BUILDING CAPACITIES FOR COMPARATIVE ENERGY ASSESSMENT

EXPANDING THE POWER BASE

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Analysis of national energy systems is reaching unprecedented degrees of complexity. In addition to uncertainty of future energy demand, technology performance and costs, planners and decision makers are confronted with issues such as environment protection, sustainable development, deregulation and market liberalization. At the same time, public sector funds for energy investment projects are being progressively reduced.

The IAEA offers its Member States a comprehensive programme of technical assistance and cooperation which covers many diverse areas related to peaceful uses of nuclear energy. In the area of comparative energy assessment, the objective of assistance is to strengthen national capabilities for elaborating sustainable patterns of energy supply and use. Assistance is provided in three ways, namely by:

- distributing state-of-the-art methodologies and decision-making tools tailored to the special needs of developing countries;
- providing training in model application, interpretation of results and translation into decision or policy making; and
- carrying out national studies in co-operation with requesting Member States.

Credit: Russel Illig/PhotoDisc

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Photo: The IAEA is providing assistance to many countries planning the expansion of electricity generation systems.

METHODOLOGIES & TOOLS FOR ENERGY ANALYSIS

The IAEA has a long history of providing data, information and analytical tools suitable for informed decision making regarding how best to meet the energy needs of a country.

Least-Cost Planning in the 1970s & 1980s. In the early 1970s, the IAEA began supporting the development and application of electricity system analysis tools used by Member States to analyze the potential role of nuclear power. Since projected future demand for electricity is an important determinant of the need for nuclear power, early efforts included development of the Model for Analysis of Energy Demand (MAED). It is used by developing countries in preparing forecasts of electricity demand that are consistent with their national economic and industrial development objectives and possibilities.

The IAEA developed MAED in collaboration with the Institute for Economic and Legal Aspects of Energy (IEJE, Grenoble, France) and the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria). The model provides a flexible simulation framework for exploring the influence of social, economic, technological, and policy changes on the long-term evolution of energy demand. Special emphasis is given to the forecast of electricity demand, not only in terms of total annual requirements, but also in terms of the hour-by-hour distribution of power demand throughout the year. Such results are an essential input to any power system expansion analysis.

The Wien Automatic System Planning Package (WASP) is designed to determine the economically optimal long-term expansion of an electricity generation system. The WASP model was developed for the IAEA, in 1972, by the Tennessee Valley Authority (TVA, USA) and has since been the IAEA's most popular and long-lived tool for electricity sector planning.

It is important to note that WASP was developed during a time when most countries considered electricity to be a strategic good. They established a single vertically integrated national utility responsible for the generation, transmission and distribution of electricity. With this type of structure of the electricity system, system operation and expansion can be analyzed in a rather straightforward manner. Unit dispatch can be modeled based on lowest variable cost, system reliability requirements can be incorporated as constraints, expansion planning can be based on system wide least-cost discounted present value, and the role of nuclear power and other generation options can be determined based on their relative life cycle costs.

Financial Analysis, Assessment of Environmental Burdens, & Integrated Analysis of Energy Systems in the 1990s. Attracting investment for electricity generating capacity in increasingly liberalized electricity and financial markets can be quite different from investment strategies by state-owned utilities under monopoly conditions. To help meet the evolving needs of energy planners and decision makers, the IAEA worked with staff of the Bank Credit Lyonnais (Paris, France) and the Pakistan Atomic Energy Commission (PAEC, Islamabad, Pakistan) in developing financial analysis software called FINPLAN.

FINPLAN is used to assess the financial consequences of a power expansion programme based on certain "ratios" that financial institutions take into consideration when judging the soundness of an investment project or programme. In addition, FINPLAN helps to identify the selling price of electricity that would permit payback on investments. Forecasts developed with the model take into account price sensitivity to exchange rates, fluctuations in demand, and foreseeable inflation rates for both domestic and foreign currencies. The model also integrates simplified taxation elements, which include calculation of revenues accounting for interest rate deductions, past reported losses, possible amortization and proportional taxation rates.

Development of a set of computer tools for energy and environmental analysis was initiated in 1993 within the IAEA's joint inter-agency programme on Databases and Methodologies for Comparative Assessment of Different Energy Sources for Electricity Generation (DECADES). These tools consist of databases and analytical software that can be utilized to evaluate trade-offs between technical, economic and environmental aspects of different electricity generation

COMPARATIVE ASSESSMENT:
ANALYZING ENERGY FUTURES IN VIET NAM

Through an IAEA technical cooperation project initiated in 1997, a national working team in Viet Nam used a range of computer tools to analyze the country's energy development. The team applied the Energy and Power Evaluation Program (ENPEP) to forecast energy and electricity demand (using the Model for Analysis of Energy Demand, or MAED; determine the optimal long-term expansion of the electric generating system (using the Wien Automatic System Planning Package, or WASP); and estimate the environmental burdens associated with power generation (using an ENPEP module called IMPACTS).

Viet Nam is moving rapidly from an agricultural to an industrial economy and has experienced substantial economic growth over the last few years which is expected to continue through 2020. In combination with accelerated urbanization, growing living standards, and rising consumer spending, the demand for electricity is projected to rise rapidly. National electric sector specialists estimate that the annual peak load of the interconnected system will grow from its 1995 level of 2.75 GWe to 24.32 GWe by 2020. The assumed average annual growth rate is 9.1% with higher growth rates at the beginning (up to 11.5%) and lower growth rates at the end of the study period (6.7%). This is mostly driven by rapid growth of electricity demand in industry, services, and urban households.

Results of the generation system expansion study show that under the reference scenario, hydro and natural gas will provide the majority of the country's power needs. However, the share of hydropower, oil, and coal are forecast to drop substantially in the period 1995-2020 at the expense of natural gas and nuclear. Hydro declines from approximately 70% to about 52% of total installed capacity. Oil generation capacity drops from about 9% to 2% while coal falls off from 16% to 9%. On the other hand, natural gas-fired combined cycle units are projected to grow from 5% to 29%. This significant growth will draw on the country's natural gas reserves, with proven reserves estimated at 6 trillion cubic feet (Tcf) and probable gas reserves as high as 10 Tcf. The first nuclear unit is expected to start operation in 2017, reaching a total of approximately 2500 MWe by 2020, a level representing 7.7% of total installed electric generating capacity.

The national team also estimated future greenhouse gas emissions from power generation by exporting the optimal configuration of electric system expansion from WASP to the environmental module of ENPEP, called IMPACTS. The module computes atmospheric pollutant releases based on fuel consumption projected by WASP and standard emission factors available in one of its databases. The results show a dramatic increase in power generation-related CO_2 emissions. Emissions from coal-fired generating units grow until 2007 as coal generation initially expands.

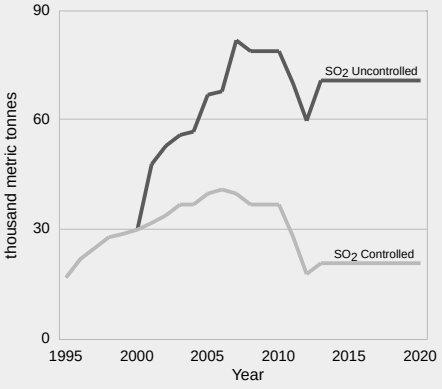
This trend noticeably changes during the second half of the study period, when existing coal units will be retired and a substantial number of hydro projects and natural gas-fired combined cycle units are expected to come on-line, along with nuclear starting in 2017. By 2020, natural gas accounts for 61% of CO_2 emissions from Viet Nam's power sector.

There is a noticeable difference in emission projections for the south and for the north of the country. Viet Nam's coal-fired units are located mostly in the north, where the majority of the country's coal reserves are found, explaining the concentration of SO_2 emissions in the northern region (83% in 2020). The retirement and replacement of old and inefficient coal units after 2007 accounts for the substantial decline in SO_2 emissions in the north observed during the second half of the forecast period. Oil and gas reserves, on the other hand, are situated in the southern region (mostly offshore) fueling the strong growth in gas-fired generation. This situation explains why the south is projected to generate about 62% of CO_2 emissions and 70% of NO_X emissions by 2020.

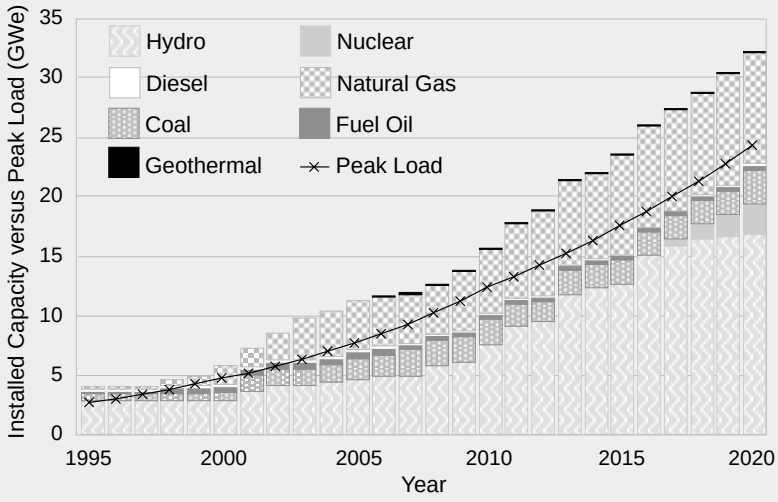
The national team also analyzed the effects of meeting Vietnamese air pollution regulations for limiting emissions of particulate matter (PM) and sulfur dioxide. To control PM, the team considered using electrostatic precipitators with a 97% control efficiency for existing units and a 99% control efficiency for new units. To meet the SO_2 emission rate ceiling for new coal units, national experts considered a dry flue gas desulfurization with a 70% control efficiency for new coal units burning domestic, low-sulfur anthracite coal (i.e., 0.52% sulfur), and a 90% control efficiency for new coal units firing imported bituminous coal with a medium sulfur content of 1.62%. The IMPACTS module was then used to estimate system-wide costs of complying with the air regulations.

One focus of the analysis was the projected effects of meeting SO_2 emission restrictions in the northern region of Viet Nam. Results showed that, at the end of the study period, emissions are reduced from 71,000 to 21,300 metric tonnes. For the entire country, a total of 858,000 metric tonnes of SO_2 is avoided during the study period because of the installed abatement technologies. These reductions come at a total discounted cost of US $180.4 million (at 10% discount rate). This turns out to be approximately US $210 per ton of SO_2 avoided. The total discounted environmental compliance cost for both PM and SO_2 is estimated to be US $282 million.

SO_2 EMISSIONS WITH AND WITHOUT ENVIRONMENTAL CONTROLS IN NORTHERN VIETNAM

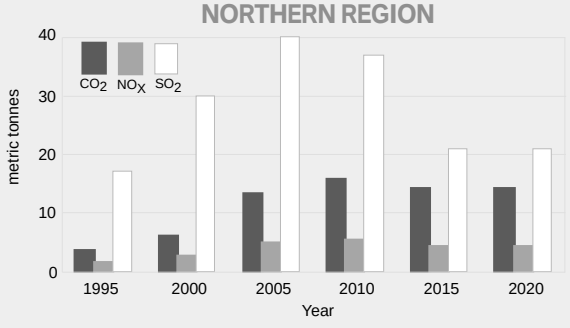


VIET NAM ELECTRIC SYSTEM EXPANSION (REFERENCE SCENARIO)



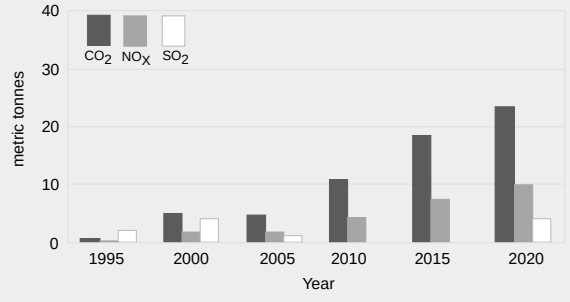
PROJECTED REGIONAL EMISSIONS FROM ELECTRICITY GENERATION IN VIET NAM

NORTHERN REGION

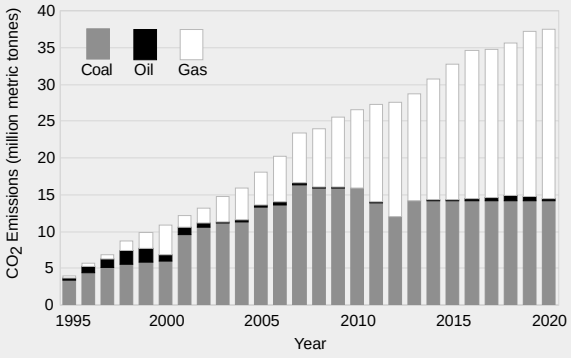


CO_2: times 10^6 tonnes
NO_x: times 10^3 tonnes
SO_2: times 10^3 tonnes

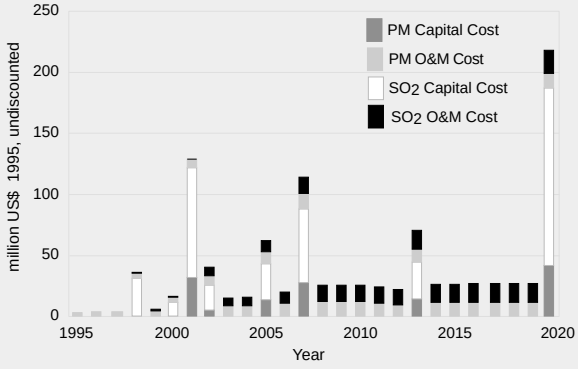
SOUTHERN REGION



PROJECTED CO_2 EMISSIONS IN VIET NAM FROM THE ELECTRIC POWER SECTOR



PROJECTED COSTS OF ENVIRONMENTAL COMPLIANCE IN VIET NAM (PARTICULATE MATTER AND SO_2)



Source: Argonne National Laboratory

technologies, chains and systems.

Two types of technology databases were developed to provide comprehensive, credible and up-to-date information on energy chains for electricity generation. The Reference Technology Database contains technical, economic and environmental data on typical facilities covering energy chains that use fossil fuels, nuclear power, and renewable energy sources for electricity generation. Country Specific Databases store data that is specific to a country or region for the purpose of carrying out case studies with the DECADES analytical software.

The Energy and Power Evaluation Program (ENPEP) was developed by Argonne National Laboratory (ANL) in the USA and later transferred to the IAEA for dissemination to its Member States. ENPEP contains a set of analytical tools for use in integrated energy/electricity system planning and the quantification of environmental burdens. One of its modules, called BALANCE, is used to trace the flow of energy throughout the entire energy system from resource extraction, through processing and conversion, to meet demands for useful energy (e.g., heating, transportation, electrical appliances) and employs a market-based simulation approach to project future energy supply/demand balances. Results of this analysis are then passed to another module, called IMPACTS, to calculate environmental burdens (e.g., air pollution, solid waste generation, land use, water pollution) associated with different scenarios of energy sector development.

The newest version of this package, for use on personal computers, provides a greatly enhanced graphical user interface for viewing and modifying a representative energy network on the computer screen. It also has improved capabilities for assessment of greenhouse gas (GHG) mitigation.

Meeting Evolving Needs in the Year 2000 & Beyond. Continued effort is required to meet the changing needs of IAEA Member States; in particular, to address important issues such as the elaboration of sustainable energy strategies in the context of Agenda 21, market deregulation, and privatization.

In 2000, the Agency will complete development of a simplified methodology (called B-Glad) for estimating and valuing external costs associated with electricity generation. Designed for use in developing countries that lack detailed data and cannot afford costly analyses, the programme runs on a personal computer and requires a minimum amount of input data. While the IAEA's other energy models estimate the level of environmental burdens associated with different energy options, the B-Glad model is used to analyze pollutant dispersion and transport, estimate the associated health and environmental impacts, and value these impacts. B-Glad also contains a Decision Aiding Module for applying multi-criteria decision analysis techniques in comparing various energy options.

Finally, the IAEA has launched an effort to redesign its WASP expansion planning methodology to account for recent changes in the electricity market. With the advent of restructuring of electricity systems around the world, to varying degrees national electric utilities are being privatized, independent power producers are being allowed access to the system, and bidding-based power markets are being opened to spur competition.

At present, the Agency's WASP model cannot readily address many of the questions raised in restructured markets. At the end of 1999, the IAEA launched an effort to develop electricity system planning tools that are better suited for helping countries answer questions related to how existing nuclear plants can compete in the new electricity market and how new nuclear units might fit into long-term development plans.

TRAINING IN ENERGY ANALYSIS

Training is a vital part of the IAEA's capacity building activities. Since 1978, more than 1000 experts from 73 countries have participated in regional and interregional training courses on energy planning organized by the IAEA. Three such courses were offered in 1999.

Under a Regional (Asia) project on Comparative Assessment of Electricity Generation Options, a training course was organized in Islamabad, Pakistan, to support sound power sector planning and decision making in light of

increased private sector participation and financial constraints in the electricity sector. Training focused on how IAEA's electricity system planning tools can be used to analyze different generation technologies and Independent Power Producer (IPP) contracts when determining electricity system expansion plans which have low cost, are financially viable and meet national limits with respect to air pollutant emissions.

A Regional (Europe) Training Course titled "Comparative Assessment of Nuclear Power and Other Options and Strategies for Electricity Generation in Support of Sustainable Energy Development" was organized in Trieste, Italy. Training centered on the conduct of a comparative assessment study by each participating national team. The main components of the study include: 1) development of a country specific database containing technical, economic and environmental characteristics of energy facilities and fuels; 2) characterization of full energy chains for electricity generation in terms of their associated costs, air pollutant emissions, solid waste generation and land use; 3) development of least-cost electricity system expansion plans; and 4) estimating the level of environmental burdens associated with alternative electricity system expansion strategies.

An Interregional Training Course on Energy and Nuclear Power Planning Study Using the Energy and Power Evaluation Programme (ENPEP) was held at ANL in the USA. This course is designed to train experts from developing Member States in methodologies for integrated energy/electricity planning and the quantification of environmental burdens associated with different scenarios of energy sector development. The main course subjects include: overview of concepts and terminology related to national energy system planning, characterization of energy chains, interrelationships between energy-economic-environmental planning, potential for reducing energy demand through conservation measures, assessment of resource requirements and environmental impacts of energy systems, methods for GHG mitigation assessment, conduct of national studies using ENPEP, and preparation and presentation of a study report.

In addition to these training events, a National Seminar on the Clean Development Mechanism (CDM) and Nuclear Power was organized to raise awareness in Viet Nam with respect to the flexible mechanisms under the Kyoto Protocol, and to explore the potential suitability of nuclear power as a CDM technology in Viet Nam. A regional seminar in the Czech Republic on the Kyoto Protocol's Joint Implementation mechanism and an information seminar in Vienna for resident missions to the IAEA were organized for the same purpose.

NATIONAL ENERGY STUDIES

The IAEA's Technical Cooperation Strategy, established in 1997, states that technical cooperation with Member States shall increasingly promote tangible socio-economic impact by contributing directly in a cost-effective manner to the achievement of the major sustainable development priorities of each country.

Several Member States have requested IAEA support for enhancing national capabilities in the area of sustainable energy development. In 1999, assistance was provided though national projects in Brazil, Bulgaria, Croatia, Czech Republic, Egypt, Lithuania, Mexico, Moldova, Poland, Slovenia, Sudan and Viet Nam *(see box and graphs, pages 10 & 11)* to assess the role of nuclear power and other energy options in the future expansion of their electricity supply systems, with due account being taken of technical, economic and environmental issues. Regional projects in Europe, East Asia and the Pacific also addressed needs of Member States in the area of comparative assessment for sustainable energy development.

Through the early 1990s, most projects focused on determining the role of nuclear power in the economically optimal electricity system expansion strategy for a country. More recently, projects have included market-based energy system studies and an assessment of environmental burdens. Future projects in this area are expected to increasingly focus on performing a more full-cost accounting of electricity generation options through the estimation of external costs, assessing the merits of nuclear energy for mitigating greenhouse gas emissions, and analyzing the role of nuclear power in privatized electricity markets.❐