# Regional co-operation in Asia and the Pacific: Energy, electricity, and nuclear power planning

*Through an IAEA technical co-operation programme, countries are acquiring experience in analyzing their energy options*

by J. Easey and P. Molina

Over the past 5 years, countries in the Asia and Pacific region have been working together through an IAEA co-operative programme to study their energy futures. The work has been done through a series of workshops and training courses arranged under the Regional Co-operative Agreement (RCA) for Research, Development, and Training Related to Nuclear Science and Technology, which was first launched in 1972. Since then, 15 countries in the Asia and Pacific region — Australia, Bangladesh, China, India, Indonesia, Japan, Republic of Korea, Malaysia, Mongolia, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Viet Nam — have become RCA members.

Over the past decades, an extensive range of RCA activities has been implemented, mainly in the fields of agriculture, industry, medicine, radiation protection, and basic nuclear science. In 1987, the programme's scope was enlarged by the initiation of the project on energy and nuclear power planning. Its principal focus was to build national experience in the use of two energy and nuclear power planning models, namely the Model for Analysis of Energy Demand (MAED) and the Wien Automatic System Planning Package (WASP). The project, originally set up for a duration of 4 years, was effectively carried out through 1992. In July 1993, national participants in the project, meeting in Jakarta, recommended its extension.

This article reviews activities under the RCA energy project, and reports on the recommended course of action for the project's next phase.

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## Economic and energy background

Over the last decade, RCA countries, along with some others in the Asia and Pacific region, have experienced rapid economic growth that largely surpasses that of other regions in the world. This has translated into improved standards of living and, quite naturally, a rise in the demand for products and services. These and other aspects have contributed to increased demand for energy in general and electricity in particular throughout the region, with some countries having very high annual growth rates.

While the figures give an impressive indication of the economic performance of RCA countries, these results need to be considered with indices expressed on a *per capita* basis. *(See tables.)* Wide disparities can then be seen between some RCA countries. Their *per capita* gross domestic product (GDP) varies from about US $130 (constant 1980 US dollars) for Viet Nam to around US $13 000 for Australia and Japan.

Similarly, *per capita* energy consumption in 1991 varied widely among RCA countries. The upper range was represented by Singapore, where *per capita* consumtion was 6667 kilograms of oil equivalent (kgoe) and Australia, where it was 5033.5 kgoe. At the other end of the spectrum were Bangladesh, with 77.4 kgoe and Viet Nam, with 148.4 kgoe. The average for RCA countries in 1991 was about 676 kgoe. This was less than half the world average, which was about 1583 kgoe in 1991.

*Per capita* electricity production in 1991 for RCA countries also followed a wide range. At the upper end were Australia (8533 kWh) and Japan (7129 kWh), while at the lower end were Bangladesh (67.1 kWh) and Viet Nam (120 kWh). It is of interest to note the high levels attained by countries like Singapore (5725.4

kWh) and Mongolia (1291.7 kWh). Nevertheless, the average *per capita* electricity consumption for RCA countries was 817.4 kWh, compared with the world average of 2195 kWh in 1991.

One possible explanation for the impressive economic growth in Asia lies in current patterns of trade within the region. Regional trade is becoming steadily more important and is expected to surpass trade with other regions of the world in the future. This will make the region more self-reliant. Economic growth in Asia is projected to continue for some years to come and this will have a great impact on the demand for energy in general and electricity in particular.

Economic development alone will force an increase in energy required to produce the goods and services expected to fuel development in the export sector. At the same time, greater demand for energy will be needed to satisfy domestic needs of the population.

Electricity's share of total energy demand is expected to increase throughout the region. Such has been the case in industrialized countries. In Asia, many countries are going through an industrialization process which will bring the installation of new, modern factories that use electricity more intensively. Additionally, the rate of electrification will increase attempts to bring services to all non-electrified villages. In turn, *per capita* energy consumption will tend to go up as the population requires more household appliances that use electricity.

From the supply side, it is recognized that the region has sufficient energy reserves to support the expected demand. Nevertheless, there are some complications. Firstly, resources are not evenly distributed within the region and not even within the countries where they are located. In addition, in many cases the principal centres of energy demand are located far away from the reserves. The problem is compounded in countries with specific geographical conditions (insular), or which lack adequate transportation infrastructures.

Such factors illustrate the need for careful planning of future facilities for energy and electricity production.

To date, countries in the region have made strong efforts to plan their energy and electricity systems. However, the efforts will have to be intensified in the future as primary energy resources become scarcer and demand continues to increase. In addition, investments in the energy/electricity sector will be highly competitive with other investments required for overall socio-economic development in areas of health care and education, for example. Furthermore, adequately balancing the energy supply/demand equation has become more complex with growing consideration of environmental issues.

In the case of electricity, all electricity production chains will have to be carefully assessed, primarily because of electricity's rising projected share of total energy. Systems based

***Average annual growth rates for RCA member countries (1980-91)***

| *Data in per cent* | Population | GDP 1980-90 | Energy consumption | Electricity production |
|---|---|---|---|---|
| Australia | 1.52 | 3.21 | 2.08 | 4.00 |
| Bangladesh | 2.56 | 3.45 | 5.95 | 11.60 |
| China | 1.48 | 8.73 | 4.49 | 7.63 |
| India | 2.07 | 5.74 | 5.09 | 9.74 |
| Indonesia | 2.00 | 4.70 | 3.94 | 11.28 |
| Japan | 0.55 | 4.25 | 2.30 | 4.41 |
| Rep. of Korea | 1.27 | 8.71 | 6 56 | 11.78 |
| Malaysia | 2.65 | 5 95 | 7 40 | 9.96 |
| Mongolia | 2.78 | 6.05 | 2.49 | 7.59 |
| Pakistan | 3.27 | 6.15 | 6.33 | 11.21 |
| Philippines | 2.49 | 1.72 | 2.04 | 1.98 |
| Singapore | 1.15 | 6.98 | 4 88 | 8.31 |
| Sri Lanka | 1.49 | 4 25 | 2 76 | 6.66 |
| Thailand | 1.56 | 7.49 | 5.75 | 12.03 |
| Viet Nam | 2.18 | 4.54 | 0.19 | 6.89 |
| Average for RCA countries | 1.80 | 5.33 | 3.97 | 6.53 |

***Per capita gross domestic product (GDP), energy consumption, and electricity production in RCA member countries***

| | Per capita GDP (1980 US $) | | Per capita energy consumption (kg oil equivalent) | | Per capita electricity production (kWh) | |
|---|---|---|---|---|---|---|
| | 1980 | 1990 | 1980 | 1991 | 1980 | 1991 |
| Australia | 10 674 | 12 595 | 4 735 | 5 033 | 6 542 | 8 533 |
| Bangladesh | 171 | 186 | 54 | 774 | 29 | 73 |
| China | 293 | 584 | 473 | 652 | 288 | 549 |
| India | 251 | 356 | 239 | 329 | 161 | 358 |
| Indonesia | 517 | 670 | 422 | 519 | 90 | 233 |
| Japan | 9 068 | 13 006 | 2 953 | 3 573 | 4 708 | 7 129 |
| Rep. of Korea | 1 637 | 3 318 | 1 156 | 2 024 | 997 | 2 956 |
| Malaysia | 1 779 | 2 439 | 760 | 1 252 | 697 | 1 486 |
| Mongolia | 835 | 1 142 | 1 424 | 1 380 | 781 | 1 292 |
| Pakistan | 328 | 431 | 222 | 306 | 172 | 389 |
| Philippines | 724 | 669 | 457 | 435 | 356 | 337 |
| Singapore | 4 853 | 8 494 | 4 478 | 6 667 | 2 700 | 5 725 |
| Sri Lanka | 279 | 364 | 242 | 278 | 111 | 192 |
| Thailand | 688 | 1 211 | 522 | 813 | 310 | 913 |
| Viet Nam | 105 | 132 | 184 | 148 | 73 | 120 |
| Average for RCA countries | 842 | 1 183 | 536 | 676 | 496 | 817 |

*Note Data are rounded*

**Power reactors in RCA member countries**

| | Power reactors | | | | Nuclear production/share of total electricity | | Operating experience | |
|---|---|---|---|---|---|---|---|---|
| | In operation | | Under construction | | | | | |
| | No. of units | Capacity MWe net | No. of units | Capacity MWe net | TWh electric | % of total | Years | Months |
| World total | 424 | 330 651 | 72 | 59 720 | 2027.4 | 16.7 | 6479 | 9 |
| ***RCA members:*** | | | | | | | | |
| China | 1 | 288 | 2 | 1 812 | 0 5 | 0.1 | 1 | 1 |
| India | 9 | 1 593 | 5 | 1 010 | 5.6 | 3.3 | 101 | 3 |
| Japan | 44 | 34 238 | 9 | 8 129 | 217 0 | 27.7 | 556 | 11 |
| Korea, Rep. of | 9 | 7 220 | 3 | 2 520 | 56.5 | 43.2 | 72 | 1 |
| Pakistan | 1 | 125 | 0 | 0 | 0.5 | 1.2 | 21 | 3 |
| Total RCA | 64 | 43 464 | 19 | 13 191 | 280.1 | 17.2 | 752 | 7 |
| Per cent of world total | 15 1 | 13.1 | 26.4 | 22.6 | 13 8 | | 11.6 | |

on the burning of fossil fuel particularly would need to be assessed in terms of their environmental impacts. Renewable energy sources and nuclear power, although accepted to be generally more benign to the environment, would have to be assessed in terms of their industrial requirements and the fuels needed for manufacturing and construction of the plant, processing or fabrication of the fuel, and disposing of the wastes. These comparative assessments not only will have to look at the fuel being burned in a plant, but at all aspects related to the fuel's use in the plant, whose construction itself will have to be addressed. In this respect, a nuclear power plant shows the advantage of having practically no atmospheric emissions compared to a fossil-fuelled plant. However, concerns still exist with regard to the disposition of the spent nuclear fuel.

**Estimates of world energy, electricity, and nuclear power consumption**

Currently the demand for electricity in RCA countries is largely met by hydrocarbons and this trend will continue in the future. At present, nuclear power accounts for about 10% of the total electricity capacity of the region and close to 12% of the total electricity generation. This is largely due to the installed nuclear capacity in Japan and Republic of Korea. *(See table.)* Only five RCA countries have nuclear power reactors in operation (China, India, Japan, Republic of Korea, and Pakistan). At the end of 1992, these countries had 64 power reactors in operation with a combined capacity of 43 464 MWe (net), altogether representing about 13% of the total nuclear capacity worldwide. The same countries have 19 power reactors under construction with a combined capacity of 13 191 MWe (net). If brought on line as scheduled, these plants will increase the RCA group's share of worldwide nuclear capacity to about 15% by the year 2000.

Beyond 2000, this share is expected to increase further from the introduction of nuclear power in some other countries. Indonesia, for example, is undertaking a feasibility study for a nuclear power project targeted for operation by

| Country Group | 1992 | | | 2000 (estimated range) | | | 2010 ( estimated range) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total energy use (EJ) | Electricity share (%) | Nuclear's electricity share (%) | Total energy use (EJ) | Electricity share (%) | Nuclear's electricity share (%) | Total energy use (EJ) | Electricity share (%) | Nuclear's electricity share (%) |
| North America | 92.1 | 38.2 | 7 3 | 94 - 95 | 40 - 43 | 7.2 - 7.3 | 95 - 99 | 43 - 50 | 7.3 - 7.4 |
| Latin America | 23.7 | 27.5 | 0.5 | 30 - 32 | 30 - 31 | 1.0 - 1.1 | 40 - 45 | 35 - 36 | 1 0 - 1.2 |
| Western Europe | 60.2 | 38.8 | 11 9 | 63 - 64 | 42 - 43 | 12 | 66 - 68 | 47 - 50 | 10 - 13 |
| Eastern Europe | 70.9 | 29.2 | 3.5 | 72 - 73 | 32 - 34 | 4.3 - 5.1 | 73 - 76 | 35 - 40 | 5.2 - 7 5 |
| Africa | 15.5 | 20.8 | 0 6 | 20 - 21 | 21 - 22 | 0.5 | 28 - 30 | 22 -23 | 0.4 - 1 0 |
| Middle East & South Asia | 27 3 | 21.5 | 0.2 | 34 - 35 | 24 | 0.5 - 0.7 | 45 - 49 | 27 -28 | 0.5 - 0 9 |
| South East Asia & the Pacific | 13.6 | 24.4 | | 17 - 18 | 27 | | 23 - 25 | 31 - 32 | 0.2 - 0 8 |
| Far East | 62.7 | 30.6 | 4.7 | 73 - 76 | 33 - 34 | 5.8 - 6 5 | 90 - 98 | 35 - 38 | 6 1 - 7 8 |
| World Total | 366.0 | 32.1 | 5.3 | 403 - 414 | 34 - 35 | 5.5 - 5.8 | 460 - 490 | 37 - 40 | 5 2 - 6.4 |

*Source IAEA Reference Data Series 1 (July 1993)*

the year 2005. Similar studies are expected to be undertaken by other countries. *(See related article in this edition beginning on page 2.)*

Based on existing trends, nuclear power is likely to make an important contribution to the future development of RCA countries. Careful planning, however, will be needed concerning both the construction of plants and, later, their safe operation. This calls for timely decisions in both areas. The planning takes on greater importance for the introduction of the first nuclear power reactor into the electrical grid of a country.

## The RCA energy planning project

In 1987, approval was given for a project on Energy and Nuclear Power Planning (ENPP) as part of the RCA programme.

The project's basic aim was to promote regional co-operation in energy and nuclear power planning by focusing on experience acquired by RCA countries in the use of the IAEA's computer models, known as MAED and WASP. Workshops, training courses, and other activities were organized for this purpose.

**Workshops.** The first workshop was held in Jakarta, Indonesia, 7-11 December 1987, and dealt basically with the WASP model. Its basic objective was the exchange of information and experience among countries in the use of the WASP methodology for planning expansions to electric systems, including nuclear power planning. A second objective of the meeting was to consider whether improvements were needed to the WASP program for better adaptation to the needs of countries in the region.

Three similar workshops followed: in Kuala Lumpur, Malaysia, 5-9 December 1988, which incorporated the MAED as well as WASP methodology; and in Beijing, China, 4-8 September 1989; and Daejon, Republic of Korea, 27-31 August 1990. The last two workshops additionally incorporated discussions on the importance of environmental issues with respect to energy and electricity planning.

Each workshop featured national presentations by participants that reviewed the status of energy, electricity, and nuclear power in their countries. This enabled the exchange of factual data and offered participants the opportunity to jointly identify major problems and formulate recommended courses of action. The MAED and WASP planning models were recognized to be very powerful tools for energy and electricity planning, and participants recommended the organization of regional training courses to provide specialized training for experts from the region.

**Training courses.** Two sets of regional training courses were arranged under the RCA project.

One set, following the recommendations made at the workshops, was organized on the subject of planning for electric system expansion. The first course was held at the Asian and Pacific Development Centre (APDC) in Kuala Lumpur, Malaysia; it was hosted by the Government of Malaysia, co-hosted by the APDC, and co-sponsored financially by the Asian Development Bank (ADB). Support was also obtained from the World Bank (IBRD) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). The second course was held at the Water and Power Development Authority (WAPDA) in Lahore, Pakistan; it was hosted by the Government of Pakistan through WAPDA and the Atomic Energy Commission of Pakistan, and co-sponsored financially by the ADB. Other support was provided by ESCAP, and by the Government of Canada through a project of the Canadian International Development Agency (CIDA) that is being carried out by ACRES International Ltd. for Pakistan.

These courses principally emphasized the linkages between energy planning, including electricity planning, and other sectors of the economy. In particular, the participants were trained in the use of the IAEA's electric system expansion planning methodology and the computer program WASP-III in its personal computer version. In each course, teams of two or three participants from the same country carried out case studies using their national data. Lecturers for the courses came from countries in and outside the region, as well as from the ADB, ESCAP, IBRD, and IAEA. A total of 58 energy and electricity planners from 10 RCA countries received training through these courses.

Another set of regional training courses was organized under a special contribution by the Republic of Korea. This set mainly focused on nuclear power project planning and implementation. Held during 1988-91, these 3-week courses were organized by the Korea Atomic Energy Research Institute (KAERI) in Daejon and included a sequence of topical subjects based on the Korean experience. Altogether, 64 specialists, including 54 from 11 RCA member countries, participated in these training courses. Most participants had extensive experience in the field of nuclear science and technology.

The courses primarily sought to provide participants with practical skills and methods in areas of nuclear power plant management, ranging from feasibility studies and bid evaluations to commercial operation. The final course par-

ticularly focused on the development of organizational, industrial, and manpower infrastructures that are essential for embarking on a nuclear power programme.

Most course lecturers were provided by the Republic of Korea and included experts from KAERI and other Korean companies, such as Korea Power Electric Corporation, Korea Power Engineering Company, Korea Heavy Industries Construction Company, Ltd., and universities. Several rounds of discussions on specific subjects were held in each course to highlight the experience gained from different approaches for planning nuclear power programmes. Also included were visits to nuclear and related sites and practical demonstrations of technology, such as nuclear plant simulators.

## Future activities of the project

In July 1993, at the Project Formulation Meeting for the RCA project on energy and nuclear power planning, participating countries explored future needs and directions. The meeting was hosted by the Government of Indonesia and organized by its National Atomic Energy Agency (BATAN) at its facilities in Pasar Jumat. Attending were National Co-ordinators from Australia, Bangladesh, China, India, Indonesia, Republic of Korea, Malaysia, Mongolia, Pakistan, Philippines, Sri Lanka, Thailand, and Viet Nam.

In reviewing the project, the National Co-ordinators agreed that the first phase had been very useful in providing experience in the WASP methodology and that it had served as an effective forum for the regional exchange of experience in energy, electricity, and nuclear power planning. They saw this investment in their analytical capabilities as requiring further exploitation nationally, through further training of key personnel using the "train-the-trainers" approach and to increase the accuracy of the results by improving the information in national databases. In addition, it was felt that this project could make a positive contribution to establishing effective strategies for nuclear power implementation.

In recommending a 5-year extension of the project, the National Co-ordinators formulated two technical objectives as the basis of future co-operation:

- To enhance and improve the reliability and quality of forecasting, planning, and analytical capabilities in the region for future energy and electricity needs and impacts.
- To facilitate national implementation of nuclear power programmes through the pooling and analysis of information on effective strategies used in RCA countries.

Through the 1990s, and into the next century, RCA countries will have to take further steps to reinforce their electricity generation capacities. The need for adequate planning is and will continue to be of tantamount importance. To assist this process of analysis and assessment, the RCA project on energy and nuclear power planning can continue to provide valuable support. ❐


Discussing plans for the Republic of Korea's first nuclear plant, Kori, back in 1974. Today nine nuclear units provide more than 40% of the country's electricity.