Argonne NATIONAL LABORATORY

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Energy and Power Evaluation Program (ENPEP-BALANCE)

Brief Model Overview - Version 2.25

Decision and Information Sciences Division
Center for Energy, Environmental, and Economic Systems Analysis

The ENPEP-BALANCE Model

The nonlinear, equilibrium ***ENPEP-BALANCE*** model matches the demand for energy with available resources and technologies. Its market-based simulation approach allows ENPEP-BALANCE to determine the response of various segments of the energy system to changes in energy prices and demand levels. The model relies on a decentralized decision-making process in the energy sector and can be calibrated to the different preferences of energy users and suppliers. Basic input parameters include information on the energy system structure; base year energy statistics, including production and consumption levels, and prices; projected energy demand growth; and any technical and policy constraints (Figure 1).

Figure 1

In this process, an energy network is designed to trace the flow of energy from primary resources to useful energy demands in the end-use sectors. ENPEP-BALANCE networks are constructed using different nodes and links, which represent various energy system components. Nodes in the network represent depletable and renewable resources, various conversion processes, refineries, thermal and hydro power stations, cogeneration units, boilers and furnaces, marketplace competition, taxes and subsidies, and energy demands (Figure 2). Links connect the nodes and transfer information among nodes.

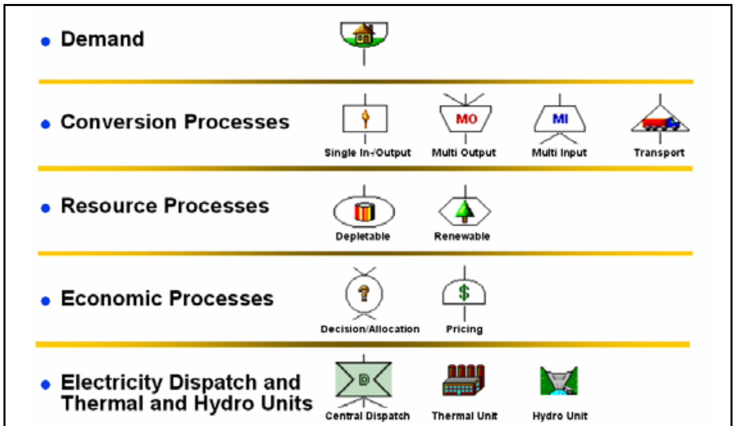


Figure 2

ENPEP-BALANCE is very versatile in that the analyst starts with an empty workspace and builds an energy system configuration of nodes and links. ENPEP-BALANCE's powerful graphical user interface makes it is as easy as "drag and drop" to build networks of regional, national, or multinational scope. Figure 3 displays an example of a typical sectoral energy network, and Figure 4 shows a detailed network for an industrial sub-sector. Drop-down menus can be used to display model inputs and results directly within the energy network. Double-clicking the nodes allows access to more detailed input and output information.

The model employs a market share algorithm to estimate the penetration of supply alternatives. The market share of a specific commodity is sensitive

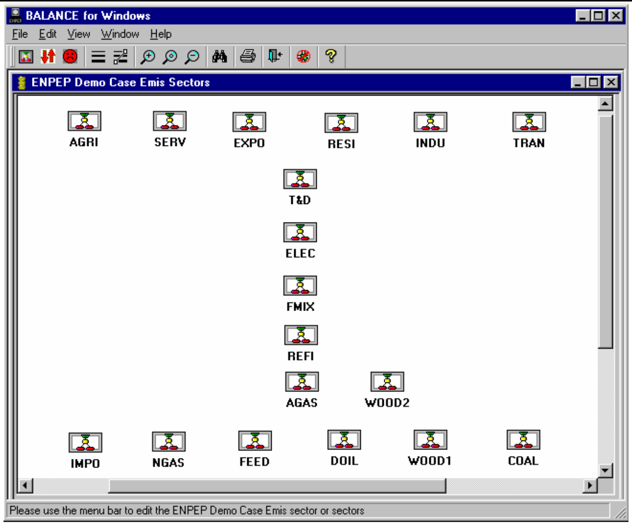


Figure 3

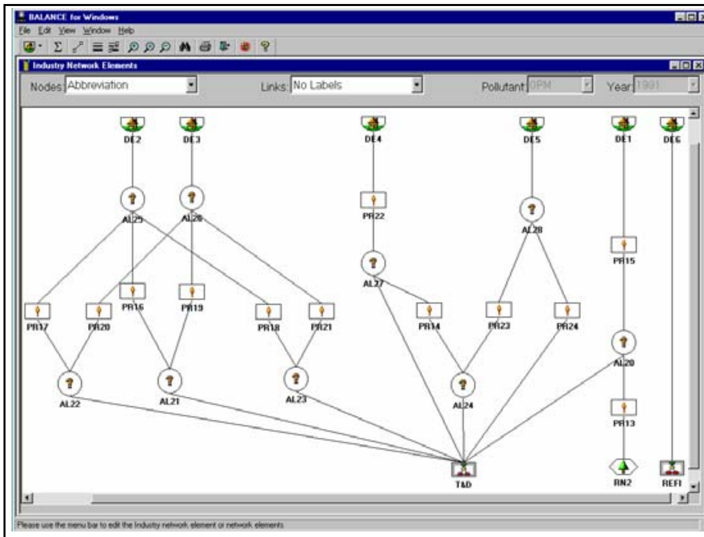


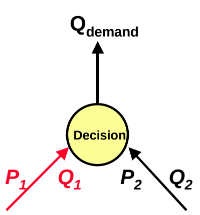
Figure 4

to the commodity's price relative to the price of alternative commodities as shown in Figure 5. User-defined constraints (e.g., capacity limits), government policies (taxes, subsidies, priority for domestic resource over imported resource, etc.), consumer preferences, and the ability of markets to respond to price signals over time (i.e., due to lag times in capital stock turnover) also affect the market share of a commodity.

Using a market share algorithm distinguishes the equilibrium approach from other modeling techniques. The ENPEP-BALANCE approach simulates more accurately the more complex market behavior of multiple decision makers that optimization techniques may not be able to capture because they assume a single decision maker. Every sector (electric, industrial, residential, etc.) pursues different objectives and may have very different views of what is "optimum." The equilibrium solution develops an energy system configuration that balances the conflicting demands, objectives, and market forces without optimizing across all sectors of the economy.

ENPEP-BALANCE simultaneously finds the intersection of supply and demand curves for all energy supply forms and all energy uses included in the energy network. Equilibrium is reached when the model finds a set of market clearing prices and quantities that satisfy all relevant equations and inequalities. The model employs the Jacobi iterative technique to find the solution that is within a user-defined convergence tolerance (see Figure 6).

$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma}}{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma} + \left[\frac{1}{P_2 \times PM_2}\right]^{\gamma}}$$



γ price sensitivity for this decision process
MS: market share
P: price
PM: premium multiplier
Q: quantity

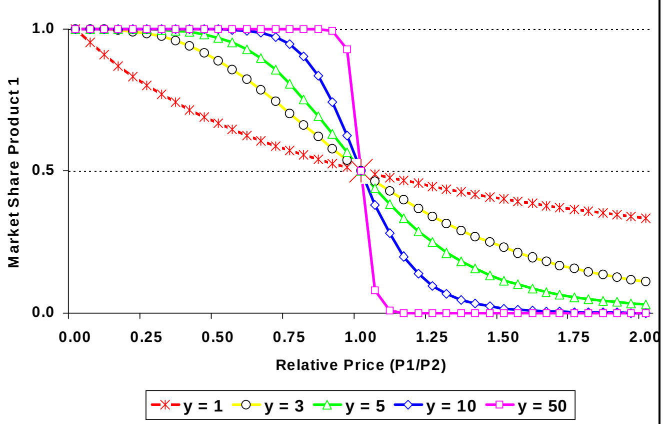


Figure 5

Concurrently with the energy calculations, the model computes the environmental residuals associated with a given energy system configuration. In addition to greenhouse gases and standard criteria air pollutants, such as particulates, SO_X, NO_X, CO, CO_2, methane, volatile organic compounds, lead, etc., these residuals may include waste generation, water pollution, and land use. Greenhouse gas emissions can be reported in a format that is compatible with the Intergovernmental Panel on Climate Change.

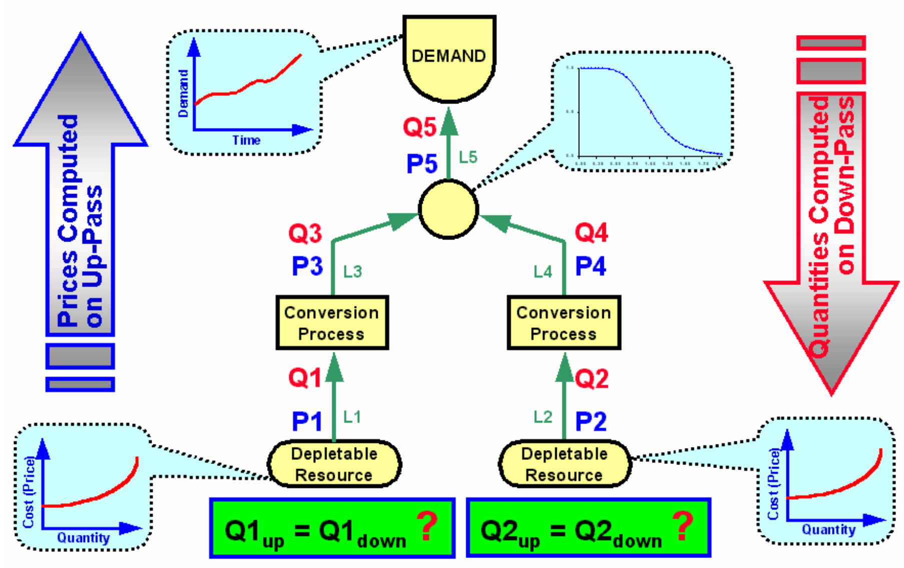


Figure 6

ENPEP-BALANCE is Used Worldwide to Analyze Priority Issues

ENPEP is used extensively in the global community to analyze today's priority energy and environmental issues. ENPEP clients include energy and environmental ministries, electric utilities, power merchants, transmission companies, consulting companies, lending agencies, and research institutions. Model applications cover the entire spectrum of issues found in today's complex energy markets, such as:

- Energy policy analysis;
- Energy market projections;
- Energy and electricity demand forecasting;
- Analysis of power sector development options;
- Analysis of production costs, marginal costs, and spot-market electricity prices;
- Operation and management of hydro power plants and reservoirs;
- Economic evaluation and timing of new investments in the power sector;
- Energy-environmental trade-offs and decision analysis;
- Natural gas market analysis;
- Carbon emissions projections;
- Projections and emission control strategies for criteria pollutants (PM, SO_2, NO_X, etc.);
- GHG mitigation studies;
- Power market and design studies;
- Interconnection studies; and
- Market deregulation issues.

Recent examples of ENPEP-BALANCE applications include the following:

- A Mexican team of experts applied ENPEP-BALANCE to develop various energy projections and evaluate different carbon mitigation options. The team consisted of experts from the power company (CFE), the oil company (PEMEX), the Ministry of Energy (SE), the National University (UNAM), the Petroleum Institute (IMP), the National Ecology Institute (INE), and the Energy Management Commission (CONAE).

- Under a regional European project, 10 countries used ENPEP-BALANCE to evaluate various GHG mitigation options, including Bulgaria, Croatia, Czech Republic, Latvia, Lithuania, Poland, Russia, Slovenia, Turkey, and Ukraine (Figure 7).

- Under a regional Asian project, 11 countries used ENPEP-BALANCE to analyze different carbon mitigation policies, including Bangladesh, China, India, Indonesia, Malaysia, Mongolia, Pakistan, Philippines, South Korea, Sri Lanka, and Vietnam (Figure 8).

- The World Bank (2001) used several ENPEP Modules (MACRO, DEMAND, WASP, BALANCE, and IMPACTS) to conduct an Energy and Environmental Review for Bulgaria. The study was carried out with the objective to better integrate energy sector development and

Figure 7

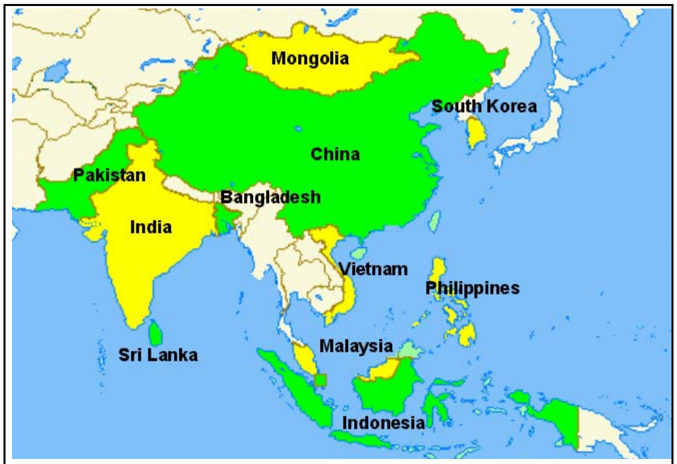


Figure 8

investment plans with the country's environmental goals.

- Harza Engineering Co. and CEEESA staff used ENPEP-WASP, PC-VALORAGUA and GTMax models to analyze the financial viability of 2 transmission lines in the Balkans (ESM 2001). The study was financed by the U.S. Trade and Development Agency and ENRON EUROPE Ltd. (http://www.adica.com/main/index.asp).

- Balajka (2001) used the model to analyze a joint implementation (JI) project that included the repowering of an industrial heating plant with a new natural gas-fired combined-cycle cogeneration unit in Slovakia (http://www.rec.org/climate/calendar/04182001/BalajkaPaper.html).

- Pasierb et al. (2001) used ENPEP-BALANCE to estimate the amount of carbon allowances Poland may be able to sell under seven different scenarios and projected the expected revenue streams assuming a likely range of carbon prices (http://www.pnl.gov/aisu/pubs/PolishET.pdf).

- A recent ENPEP study was conducted by Harza Engineering Co. and CEEESA staff for the electric power system of Macedonia (ESM 2000). In this World Bank-financed study, the WASP/VALOR-AGUA methodology was applied to analyze long-term development options for the Macedonian electric power system.

- The Ministry of Environment of the Slovak Republic (2001) used ENPEP-BALANCE to analyze energy sector mitigation options for its 3. National Communication (www.enviro.gov.sk/minis/ovzdusie/tns/prehladtns.htm).

- Jamaica Public Service Company (JPSCo) used ENPEP-WASP to develop a least-cost expansion plan for their system. CEEESA staff reviewed this plan in a project sponsored by the National Investment Bank of Jamaica (Koritarov et al. 2000).

- Using the ENPEP-WASP model, CEEESA staff developed a methodology for the evaluation of bids for the IPP projects in Hungary and served as technical auditor for the Hungarian Power Companies in the bid evaluation process (Conzelmann et al. 1999)

- CEEESA staff, in association with the Romanian Institute of Power Studies and Design (ISPE), used ENPEP-BALANCE to develop a long-term energy strategy for Romania. The study was sponsored by The World Bank with the aim to help the Government of Romania in developing an appropriate energy and fuel policy for the period until 2020 (Koritarov et al. 1998).

- The World Bank (1998) used ENPEP-BALANCE in a study for the Slovak Republic to project carbon credits that the country could potentially have available for sale (http://www.admin.ch/swissaij/pdf/cb_nss_skreport.pdf).

- CEEESA staff used ENPEP-BALANCE to analyze carbon mitigation policies in Turkey for The World Bank (www.adica.com/main/index.asp).

- The Colombian Ministry of Energy uses ENPEP-BALANCE for their annual gas and electricity market projections (http://www.upme.gov.co/docume.htm).

- Poland's Energy Market Agency used ENPEP-BALANCE and GTMax to evaluate the potential for distributed generation in the deregulated Polish electricity market (www.adica.com/main/index.asp).

For more details and additional information on the ENPEP-BALANCE software, the reader is referred to Jusko et al. (1994), Koritarov et al. (2001), Veselka and Thimmapuram (2001), and Conzelmann (2002).

ENPEP-BALANCE is distributed by CEEESA (energycenter@anl.gov), ADICA Consulting, LLC (www.adica.com), the U.S. Department of Energy, The World Bank, and the International Atomic Energy Agency.

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