich sind, um die genannten Anforderungen zu erfüllen.

Table of Contents Page

1. How Urgent is Nuclear Power to Saudi Arabia ?

It is convenient to state that Saudi Arabia is not in immediate need of nuclear power for a number of reasons, among which are:

(1) This country has gigantic petroleum reserves, as known to every one.
(2) Its local consumption of electricity is rather modest.
(3) When using nuclear fuels, the lack of home-made technology can result in high dependency on foreign suppliers and may even end up subjecting the country's power system to oscillations of policies that may take place in the supplier's country.

However, this is only one face of the coin. Its other face can be demonstrated as follows:

1.1 Keeping Pace with the Free World

In Saudi Arabia the industrial, agricultural, and economical development of the country is founded on close technological partnership with USA, Japan, and the leading countries in Western Europe. Likewise, the development of the power industry in the country must be seen within the frame of this same partnership. That is, the planning for the growth of the power industry in the country should be in correlation with the different electricity production tendencies now going on in these countries.

In most of the technological partner countries of Saudi Arabia, e.g. France, Germany, Japan, USA, etc., the share of nuclear power in electricity production is steadily growing, regardless of the several detestations suffered by the nuclear industry in these countries from time to time.

Keeping pace with this electricity production tendency in the supplier countries will be the most straight way to follow. Otherwise, in the long run the country will be faced with technological and economical burdens in case if it chooses to support and maintain on its own its traditional power system (based on oil and gas) which is to some extent diminishing in the supplier countries.

1.2 The Three Fronts of Petroleum

The petroleum reserve in Saudi Arabia is explored on 3 fronts:

(A) As the main source for foreign currency: Through exporting crude oil the country's economic and social development are financed.

(B) As the principle means for national income diversification: There is an organized effort from the government of Saudi Arabia to expedite the development of the country in the best systematic way, the 5-year development plans. These started in 1970, hence two plans have been already implemented. The third one is on the verge of execution. The development target is to diversify the national income by means of industrialization in the first place. However, the potential industries for the next couple of decades are of the energy intensive type (e.g. refinaries, petrochemicals, fertilizer industries, aluminum, steel making, etc) which are mostly dependent on petroleum as the primary raw material.

(C) As the main energy resource for implementing the development program.

1.3 Expansion in Electricity Consumption

The argument that the local consumption of electricity is modest does not hold firm any more. While in 1975 the total installed capacity was only 1256 MWe, it reached in 1980 around 5000 MWe. According to a study performed recently /1/, the installed capacity will expand five folds during 1980-2000.

1.4 Additional Energy Market

In Saudi Arabia, there is another remarkably fast growing market for thermal heat, namely desalination. Large desalination plants are now in operation on the west and east coasts. As of 1980, planned total capacity is around 600 thousand m^3 per day of desalted water. Accordingly the consumption per capita is nearly 0.3 m^3 per day. By the year 2000, this value will lift up to around 1 m^3 per day, whereas the expansion in desalination capacity can reach up to 5 million m^3 per day /1/.

This means, the demand for thermal input for desalination requirement (at the rate of 610 Btu per gallon of product water /2/) will be in the year 2000 nearly 8 times that in 1980.

The energy component cost makes up a substantial component of the desalted water cost /3/. It is then quite obvious that energy expenditure for desalination will constitute in the year 2000 a substantial part of the total energy bill. Thus with respect to desalination there is a high incentive for searching new alternatives of energy.

1.5 Reactor Centered Industrial Complexes

Industrial siting in the country is planned in the form of industrial complexes which can benefit from common energy supply sources. The necessary infrastructures are already erected to a large extent at two of such complexes, namely the Jubail industrial complex on the Gulf, some 90 km from Dammam, and the Yunbu industrial complex on the Red Sea.

Planned industries in these complexes are of the energy intensive type. For example, planned industries in Jubail include a gas gathering plant, a steel mill, an aluminum smelter, two refinaries for export of petroleum products and three petrochemical complexes.

In addition to such large complexes, smaller industrial estates are also growing at the main cities in the country. In this case the private sector is particularly active in cement manufacturing, flourmilling, food and beverage products, clothing, furniture, paper, plastics, and chemical products.

Both industrial complexes and industrial estates require permanent, reliable, and more important inexpensive energy supply source.

The nuclear power reactors which are fueled in most cases once annually are in position to provide the required various types of steam (e.g. injection, extraction, process steam), beside pure water, and of-course electricity. For example, an advanced type of reactor such as Fast Breeder Reactor (FBR) and High Temperature Gas Cooled Reactor (HTGR) can provide a refinary with hot gas or steam at the required temperature levels. For instance:

	(^{0}C)
Atmospheric Distillation	360
Vaccum Distillation	400
Gas-oil Desulfurisation	330
Catalytic Reforming of Carbohydrates	540
Steam Reforming of Carbohydrates	800-900

1.6 Reactor for Mining

Saudi Arabia is also endowed with vast mineral deposits. Rich veins of iron are found at several locations. Four million tons of 70 % iron ore together with 25 million tons 45 % ore and at least a 1000 million tons with a lower iron content has been already identified.

The substantial deposits recorded in the Arabian Shield suggest that this area could become the richest mining sector in the world. The deposits and their locations are shown in Figure 1.

The exploitation of these deposits and those in the Red Sea thus constitutes still a further future energy market in the country. As all industrial products in the country, the exploitation of the local minerals also must withstand the severe world market's competition. Lower energy expense is one effective measure to minimize production cost.

In this respect, the application of nuclear reactors to mining will be particularly advantageous due to the inherent feature of nuclear energy which tends to stablize the price per kilowatt-hour.

Generally in an oil power station, the cost of the fuel accounts for two thirds of the generating cost. This proportion will hold true even in Saudi Arabia if the calculation considers fuel transportation cost involving some 1200 km, from the oil fields located in the far East to the mining sites in the far West.

On the other hand, in a nuclear power reactor (e.g. Light Water Reactor, LWR), the cost of the fuel accounts for only one-fifth (using the plutonium recycling fueling option) of the generating cost. This cost, in turn, is made of a number of cost factors, namely cost of: natural uranium, enrichment, processing and manufacturing of fuel and fuel assemblies, and waste management.

Furthermore, the afore mentioned cost factors are completely independent of each other. Thus, unless prices of all items increase substantially and simultaneously, power generating cost will remain relatively insensative to price fluctuation in one or two items.

1.7 Tentative Conclusion

Having stated briefly the pros and cons, a conclusion may be made with respect to nuclear power in Saudi Arabia. We are of the opinion that this country may tolerate the absence of nuclear power up to the year 2000 but not much far beyond that.

In the vicinity of the year 2000, the first sign of industrial maturity will emerge. One backbone support of it, as planned now, will be the achievement of the required size of skilled man power.

However prior to reach such a level of industrial maturity it will be somewhat a compulsory measure to decelerate the governmental subsidizies which are now received by all production sectors in different forms and scales.

With respect to energy generating sectors the end effect of the gradual displacement of subsidizies will be to grade up the low fuel prices used nowadays to the scale of the oil export price. At point of time when this will happen (most likely in the vicinity of the year 2000), it is then the real impact of the fuel price on electricity and fresh water production that will surface and the need, as experienced internationally, for new energy alternatives will be realized.

Undoubtedly, solar energy will be one natural alternative energy source to petroleum in Saudi Arabia, a country with much solar assets /4/. Saudi Arabia's researches in the field of solar technology is in progress. But whether large scale solar power production will pass the threshold of the commercial viability during the next 25 years remains questionable. On the other hand, the most advanced nuclear fission reactor, namely the Liquid Metal Fast Breeder Reactor (LMFBR) will be commercially feasible in Europe as early as 1990 /5, 6/.

Let us keep in mind that the natural evolution of the power system in a country is thought to progress in phases: near term phase based on conventional energy supplies (e.g. petroleum, hydro, and coal), transition phase based on fission nuclear power, and far future phase based on fusion or solar energy.

Due to the oil reserves in Saudi Arabia on one hand, and its high solar potentiality on the other hand, some observers tend to think that it may be possible for this country from the resource point of view to circumvent the transition phase by stretching the time scale of the near term (based mainly on petroleum) up to the threshold of the commercial feasibility of solar energy or fusion. But the effort for stretching the near term phase will place the country in two predicaments:

First, the country's power system will remain static for at least 20-30 years to come which can jeopardize the achievement of an industrial maturity in the country through imposing the need for burning the readily available energy commodity (but more liable to become much expensive in the long run), namely petroleum, than consuming the less expensive one, nuclear fuel.
Second, during this static or freezing period of the power system, the country's experience in the field of nuclear power will remain completely absent. The set back in this case would be rather

severe if the country, say in the year 2000, will reach the conclusion that its power system cannot rely entirely on solar energy but rather on a combined system consisting of both solar and nuclear energy.

Moreover, turning the face to nuclear power in the year 2000 or 2010 would require still another 20 years or so to build up the necessary man power for executing a nuclear power program. During this period, again, the burden on petroleum as the principle energy resource will continue.

Thus, a 50 years petroleum based power system must be accounted for in case if Saudi Arabia does not plan to integrate nuclear power plants in the vicinity of the year 2000.

Therefore, we are of the opinion that while there is no such an urgent need for nuclear power during 1980-2000, this period is most conducive for an organized effort to conceive a nuclear vision and start preparing the required local staff of nuclear energy specialists.

2. Constraints Concerning the Introduction of Nuclear Power

In almost all developing countries, electricity is generated by small unit sizes. The electrical grids, if there are any, in these countries are not large enough for integrating nuclear power plants of the economical unit sizes, namely in the range of 500-1300 MWe.

The electricity generation in Saudi Arabia has been traditionally based on small units owned and operated by private companies but regulated and supervised by the government. A survey carried out by the Ministry of Central Planning (MCP) revealed that the total number of the electrical units in the country amounted in 1975 to 261 units having the total installed capacity of only 1256 MWe /7/.

Most of these small units were not interconnected. However, the planners realized that since electricity generating capacity was forcasted to reach in 1980 four times that in 1975, establishing integrated system will be most advantageous concerning the technical, man power, and investment requirements. Interconnection will result in both an organized distribution of electricity and the elimination of smaller units. It was made clear (in 1975) that to meet the electricity generation requirement in 1980 (i.e. 5335 MWe) the total number of units would be 204 (on the average of 20-30 MWe) for an integrated system compared to 560 (on the average of 10 MWe) units for nonintegrated system. Since then the governmental effort to establish interconnected grids were greatly intensified.

The planners conceived the erection of 3 national grids as shown in Figure 2. The largest is the one to serve both the eastern and the central parts of the country. As foreseen now, by 1990 these grids will be well established and it is possible that by the year 2000 they will be interconnected, forming one large national grid served by few modern power stations.

Since 1970, the Desalination Organization (DO) has emerged as a "production-partner" to the electricity companies. Desalination at many locations means in principle the dual production of electricity and fresh water. Table (1) shows the dual production planned capacity up to 1980. It reveals that electrical units of

200 and 500 MWe are already planned for integration. Hence, it seems logical to state that in future times small unit sizes will gradually disappear.

This means, in turn, what is seen now to constitute a high constraint, namely the small grid size, will not be actually of great worries in the future and especially at times of the introduction of nuclear power to the country, e.g. in the vicinity of the year 2000.

But Saudi Arabia is still faced with two main constraints; the first is due to lack of water for cooling and the second is due to having low population.

2.1 Constraint Concerning Cooling Requirement

Saudi Arabia is a large country, having the total area of 2149 690 km^2. This country was born without a single river. Average rainfall is less than 101.6 mm/y, except at the highland regions of the South-West where it can be up to 304.8 mm/y /8/. Underground water resources are abundant but only at certain locations.

The seas, the Red Sea in the West and the Gulf in the East, are now referred to for desalination and for cooling all systems that need to be cooled. Similarly, the first few nuclear power plants will be located on shores and cooled directly by sea water.

On the other hand, inland siting of nuclear power plants will be necessary for a number of reasons, among which is coupling of a reactor to mining industries at locations within the Arabian Shield. In this case, the highest constraint will be attributed to the requirement of large quantities of water for condenser cooling. In fact, the application of wet cooling tower for inland siting is just not practical on the account that a large Pressurized Water Reactor (PWR) station (e.g. 1300 MWe) operating under the Saudi desert condition will require daily over 100 thousand m^3 as make up water supply /1/. This is a tremendous amount of water for a desert location.

The only remaining alternative for all inland siting will be then the application of dry cooling towers. Compared to wet cooling, cooling with a dry tower imposes two penalities; a higher cost penality and a penality due to lower plant thermal efficiency. To compensate, reactors with higher efficiencies than water reactors, e.g. HTGR, FBR, will have to be considered in the long run for inland sitings.

2.2 Constraint Concerning Man Power

Compared to its large area and vast boundaries, the total population in Saudi Arabia is rather low. In the statistical indicator of the country issued in 1977, the 1974 census appeared to be 7.01 million /9/.

Available man power, both skilled and unskilled, runs always in shortage of the demand. It was forecasted that the demand for unskilled manpower will increase during 1975-1980 from 304,000 to 446,000 while the available unskilled worker in 1980 will be only around 296,000. During the same period, the demand for skilled labor will increase from 1,218,000 to 1,865,000. Thanks to vocational training centers in the country, the available skilled labor in 1980 will be around 1,100,000 /7/.

Due to such limits on skilled and unskilled man power, certain necessary and appropriate measures have been taken in the country in order to ensure that foreign workers can be obtained and retained in sufficient numbers to meet development requirements. Therefore, unlike in many parts of the world, foreign workers in Saudi Arabia are highly paid. This high payment policy is an appropriate measure for the time being. But if it extended to a longer period than necessary, it definetly leads to high production costs in the country which in turn can weaken the competetiveness of the local products with those imported.

In recognition of the needs for trained, skilled, and well-educated Saudi citizens, the development of man power occupies the highest priority in the country. So has been always the policy and practice since the early time of establishing the Ministry of Education, headed originally by the Crown Prince Fahd Ibn Abdulaziz.

The late King Faisal declared "We continue to drill wells for water and oil, but most important is the well of knowledge". The Saudi government kept this committment always alive; as much as 25 % of the national budget is now allocated for education.

Science, engineering, and related subjects are tought in 4 universities in the country. Vocational training is carried out independently of the formal education. Quite a number of vocational centers are established throughout the country to cater for industrial and service needs. The training program covers industrial induction, craft upgrading, on the job training, and instructor training. In addition, the Saudi government spares no effort in providing education abroad. A large number of Saudis are receiving higher education and job training at several qualified educational and vocational institutions in USA and western Europe.

However, it must be reminded that the development target in the country is to diversify the national income. For this particular reason, there are well defined priorities for which the available man power must be enlisted. This means, unlike many of the highly populated developing countries, in Saudi Arabia there is no surplus of college graduates and trained technicions that can be diverted for the purpose of in nuclear energy.

We should emphasize, however, that Saudi Arabia, as a late coming country, needs not to be engaged heavily in nuclear researches but rather make benefit of the technology which has been already developed in industrialized countries. We are convinced that most of the technological partner countries to Saudi Arabia will be willing to extend, through the concerned international agreements, the sound technology they have developed for peaceful application of nuclear energy.

This, however, does not mean that there should be no research efforts in Saudi Arabia. In reality, there are several problem which are particular to the region. To mention one, the application of nuclear reactors for desalination is not yet a reality in the free world. Hence, the technology of coupling a desalination plant to the cold end of the nuclear power station could be a task that Saudi Arabia could help to develop.

In the duel production case, the reactor is the heat source and the desalination plant is the heat sink. Thus, the shut down of one end will result in loss of the two products simultaneously. The question is: How high is the availability of a dual production station? These problems and other similar ones are not of much concern to developed countries; they, admittedly, could be best solved only by experienced inhabitants of the region.

Nuclear energy is one area where as many as possible native scientists and engineers must be involved. This field covers a wide spectrum of industries. If planned correctly, flow of technology to the country can be achieved in paralell to the erection of a reactor from its early conception.

Planning for the transfer of nuclear technology can be best accomplished by a local group of multidisciplinary character, being fully aware of the country's assets and limits and having full access to its regulatory channels.

Admittedly, it is quite true that consultance service from abroad can be always obtained. But the point to emphasize is that without having a local "nuclear intelligence" there will be only a loose link between the local industries and the newly coming nuclear energy with its multilateral technology, as has been seen too often the case in the past.

3. Recommendation Concerning Initiation Steps for Developing Man Power

In the following we state our opinion about how to proceed. There are two factors to consider:

(1) The advent of nuclear power is envisaged in the vicinity of the year 2000.

(2) There are high priorities for diverting human resources to areas other than the field of nuclear energy, coupled with a somewhat tight availability of man power in general.

Viewing from these two factors, the initiation steps to build up during the next 20 years the (minimum) required local man power are now discussed.

In the first place, a "nucleus" for the future nuclear energy organization must be established as early as possible. Let us call this "nucleus" as the Committee for Atomic Energy Promotion, abbreviated as (CAEP).

At its infancy, the CAEP should comprise at minimum of ten scientific members guided by a council in legislation and administration. The scientific majors of the CAEP members, mostly required on master and Ph.D. levels, should include: Nuclear Eng., Mechanical Eng., Electrical Eng., Industrial Eng. (Planning), and Chemistry and Physics.

The scope of the CAEP will be associated with the following responsibilities as arranged in descending order of priority:

First: Lay down the fundamentals for enabling the adoption of the required nuclear legislations for the protection of public health and safety and the environment from adverse impact which can result from peaceful application of nuclear energy.

Legislation and regulatory provisons are well established in many countries which, together with the advisory service of the IAEA, are willing to cooperate with all developing countries at request.

In this respect, the main task of the CAEP will be to review several nuclear regulations which are enforced at different countries, select the most proper provisions, identify areas of modification, and submit to the guiding council for adoption in accordance to the country's legislative and administrative patterns.

Whether the country will soon embark on a nuclear program or not, radioisotopes will be applied independently from time to time by specialists in medicine, ground water hydrology, industry, etc.. Whatever the scale of application is, there should be normal radiation protection measures in the country. Thus, the CAEP should establish the means for training in Healt Physics. Parallel to it, a health physic laboratory should be established in the country as early as possible.

Second: The CAEP next should dedicate itself to its most important task, namely formulating a program for the peaceful application of nuclear energy in view of the transfer of nuclear technology to the country.

Peaceful application of nuclear energy is understood throughout the world largely in two terms, power production and radioisotope technology. Thanks to the initiation of President Eisenhower, details of technology in these two areas are well documented by the IAEA, of which Saudi Arabia is a member state.

To be able to draw a reasonable program, the CAEP will have on one hand to employ the service of several adivisory committees and on the other hand to acquire a consultance service from competent bodies from abroad. The procedure should be in the following sequences:

(1) Define the potential applicants of isotopes in both public and private sectors (including accedemic research centers)
(2) Review the power system in the country (e.g. generation capacity, distribution pattern, man power, planned expansion, etc.)
(3) Survey present capacity of local industry and its planned future expansion.
(4) Compile data in order to have a clear reflection of the extent to which the country can benefit from introducing nuclear technology in the course of time.
(5) Conceive a nuclear program and determine the extent of technology transfer.

Having conceived a nuclear program, the CAEP will be able to cast light, to a large extent, on the necessary (minimum) local man power required for the implementation of the program at its different stages.

The next step is that the CAEP should split itself into two broad divisions; one which will grow to the form of a Regulatory Board (RB) and the other to the form of a Program Organization Body (POB). In this particular case, both divisions are conceived to be independent governmental agencies either as self autonomous bodies or joined under a greater governmental authority as in the form of an Atomic Energy Commission or so.

Concerning the structures of both the RB and POB, one cannot advocate any existing pattern, because they should reflect the constitutional system and administrative organization of the country. The size of each body will be proportionally dependent on the size of the program.

Concerning tasks and responsibilities, the RB will have to determine or adopt safety criteria and standards, and will be responsible for licensing, inspecting, and regulating the construction and operation of all nuclear facilities that the program calls for erection. The PO will be responsible for implementation of the nuclear program step by step, coupled with the preparation of the staff for Project Organization, Project Operation and Maintenance.

Concerning qualification of the RB and the supporting committees, the end goal should be to achieve experienced and knowledgable staff in the following fields /10/:

Chemical engineering
Civil engineering
Computation methods
Corrosion chemistry
Ecology
Electrical engineering
Geology
Health physics
Hydrology
Instrumentation and control
Mechanical engineering
Metallurgy
Meteorology
Nuclear engineering
Nuclear safety
Quality assurance
Reactor operations
Reactor physics
Reliability engineering
Seismology
Soil mechanics
Structural engineering
Thermohydraulics and heat transfer

Furthermore, since the implementation of the nuclear program will require the POB to engage on large organizational activities, as both to guarantee smooth transfer of technology and to prepare the required technical staff as predetermined, staff recruiting should look forward to experienced executives in all branches involving the transfer of technology.

Finally, a word concerning the technical preparation of specialists required by the Regulatory Body and those required for implementing the nuclear program:
To start with, the technical preparation can be carried out at selected research centers abroad along with teaching a carefully designed curriculum in nuclear technology at one or two universities in the country which should be especially equipped with nuclear energy facilities. Timing here is particularly sensative, because on one hand highly qualified staff must be secured from the early stage of the program and on the other hand too long a delay in implementation of the program will gradually

drain available qualified staff. An ideal case would be to build up man power in paralell to the step-wise implementation of the program.

4. Summary

On the international scenery, resources, economical, and technological aspects suggest that every country, at a point of time or another, should consider nuclear power. Oil producing countries are no exceptions.

On the local scenery, the oil producer Saudi Arabia steps rapidly toward industrialization with growing affinity for peaceful uses of nuclear energy in areas concerning:

Isotopes application in medicine, agriculture, industry, etc.
Nuclear power production
Nuclear desalination
Nuclear process heat application

We have the confidence that this highly stable middle eastern country will be readily assissted by all IAEA members in transferring the technology for peaceful application of nuclear energy.

However, on the account of several interrelated issues (e.g. economic, technical, health and safety, environmental, safeguards, and liabilities), the country must not rely solely on assistances received from abroad but rather found a local group to conceive the most conducive steps for the transfer of technology. Only a dedicated local group can put up most serious efforts and come out with a clear-sighted nuclear program for the country.

Absence of local participation at times of defining the nuclear program can simply inspire the consultant, or the "tutor" country, to recommend a program based on extrapolation of experiences gained from consulting one or several developing countries. The danger in this case is that too extensive a program, or the converse, can be recommended, which may in the course of time run into too many unforeseen serious difficulties which, in turn, may lead the whole program to a dead end.

Also, trained and experienced local staff are highly desirable for implementing the nuclear program and above all for regulating the entire nuclear activities in the country in order to assure save handling of radioactivity.

Fortunately, the country has sufficient lead time (e.g. the period 1980-2000) to prepare and train qualified staff to take up the responsibility of framing and adopting a nuclear program and later on executing it in the most organized way.

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East Coast

Plant Identification	Capacity m^3/d $(10)^3$	Year of Operation	Gross Electricity Product MW(e)	Inter. Electr. Consumption MW(e)	Product Ratio = W/E = $(m^3/d)/KW(e)$
Al-Khobar Phase I	28.5	1974	10	3.0	2.85
Al-Khobar Phase II	190.00	1980	500	20	0.38
Khafji Phase I	0.455	1974	--	0.05	--
Khafji Phase II	19.00	1979	50	2.0	0.38
Jubail Phase I	9.00	1977	25	0.95	0.38
Jubail Phase II	76.00	1979	200	8.0	0.38

West Coast

$(10)^3$

Plant Identification	Capacity m^3/d $(10)^3$	Year of Operation	Gross Electricity Product MW(e)	Inter. Electr. Consumption MW(e)	Product Ratio = W/E = $(m^3/d)/KW(e)$
Jeddah Phase I	19.00	1970	50	2.0	0.38
Jeddah Phase II	38.00	1977	80	4.0	0.475
Jeddah Phase III	76.00	1980	200	8.0	0.38
Al-Waji Phase I	0.228	1970	--	0.024	--
Al-Waji Phase II	0.455	1976	--	0.05	--
Duba Phase I	0.228	1971	--	0.024	--
Duba Phase II	0.455	1976	--	0.05	--
Duba Phase III	19.00	1979	50	2.0	0.38
Hagl Phase I	0.455	1979	--	0.05	--
Hagl Phase II	5.700	1979	15	0.60	0.38
Medine Phase I	76.00	1980	200	8.0	0.38
Rabig Phase I	0.91	1977	--	0.096	--
Al-Lith Phase I	0.46	1979	--	0.048	--
Qunfudah	3.800	1979	10	0.4	0.38
Farasen Phase I	0.455	1977	--	0.05	--
Yenbu Phase I	19.00	1979	50	2.0	0.38

Table 1:

The Dual Production Capacity up to 1980 in Saudi Arabia

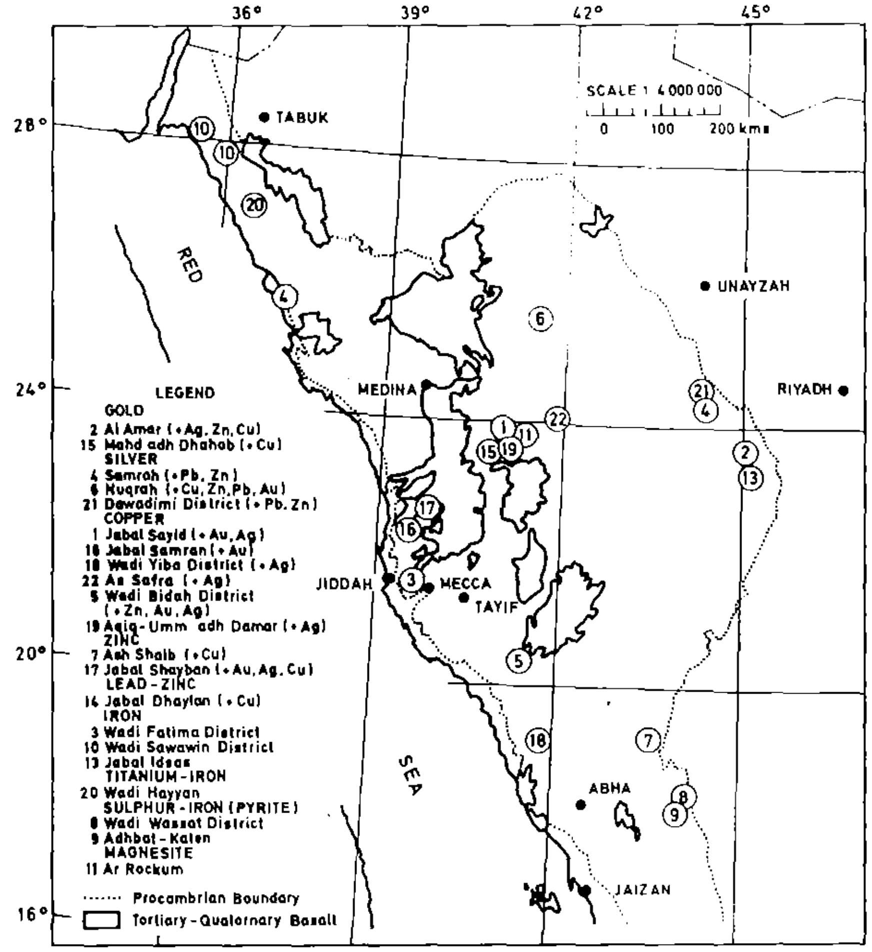

Figure 1:

Mineral Deposits in the Precambrian Arabian Shield /7/

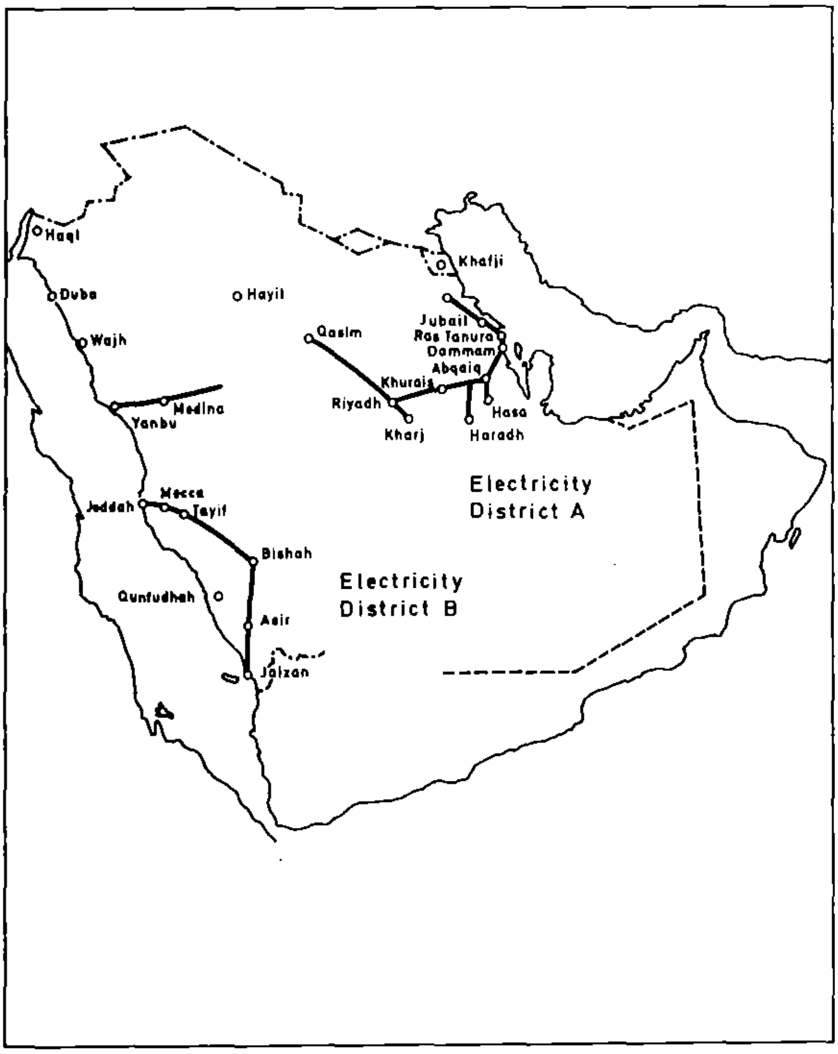

Figure 2:
Three National Electricity Grids in Saudi Arabia /1/