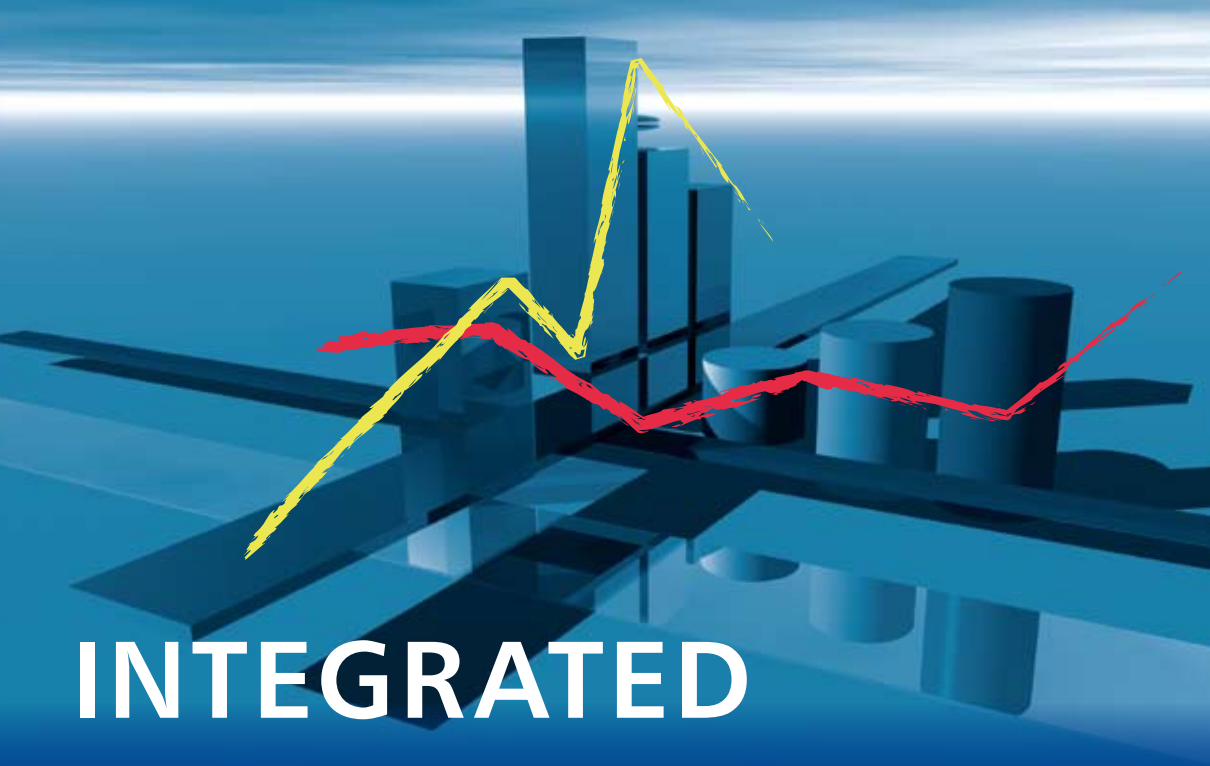


INTEGRATED ENERGY PLANNING FOR SUSTAINABLE DEVELOPMENT

IAEA
International Atomic Energy Agency

ENERGY HOLDS THE POWER

to drive economic development

Energy is the engine for the production of goods and services across all economic sectors: agriculture, industry (mining, manufacturing), transportation, commerce, public administration, etc.

and accelerate social progress.

It is equally vital to the provision of basic civic services (health care, clean water, sanitation, etc.), to improving access to education and, ultimately, to raising incomes.

"...with availability of modern energy, life changes"

Energy options reflect human innovation

People have found ways to utilize many different energy sources: human and animal power, sun, wind and water, fossil fuels and nuclear power.

The value of energy derives from its ability to heat, to illuminate and to make things move.

Each country uses various energy sources in different measures and combinations usually reflecting its endowment with natural resources.

The composite of extraction and conversion technologies and processes that deliver energy services to end users is known as the **energy system**; the individual recipe as the **energy mix**.

A vital role for technological innovation

Technology is the critical link between energy services and access, affordability and environmental compatibility.

But energy planners must think of technology as more than power plants, motor vehicles and appliances. They must consider infrastructures such as buildings, settlement patterns, road and transportation systems, and industrial plants and equipment.

Technology choices are also linked to laws and regulations that reflect national capabilities, social preferences and cultural backgrounds.

IMPROVING ACCESS TO ENERGY

Energy is essential to all human activities and, indeed, critical to social and economic development. Lack of energy is a contributing factor to states of perpetual poverty for individuals, communities, nations and regions. In contrast, access to energy opens many new opportunities; and meeting the United Nations Millennium Development Goals cannot be accomplished without access to affordable energy services.

is a multi-faceted challenge

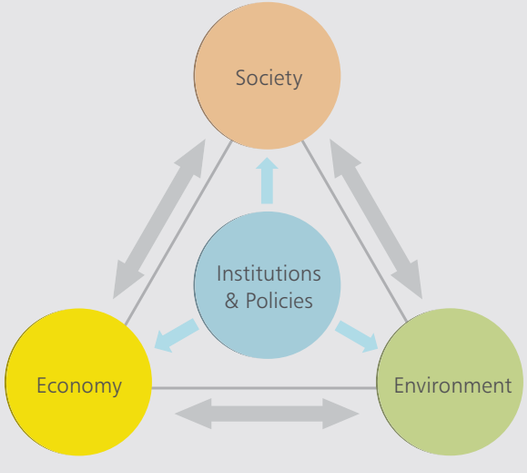
Delivering energy to end users requires multiple processes (production, conversion, transformation and distribution) and many players, from both the public and private sectors. This creates competition within the energy sector, not only for energy sources but also for access to financial, human and other vital resources.

that has far-reaching implications

Energy extraction, conversion and use always generate undesirable by-products and emissions – far more, in fact, than any other sector. Inappropriate exploitation of energy sources can have devastating effects on the natural systems that support life on this planet.

and long-lasting obligations.

Today's choices about how energy is produced and used will determine the sustainability of the future energy system and, thereby, of socioeconomic progress. Most energy plants and equipment have long operating lives (25–40 years and more); in some cases, they require special management long after their operational lives.



Energy and sustainable development: A central role for governments

The concept of sustainable development generally encompasses three pillars: social, economic, and the environment linked by effective government institutions.

Energy planning is an example of the need for the vital role of government institutions in ensuring that energy supply and demand decisions made by all stakeholders – producers, consumers, investors, etc. – are compatible with overall goals for national sustainable development.

THE 3-E INTERPLAY: ENERGY, ECONOMICS AND THE ENVIRONMENT

Today's energy planners must strive to balance many conflicting factors. At the most basic level, they must seek to balance energy needs (demand) and energy resources (supply) across two dimensions:

- Ensuring access to adequate, affordable and secure energy services to satisfy human needs and achieve socioeconomic development.
- Promoting production and use of energy services in ways that are consistent with the pursuit of sustainability.

ENERGY: MORE THAN JUST A QUESTION OF RESOURCES

It is often thought that energy resources drive the energy system – basically in a top-down fashion. In fact it is bottom-up – driven by the demand for energy services. While the domestic endowment with energy resources is a critical element in energy planning, technology provides the link between resources and the supply of energy services.

Technology and technology change

- Affect the energy system from resource exploration, extraction, refineries, electricity and heat generation, transmission and distribution to end use devices (cars, boilers, housing stock, industrial processes);
- Extend the reach of limited resources – do more with less (i.e. efficiency improvements);
- Make previously inaccessible resources accessible;
- Reduce harmful emissions.

Domestic energy resources versus energy imports

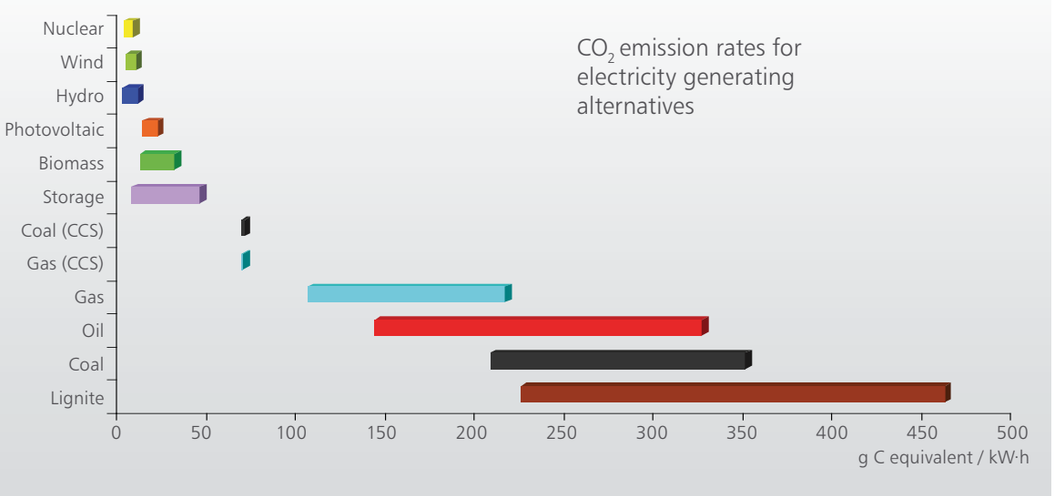
This creates a complex challenge for today's energy planners, who must give due attention to many conflicting factors. The depletion of finite energy resources (coal, crude oil, natural gas, uranium) generates a need for investment in alternative sources. Greater self-sufficiency and diversity of supply is necessary to counteract the risks associated with dependence on other countries or with supply disruptions due to inadequate infrastructures or accidents.

Responsibility and reform

Governments are responsible for the protection of public health and the natural environment. They must also ensure that the benefits of long term public investment for infrastructure development are not undermined by short term, profit-seeking entrepreneurs. Thus, they play a lead role in building compatibility within the energy system and fostering societal acceptance of new technologies and policies.

Energy security

Developing nations are increasingly concerned with the issue of energy security. Importing energy drains the local economy; it also leaves the supply system vulnerable to changes that are beyond the control of national planners. Resilience to external shocks can be improved through diversity of supply, a better balance between local production and imported energy, and participation in regional networks.



CO_2 emission rates for electricity generating alternatives

ECONOMICS: MONEY MATTERS ON MANY LEVELS

The economic aspects of energy are complex, particularly for developing nations. It is not always evident that investment in the energy sector underpins achieving overall objectives such as health care, education, increasing employment and participating in international markets.

Financing infrastructure development

In many cases, the first challenge is to attract/arrange investment for energy infrastructure projects. Few developing nations have the resources required to finance the needed development. Over the past decades, it has become clear that transforming centrally controlled energy systems into liberalized markets can create the right conditions to direct investment and facilitate competition.

Ensuring affordability of services

Energy must also be priced appropriately to cover the full cost of supply, yet access to it should not be limited. Pricing adjustments may be necessary to ensure that all consumers can afford to realize the benefits of energy. In the commercial sectors, energy pricing directly influences the competitiveness of goods and services, both locally and internationally.

ENVIRONMENT: SAFEGUARDING THE EARTH SYSTEM

A sustainable energy system is often defined as one in which the production and use of energy do not endanger the quality of life of current and future generations and do not exceed the carrying capacity of ecosystems. If the environmental aspect is not properly managed, it can jeopardize the social and economic benefits that accrue from the provision of energy.

Encouraging sustainable production

All energy production has direct and indirect impacts on the environment. Minimizing these impacts may require institutional change in the form of policies and regulations that direct the development of the energy system. Energy planning helps to identify which resources to exploit; it also influences the direction of investments and the orientation of technological development.

Changing patterns of consumption

The consumption side of the environmental equation also holds many challenges, particularly in areas such as the inefficient use of energy, use of sub-standard fuels and technologies, and lack of environmental standards. Providing consumers with cleaner fuels and more efficient technologies must be accompanied by effective environmental policies and regulations – and the mechanisms to enforce them.

Counting the costs

One of the most effective ways to encourage more sustainable production and consumption is to properly account for the costs of environmental impacts. This provides direct incentive to invest in technologies that mitigate impacts, to manage emissions and waste more effectively, and to use energy more efficiently.

INTEGRATED ENERGY PLANNING

Integrated energy planning is the systematic analysis of all the factors that influence the evolution of energy systems. It facilitates problem solving and makes it possible to explore linkages, evaluate trade-offs and compare consequences, thereby helping countries to develop an effective energy strategy that supports national sustainable development goals.

delivers immediate benefits

Energy planning allows governments to make timely, informed decisions about managing energy supply and demand. It provides a means to:

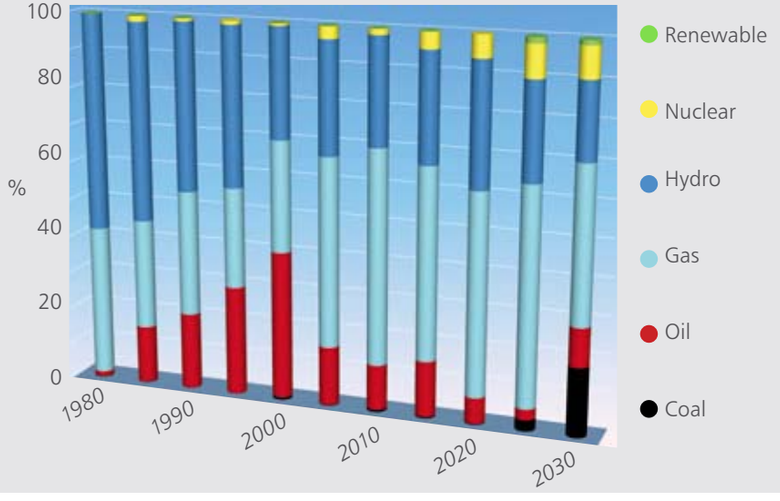
- **Identify options,** assess their strengths and weaknesses;
- **Compare alternatives,** calculate the costs and benefits of different scenarios;
- **Explore constraints,** analyse the limitations of existing or future frame works (financial, policy, etc.);
- **Evaluate possible outcomes,** gauge the potential for success over the short and long term.

and lasting value.

Energy planning is particularly valuable given the long operating life of energy systems. It clearly shows how decisions taken today might lock in the future or foreclose on various options. It also makes it possible to evaluate each near term decision in relation to its long term implications for the economy, the environment and for society. Ultimately, energy planning supports wise and efficient investment decisions.

A model case of effective energy planning

In the late 1990s, energy experts in Pakistan used IAEA energy planning tools to carry out a landmark study in support of the Government's **Energy Security Initiative.**



In four different scenarios, energy modelling showed that, to keep pace with demand, Pakistan needed to significantly increase net power generation capacity by 2030 – by as much as 147 000 MW. Clearly, substantial infrastructure investment was required. But modelling showed that if Pakistan continued to rely primarily on fossil fuels it would become even more dependent on imported energy and would suffer tremendous environmental impacts.

Modelling 30 years ahead showed that expanding renewables (particularly hydro) and building nuclear capacity were the best options to minimize environmental impacts and increase energy security. But both options have long lead times. Thus, in the nearer term, the new strategy remains oriented toward fossil fuels but has a greater diversity of sources (coal, oil and gas) and of suppliers (e.g. gas pipelines are planned from Qatar, the Islamic Republic of Iran and Turkmenistan).

ENERGY PLANNING CAPACITY

Governments hold the primary responsibility for ensuring that long term planning adequately accounts for all aspects of energy demand and supply. They have a critical role in creating robust policies that permit energy sector players to actively participate in development, operation and evolution of effective, efficient energy systems.

is an essential service

Governments in developing countries have much to gain by building local expertise in energy planning. It is a service that holds significant value for all energy stakeholders (utility and power companies, research centres, investors, etc.) It helps to engage all players and more effectively address the full range of energy issues. Early investment in building capacity ensures that short and medium term decisions support long term goals.

and a national asset

Comprehensive planning capacity increases a country's ability to anticipate and respond to the rapid changes occurring — and new issues arising — in the energy system. The value of this asset increases over time, as experts gain experience in applying their skills, build the local knowledge base and forge relationships with stakeholders from diverse sectors.

that requires long term support.

Energy planning capacity ultimately supports self-sufficiency and sustainability in the energy sector. To realize its full potential, it must be pursued on a continual basis by a dedicated team of highly trained experts. This implies the need for ongoing public support in terms of financial and human resource – energy planning never ends.

HIGHLY TRAINED ANALYSTS ADD THE TRUE VALUE TO ENERGY PLANNING

Energy planning is most successful when carried out by local experts representing essential stakeholders. Their in-depth knowledge and understanding of national energy systems are necessary to structure the analysis correctly, judge the credibility of results, interpret the analysis and findings, and compare the validity of various scenarios. Ultimately, it is these expert teams who will apply modelling results to real-life energy decisions and policy making.

Proven approach to building local capacity

At the request of Member States, the IAEA offers comprehensive training that is customized to reflect the country's current situation and development priorities, and aims to put the right tools into the hands of local experts. To date, the IAEA has helped more than 115 Member States acquire its energy models and has trained more than 1000 local experts in their use.

Delivers long term returns on initial investment

But learning to use the tools is only the beginning. The impact of the IAEA programme is not calculated by counting the number of models installed and people trained, but by how – and how often – these tools and expertise are applied to perform real analysis and to enlighten policy and investment options and strategies.

Local energy experts acquire skills to compile and reconcile data from diverse sources, and to apply quantitative methods for:

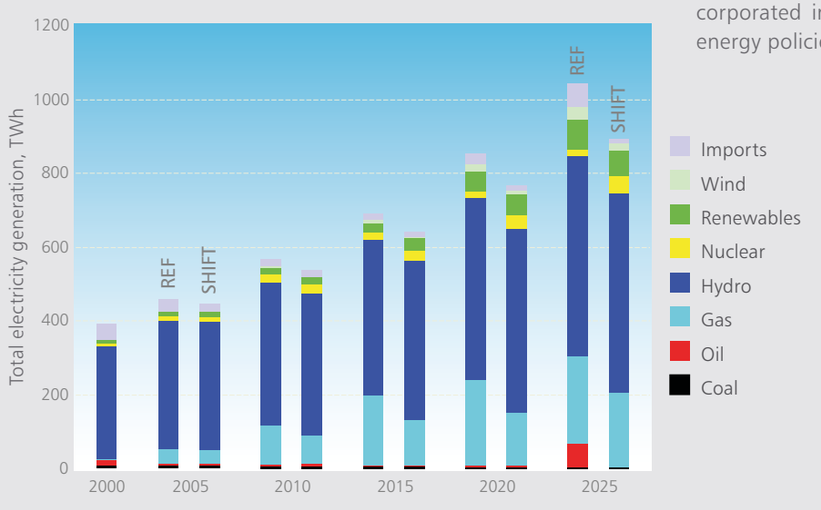
- Analysis and evaluation of energy options, including their technical, economic, environmental and human health impacts.
- Integrating systematic analysis and planning procedures in decision making related to energy and environment policy.
- Cost and benefit accounting for all aspects of energy projects, including environmental impacts.
- Participation in the international debate on sustainable energy development and climate change issues.

Brazil: A country profile on sustainable energy development

The Brazil study represents the first of a series of national studies initiated by the IAEA through a partnership initiative under the World Summit on Sustainable Development and the United Nations Commission on Sustainable Development. It was conducted in cooperation with the Energy Planning Programme, Graduate School of Engineering (COPPE), the Brazilian Reference Centre on Biomass (CENBIO) of the University of São Paulo and the United Nations Department of Economic and Social Affairs (UNDESA).

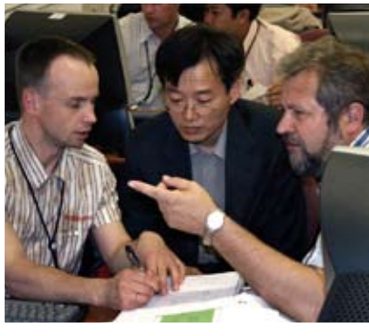
The study reviews past and current sustainable energy issues in Brazil and explores the possible paths towards sustainable energy development for Brazil through 2025. It comprises a first-of-its-kind interlinking of energy system modelling and the use of indicators for sustainable energy development to assess the consonance between energy policies and the country's social, economic and environmental development goals.

The energy policies and investment strategies recommended in this study include expansion in supplies from low carbon/carbon-free fuels/sources and increased efficiency in production and use of energy/electricity. Many of these proposals are being incorporated into national energy policies.









SUITE OF TOOLS SUPPORTS COMPREHENSIVE ANALYSIS

Computer supported modelling forms the core of the IAEA's approach to energy planning, but it all starts with current realities. National economic and energy statistics comprise the input that enables the models to simulate multiple future scenarios. Energy planners can then compare these scenarios in relation to their ability to support development goals. The process helps to chart robust courses of action across different potential futures – and identify ways to avoid undesirable consequences. The outcomes help energy planners define critical aspects of the energy strategy and determine the most cost effective approach to meeting future energy needs.

Projecting future demand for energy and electricity

Model for Analysis of Energy Demand (MAED)

MAED evaluates future energy demand based on a set of consistent assumptions on medium to long term socioeconomic, technological and demographic developments in a country or a region. Future energy needs are linked to: (i) the production and consumption of goods and services; (ii) lifestyle changes caused by increasing personal incomes; and (iii) mobility needs, etc. Energy demand is computed for a host of end use activities for three main "demand sectors": household, services, industry and transport.

MAED provides a systematic framework for mapping trends and anticipating change in energy needs, particularly as they correspond to alternative scenarios for socioeconomic development.

Supply side planning for optimal power generation

Wien Automatic System Planning Package (WASP)

WASP is an exceptionally effective tool for power planning in developing countries. It defines 'optimal' power generation within constraints identified by local analysts, which may include limited fuel availability, emission restrictions, system reliability requirements, etc. WASP explores all possible sequences of capacity additions that are capable of satisfying demand while also meeting system reliability requirements. It accounts for all costs associated with existing and new generation facilities, reserve capacity and unserved electricity.

Accounting for environmental impacts and external costs

Simplified Approach for Estimating Environmental Impacts of Electricity Generation (SIMPACTS)

SIMPACTS is a user friendly model that estimates and quantifies the health and environmental damage costs, the so-called externalities, of different electricity generation technologies. It can be used for comparative analyses of fossil, nuclear and renewable electricity generation, siting of new power plants or cost effectiveness of environmental mitigation policies.

A key strength of SIMPACTS is that it already delivers useful results even when limited data are available.

Establishing signposts to mark progress

Indicators for Sustainable Energy Development (ISED)

ISED framework is a series of 'snapshots' of ratios (indicators) reflecting the interaction of energy with the economic, environmental and social pillars of sustainable development over time, It provides a flexible tool for analysts and decision makers at all levels to better understand their national situations and trends, the impacts of recent policies and the potential impacts of policy changes. ISED was developed by the IAEA in collaboration with the UN Department of Economic and Social Affairs (UNDESA) and other partners.

Assessing alternative energy supply strategies

Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE)

MESSAGE combines technologies and fuels to construct so-called "energy chains", making it possible to map energy flows from supply (resource extraction) to demand (energy services). The model can help design long term strategies by analysing cost optimal energy mixes, investment needs and other costs for new infrastructure, energy supply security, energy resource utilization, rate of introduction of new technologies (technology learning), environmental constraints, etc.

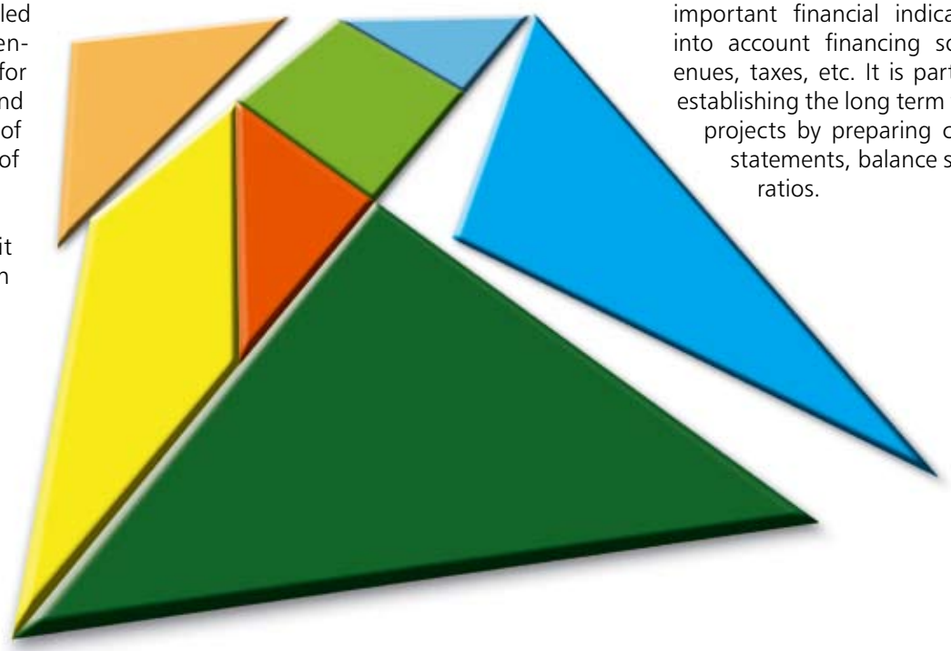
Energy and Power Evaluation Programme (ENPEP)

ENPEP is designed to simulate the energy market clearing mechanism, with the aim of concurrently maximizing benefits to both producers and consumers. The model combines MAED and WASP results to determine the long term energy supply-demand balance through computation of market clearing prices and quantities.

Calculating the financial viability of plans and projects

Model for Financial Analysis of Electric Sector Expansion Plans (FINPLAN)

Financial constraints are often the biggest obstacle to implementing optimal energy strategies. FINPLAN clarifies the feasibility of electricity generation projects by computing important financial indicators while taking into account financing sources, costs, revenues, taxes, etc. It is particularly helpful for establishing the long term financial viability of projects by preparing cash flows, income statements, balance sheets and financial ratios.



ENERGY PLANNING – PUTTING INTO USE

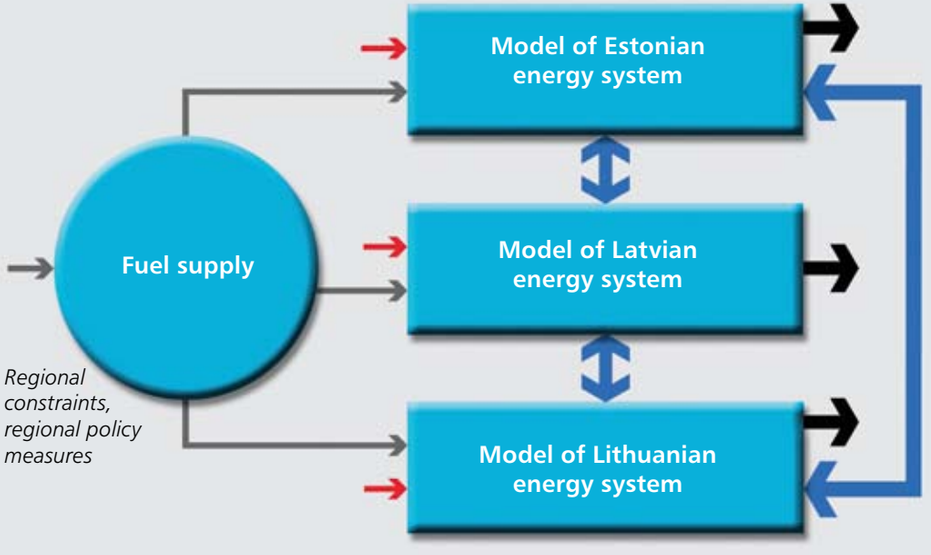
Regional perspective alters plans for three Baltic nations

As part of its bid to gain entry into the European Union, Lithuania agreed to dismantle a sizable legacy of its Soviet past, namely the Ignalina nuclear power plant. The closure of Ignalina threatens to unbalance Lithuania's demand and supply equation and leave a large gap in its energy security strategy. At present, the plant supplies some 70–80% of Lithuania's electricity demand and contributes significantly to supply in the neighbouring countries of Latvia and Estonia, jeopardizing the diversity of energy supplies for all three countries.

The Lithuanian Energy Institute (LEI) sought IAEA assistance to develop energy planning capacity, and subsequently undertook a detailed study to compare energy options – including the possibility of building a replacement nuclear power plant. The results showed that commercially available nuclear plants did not meet least-cost criteria under most of the scenarios considered.

Needing an innovative solution, Lithuania invited Estonia and Latvia to join the dialogue, a logical move considering the three countries already share interconnected grids and other energy infrastructures. Expanding energy planning to the regional scale produced dramatically different results.

It showed that the best economic solution for meeting future electricity demand and maintaining desired levels of energy security centred on two key elements: expanding and sharing Latvia's natural gas storage facilities and jointly building a nuclear power plant to serve all three countries.



Expanding IAEA capacity building programme through e-training solutions

To meet increasing needs for capacity building, training programmes are supplemented with "Distance learning". Specially designed web–oriented training packages have been developed. These packages are being used for on-line delivery of training through web based learning management and audio/videoconferencing technologies.

Working with global development partners

The IAEA is the lead UN agency for training and capacity building in energy planning, as well as a member of UN Energy — an interagency network comprising 20 members with expertise and interest in energy issues.

As such, it actively contributes to initiatives that are jointly organized by sharing the technical resources and costs, providing technical inputs through analytical tools and trainers, and participating in joint studies.

IAEA ASSISTANCE ALIGNED TO MEMBER STATE PRIORITIES

Developing nations have unique needs in the area of energy planning. The IAEA offers a range of assistance programmes that correspond to specific aspects of building capacity in energy planning. The goal of all assistance is to see Member States achieve their own objectives.

Technical cooperation programme (TCP)

TCP provides assistance – usually through expert advice, training or equipment delivery – to help Member States achieve development priorities.

Project approval depends on a clear intent to use nuclear technologies for peaceful purposes and a high probability of achieving the expected outcomes, as evidenced by strong government commitment and financial support.

Typical TCP projects include assessments of future energy and electricity needs; technical, economic and environmental evaluation of energy supply options; and formulation of energy strategies.

Coordinated research projects (CRPs)

CRPs promote research in technical programs approved by the IAEA.

In the area of energy planning, this includes testing new ways to assess the economic and environmental effectiveness of various technologies; analyse sustainable energy development and climate change; and update and expand relevant databases.

CRPs typically bring together research institutions from several Member States to facilitate substantive synergies, rapid exchange of results and dissemination to others of knowledge and experience gained.

Regional and national workshops and training courses

Workshops and training courses on energy models at both national and regional levels are structured to include topical and specialized lectures, group discussions and hands-on work sessions. Target output is a country study addressing a topic of national interest.

Each workshop or training course focuses on one model and is designed to provide an understanding of the methodology and to train participants to collect and compile input data, operate the model, interpret its results and synthesize policy recommendations.

Training the trainers

The IAEA organizes training for trainers to expand the pool of experts who contribute to regional and national workshops on energy and also assist in the application of IAEA's energy models for national energy studies.

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