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Introducing Nuclear Power into Currently Non-Nuclear States

Abstract

As the nuclear renaissance gains momentum, many countries that currently have no nuclear power plants will begin to consider introducing them. It is anticipated that smaller reactors such as the Pebble Bed Modular Reactor (PBMR) will not only be sold to current nuclear states but also to states where there is currently no nuclear experience.

A range of issues would have to be considered for nuclear plants to be sold to non-nuclear states, such as the appropriate regulatory environment, standardisation and codes, non-proliferation, security of supply, obtaining experienced merchant operators, appropriate financial structures and education and training.

This paper considers nine major issues that need to be addressed by governments and vendors alike. International cooperation by organisations such as the IAEA, financial institutions and international suppliers will be required to ensure that developing countries as well as developed ones share the benefits of the nuclear renaissance.

The opportunities that the nuclear industry affords to develop local skills, create job opportunities and to develop local manufacturing industries are among the important reasons that the South African government has decided to support and fund the development of the PBMR project. These considerations are included in this paper.

Introduction

There are strong indications of a resurgence in nuclear power all around the world. Nuclear power has an excellent safety record. It is very reliable and has high load factors. Because the fuel is small in mass and easy to transport, nuclear power does not have the siting restrictions of coal or hydro power. Reserves of uranium are abundant and fairly evenly spread around the world, and nuclear fuel has more price stability than gas or oil. Nuclear power is exceptionally clean, and over the full energy cycle releases very low amounts of greenhouse gases per kilowatt of electricity produced. Nuclear power is economically competitive and for many countries the cheapest source of electricity. For all these reasons, countries that now have no nuclear power are beginning to consider adopting it for some of their future electricity supply.

Some of these countries, such as Australia and Italy, have advanced economies and mature political, financial and legal systems. Some, such as Nigeria and Iran, do not. Every country developing nuclear power for the first time will have to set up political, legal, regulatory, financial, commercial, management and educational systems for accommodating it. This paper gives an outline of the considerations in setting up these systems.

This paper divides the systems needed to adopt nuclear power successfully into nine areas:

1. Political enabling framework;
2. Regulatory framework;
3. Responsible owner;
4. Responsible operator;
5. Finance;
6. Contract management;
7. The fuel supply and waste management framework;
8. Training and education; and,
9. Industrial infrastructure.

The setting up of these systems is not only necessary for a successful nuclear power programme but brings benefits of its own in the economic development of the country in question. It helps to build up technical, legal and financial skills there.

1. Political enabling framework

The government of the country must be the highest authority for its nuclear power programme. No such programme is possible without the full approval of the government.

Nuclear policy, including the use of nuclear power and the operation of all nuclear facilities, must be part of a framework approved by the government. There must be enabling legislation to bring this about.

The government of any country acquiring nuclear power must sign and comply with all the provisions of the international Nuclear Non-proliferation Treaty (NPT). Most countries supplying nuclear equipment, including South Africa, will refuse to allow their vendors to deal with countries that have not signed the NPT.

When a nuclear power station is being sold from a vendor in one country to a customer in another, there must be good cooperation and understanding between the two governments in question.

All governments with nuclear power so far underwrite or limit nuclear liability. This will probably be necessary for new countries acquiring nuclear power.

The government acquiring nuclear power might want to provide incentives, such as tax relief, special terms of trade or reciprocal arrangements, in order to stimulate and facilitate the introduction of nuclear power for the first time in a country. The U.S.A. has provided incentives to initiate a new build programme.

Wrong public perceptions have been one of the greatest problems for nuclear power. The new country acquiring it should embark on a major programme of public education on nuclear power, explaining how it works and what its advantages are. It should meet all the perceived problems, such as radiation, safety, weapons proliferation and waste disposal, head-on, shrinking from none of them. It should take the public fully into its confidence from the very beginning. It should not wait to react to anti-nuclear organisations but pre-empt them and reach the public before they do.

2. Regulatory framework

Every country adopting nuclear power must set up a regulatory framework for it. It will already have an electricity regulator, an environmental regulator and inspection authorities and these can relatively easily be adapted to encompass nuclear power. However, a nuclear regulator, which will be new, must be established. The nuclear regulator will have final and complete authority over all safety aspects of the building and operation of the power station, and of waste disposal and decommissioning.

The new country must choose its nuclear regulatory system with care. The three vital criteria in this choice are (i) suitability for the country; (ii) clarity; and, (iii) consistency. A full system of nuclear regulation is complicated and it would not make sense for any new country to devise one from scratch. Instead, it should adapt a regulatory system already working well in an established nuclear power country. There is a tendency for the new country to adopt the nuclear regulations of the vendor country. This route must be regarded with caution. What if there are vendors from different countries? There could then be different nuclear regulations within the host country, leading to inconsistency, which should be avoided at all cost. The best route seems to be to choose the regulations of the existing nuclear power country whose conditions are closest to the new country's and to adapt them to suit local circumstances and the likely new power stations.

To give just one consideration in deciding on the nuclear regulations, should acceptable nuclear risk be based on deterministic evaluation or on Probablistic Risk Assessment (PRA)? The latter, and more modern, route might well be deemed more logical by any new country acquiring nuclear power.

It would be most useful if the International Atomic Energy Agency (IAEA) could review and approve of the nuclear regulations drawn up by a new nuclear power country.

In the case of South Africa's Pebble Bed Modular Reactor (PBMR) Company selling PBMR units to a country currently without nuclear power, South Africa's National Nuclear Regulator (NNR) could assist that country in drawing up its nuclear regulations.

The government will also have to help set up safety regimes such as emergency evacuation plans where necessary. (However, the risk from any modern nuclear power station of an accident that would require the mass evacuation of the local population is much lower than the risks from other industrial activities, such as oil refining or chemical production, which do not have emergency evacuation plans, and a rational government might well decide to dispense with them.)

3. Responsible owner

The owner of the nuclear power station in the new country might be part of the government itself or a private company. Either way it must operate within the policy framework of the government. The owner must have the managerial capacity to do this.

The owner must undertake feasibility studies and prepare a bankable business plan. He must be part of the process of selecting the site and establishing its ownership. Submissions to all regulatory bodies must be done in the name of the owner. The owner must conclude agreements with the owner of the transmission infrastructure (within the country and across borders where applicable). He must make pooling arrangements with other generators and transmission systems where applicable.

The owner must have the financial and commercial ability to engage with the vendor.

The owner must raise equity finance to fund the initial costs.

4. Responsible operator

The operator of a nuclear power plant is not necessarily the same as the owner. There are many examples of international merchant operators that operate plants and systems on behalf of countries or utilities. South Africa's Eskom is, however, owner and operator.

The responsible operator must have the required nuclear operating experience. He must, for example, have the required number of licensed nuclear operations staff for the relevant nuclear power station.
The responsible operator must accept responsibility for commissioning, operating and maintenance. In terms of the IAEA position, the operator is fully liable and a responsible operator must be able to assume that responsibility.

In a country that has not had nuclear power before, the responsible operator must undertake the training of local operating staff. This includes the instilling into the local staff of a safety culture. This requires a considerable understanding of how the nuclear plant works, what could go wrong, how to prevent its going wrong and how to deal with it if it does go wrong. The need for constant vigilance and high standards must ceaselessly be emphasised.

5. Finance

Power stations, vital for any modern economy, are enormously expensive. Many countries acquiring nuclear power for the first time will be developing countries, where the financial undertaking will be proportionally much greater. It is essential that the financing of the new nuclear power station and the revenue stream eventually coming to it should be planned and implemented with the utmost clarity and certainty.

Government support is essential for the financing of any nuclear power plant in a developing country, such as any country in Africa.

Finance may be raised through equity and debt. A 50/50 ratio is usually accepted as the best way of sharing risk and opportunity, but this would depend on local conditions. In developing countries, where risk is usually regarded as being higher than in developed countries, the costs of debt are also likely to be higher.

Debt could be raised through commercial loans, loans from export credit agencies, loans from international finance agencies, or from the issuing of bonds. Each country would have to calculate and decide upon the best selection for itself. Local circumstances will determine the best choice.

Absolutely crucial for the economic success of any new nuclear power station (or any power station for that matter) is the revenue from the electricity customers. There must be clear and suitable tariffs that everyone can see and understand. Political pressures for subsidies must always be resisted except if a limited subsidy for small amounts of electricity to the very poor is shown to be economically viable.

There must be an effective, honest and universal infrastructure for collecting electricity fees. Any prospect of stealing electricity will act like a cancer on the economic health of the electricity supplier. Political pressures must never be allowed to bend the simple rule that the electricity consumer must pay for what he consumes. Otherwise, the electricity supply industry will be endangered.

The government of a developing country might well and usefully decide to provide incentives for new customers to switch to electricity, for example by subsidising the costs of installation of an electrical connection to a township household. Such measures can be greatly beneficial, socially and economically, as long as they are strictly limited and clearly understood by all to be so.

6. Contract management

In the long process of building a power station, perhaps no step is as critical to its success as the setting up of the contracts to supply and construct it. For both the vendor and the buyer the stakes are very high. Setting up the contracts can be lengthy and often unavoidably so.

It is essential that the customer compiles his User Requirement Specification (URS), detailing exactly what he requires in terms of reliability, efficiency, economy and availability of electricity supply from the proposed power station.

The type of contract will depend upon local conditions and local preferences. There are three broad categories of business models for the contract.

The first is the State model where the State electricity utility, backed by State guarantees, implicit or explicit, deals with the vendor. This is the model used by France, India, China, Russia and South Africa. This might not sit well with supporters of free enterprise, but the fact of the matter is that it has delivered to France a highly efficient and reliable electricity supply and to South Africa the cheapest electricity in the world. Electricity supply, which delivers an unchanging product (the electricity we receive in 2006 is no different from that we received in 1906) and which is cheapest when investors can accept a low return over a very long period, is an important exception among most of the goods of a modern economy. This State model might well be the best for most developing countries, indeed for most developed countries.

The other two models are mixtures of private enterprise and State guarantee. In Finland, corporate funds finance the new nuclear power station, accepting long term returns from electricity fees, and the State accepts liabilities for

waste disposal and decommissioning. In the U.S.A., where this is proposed but not yet implemented, private enterprise will fund the nuclear power station but the State will give loan guarantees, investment protection against delay and production tax credit.
The contract may be costed on "cost plus" or on "fixed price, fixed schedule, guaranteed performance". The latter is almost always preferable as it enforces discipline upon the vendor and gives certainty to all parties.

The contract may be "turnkey", where a single general contractor is responsible for all of the plant, or it may be made up of several contracts for different parts of the plant with an architect engineer and project manager controlling the whole construction. Turnkey contracts will usually be more suitable for developing countries building their first nuclear power station.

Contracting for any power station is complex and the buyer country must have the ability to compile the tenders and adjudicate them. If it does not have this ability, it must use carefully selected consultants to provide it.

7. The fuel supply and waste management framework

Most nuclear power reactors use enriched uranium as their fuel. Some, such as the CANDU reactors, use natural uranium with heavy water as a moderator. In either case, the buyer country must set up nuclear fuel supply agreements (and heavy water supply agreements in the case of CANDU) and establish systems for managing nuclear waste and eventually decommissioning the power station.

The uranium fuel needs to be mined, refined, usually enriched, and then fabricated into the final form for the reactor in question. The buyer must beforehand enter into agreements with the nuclear plant vendor or with other suppliers to ensure a secure supply of finished nuclear fuel.

It will seldom, if ever, make economic sense for the new buyer country to enrich and fabricate its own nuclear fuel. It will be much cheaper simply to buy it from a selection of large international suppliers. Since nuclear fuel is easy to store and since there is competition between suppliers, the fact that a country does not provide its own finished fuel does not jeopardise its security of supply.

The buyer country must establish a nuclear transport policy within the framework of nuclear regulations. The transport routes, by ship, rail and road, must be clearly delineated and the communities through which they pass well informed about them. Containers for the fuel must ensure isolation of the fuel and protection against criticality. It would make sense for the new buyer country simply to use existing container design and fuel transport management of nuclear power countries with the same type of reactors.

Agreements must also be entered with the fuel conveyors (shipping, road and rail companies).
The management of nuclear waste is simple technically, but fraught with political difficulties. Nuclear waste in fact presents much less danger to the public than the waste from other industries or from coal power stations but it is perceived by the public as presenting special problems. The new country acquiring nuclear power should from the outset establish and publicise a management system for handling, containing and storing nuclear waste. Low level and medium level waste can be sent to carefully selected places of final disposal as is done in existing nuclear power countries. For high level waste (spent fuel), the new nuclear power country would probably do best to "wait and see", simply watching the progress of countries such as Sweden, Switzerland and the USA in setting up final depositories. Once these are completed and approved, the new country could follow the example of one of them. High level waste is very small in volume, and any new nuclear power country could store it for decades on the site of the power station.

There is at present political resistance against the idea of one country storing the nuclear waste of another country. This is irrational. In the same way as some countries have the advantages of mineral reserves for exporting minerals or good agricultural conditions for exporting foodstuffs, so some countries have the advantage of large, barren, arid, unpopulated, geologically stable areas that would be ideal for storing nuclear waste. Such countries could make money from storing other countries' waste. This is not politically feasible now, but in future it might well be.

The new nuclear power country must have clear policies on decommissioning and clear agreements on it. Decommissioning of the nuclear plant must be accounted for before the plant is built. Successful decommissioning has already been accomplished in nuclear plants such as Shippingport and Maine Yankee in the U.S.A. Decommissioning of modern nuclear plants will be easier because their design considers it and because of increasing experience with it. Funds must be allocated to decommissioning from the outset.

8. Training and education

The building of a nuclear power station in a country that has not had nuclear power before offers a huge opportunity to increase the skills of the country and to stimulate employment.

There should be technology transfer agreements between the vendor or the vendor country and the buyer country.

The vendor country could help set up training institutions and structures to train engineers, scientists, technicians, operating staff, artisans and inspectors.

During the building, commissioning and operation of the first nuclear plants, local engineers, technicians, artisans and operators should always work closely with those from the vendor country to learn from them.

Existing universities and technical colleges in the buyer country could be helped to set up courses for nuclear engineers, reactor physicists and health physicists. The country could have its own research and development initiatives arising from nuclear power in fields such as materials research, radiation science, specialised nuclear engineering component manufacture and so on.

The sheer presence of the nuclear power station will act as a centre for technical and scientific awareness, stimulating study in physics and engineering, introducing people for the first time to the practical reality of nuclear energy being harnessed to provide ordinary citizens with electricity.

9. Industrial infrastructure

The new nuclear power station will require a local infrastructure to support it. Local skills and industry should be used as far as possible to build and maintain this infrastructure. Where it is not possible, there should be industrial technology transfer from the vendor or vendor country to the buyer country.

"Localisation", that is, the replacement of foreign capacity with local capacity in manufacturing, constructing and commissioning nuclear power stations, is highly desirable and will help greatly in the industrial development of the country. Localisation is unlikely to occur when only one or two reactors are built. However, the more reactors, the greater the advance of localisation. This strengthens the case for smaller reactors such as South Africa's PBMR, which has a capacity of 165 MWe. Six PBMR units will stimulate far more localisation than one 1000 MWe conventional reactor.

Since nuclear power does not have the siting restrictions of hydro, coal or even gas power stations, the nuclear plant can be sited close to the electricity users, either near cities or industrial centres. This will reduce the need for long transmission lines. At the same time it will help strengthen the local electricity grid, bringing more stable and reliable electricity to the users. The nuclear plants could act as hubs of an electricity supply industry that would gradually extend transmission lines across the country as it develops.

Conclusion

It should be clear from the preceding that a number of very important issues need to be taken into account by states that are keen to introduce nuclear power into their countries. To enable many countries that require access to this energy source, a new international cooperative framework will have to be established to facilitate and assist countries in this regard. Governments, international organisations such as the IAEA, Development Finance Institutions and vendors will have to find cooperative mechanisms to provide the necessary support and advice.