META
Model for Electricity Technology Assessment

Integrating Externalities into Electricity Supply Decisions

ESMAP

Energy use is projected to grow 53 percent over the next 25 years, and demand for electricity is growing by leaps and bounds, particularly in fast-growing developing countries. These countries are faced with difficult decisions when it comes to their electricity supply options, and must balance demands for affordability, reliability, and sustainability. At the same time, renewable energy is becoming more attractive to developing countries as they work to shore up energy security, reduce the fiscal burden of importing expensive fossil fuels, and improve the sustainability of supply over the long term.

The Energy Sector Management Assistance Program (ESMAP), a global technical assistance program administered by the World Bank, developed the **Model for Electricity Technology Assessment (META)** in 2012 to assist countries in making informed choices among electricity generation technologies and fuels. META provides a comparative assessment of the economic costs of more than 40 electricity generation and delivery technologies, including conventional generation options such as thermal, renewable options including hydroelectric and wind, and emerging options such as power storage and carbon capture and storage.

Electricity Generation Technology Options in META

Renewable Energy Options		Thermal Energy Options		Nuclear Energy Options
Solar PV	Biomass Municipal Solid Waste	Diesel/Gasoline Generator	Coal Ultra Supercritical w/o CCS	Nuclear-Pressurized Water Reactor (AP 1000)
Wind On-shore	Biogas Landfill Gas	Gas Engine Generator	Coal Ultra Supercritical w/ CCS	Nuclear-Pressurized Water Reactor (VVER)
Wind Off-shore	Pico Hydro	Micro Gas Turbines	Coal-integrated Gasification Combined Cycle w/o CCS	Nuclear-Boiling Water Reactor
PV-Wind Hybrids	Micro Hydro	Fuel Cells	Coal-integrated Gasification Combined Cycle w/ CCS	Nuclear-Pressurized Heavy Boiling Water Reactor
CSP w/ Storage	Mini Hydro	Oil/Gas Combustion Turbines	Coal Circulating-Fluidized Bed (subcritical)	
CSP w/o Storage	Large Hydro	Oil/Gas Combined Cycle	Coal Circulating-Fluidized Bed (supercritical)	
Geothermal Binary	Pumped Storage Hydro	Coal Subcritical	Oil Steam	
Geothermal Binary	Energy Storage (lead acid battery)	Coal Supercritical w/o CCS	Natural Gas Steam	
Geothermal Dual Flash	Energy Storage (NaS)	Coal Supercritical with CCS		

AP - Advanced Passive 1000 (nuclear power plant) | CCS – carbon capture & storage | CSP – concentrated solar power | NaS – sodium sulfur | PV – photovoltaics | VVER - Voda Voda Energo Reactor (Russian pressurized water reactor)


A Flexible Model

META yields levelized costs for generation, transmission, and distribution for each electricity supply technology option from a relatively few input parameters. One of the features of META is that it allows for integration of environmental externalities, such as local pollution and greenhouse gas emissions. Users can easily see the cost of adding or expanding generation from a particular power source if, for example, a carbon price is factored in. META is currently populated with default performance and cost data inputs drawn from three representative countries: India, Romania, and the United States, which were chosen as proxies for developing, middle-income, and developed countries, respectively. Users also have the option of adding in data for others countries by directly entering it into the model, along with as many parameters as they consider necessary. The META tool can also be used to undertake uncertainty analysis to show quantitatively the effect on the energy generation cost of having uncertain inputs (e.g., capital costs, fuel costs, etc.).

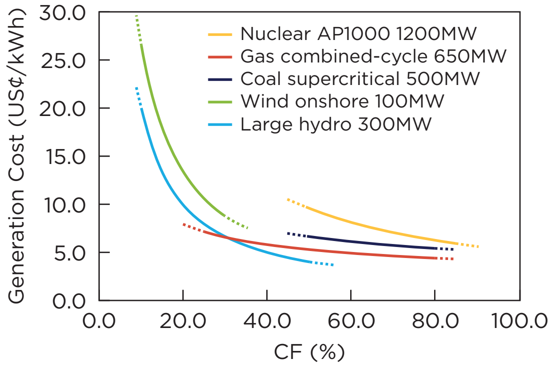
The META tool and underlying META report build on two earlier ESMAP flagship reports that covered competing generation options and their associated performance and costs: ***Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid Electrification Technologies*** (December 2007) and ***Study of Equipment Prices in the Power Sector*** (December 2009).


Functions of META

META can be used in a number of different areas:

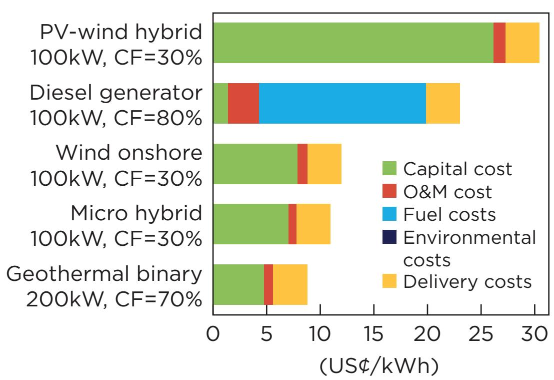
- **Planning Electricity Technology Costs.** While META does not take a system-wide approach to power sector planning and is not an optimization model, it can be used for a more accurate determination of the technical and cost characteristics of different electricity supply options and used along with traditional power system planning models. META provides screening curves, which show the levelized cost per kilowatt hour (kWh) for a range of capacity factors.

Screening Curves for Grid-Connected Supply Cost in the USA (US¢/kWh)



- **Investment Projects.** META can be used in the economic analysis of power sector investment projects. META provides performance and cost estimates for different power generation technologies utilizing data from actual projects.

Mini-Grid Supply Costs in India (US¢/kWh)



- **Energy Policy.** META can be used to inform long-term policy in client countries. It can provide answers to policy-level questions such as the choice between renewable technologies and conventional technologies or between small distributed generation (which avoids transmission costs) and large scale generation (which requires transmission but with the associated economies of scale).

- **Sector Studies.** META is able to undertake a deeper analysis of the effect on the energy generation cost of having uncertain inputs through Monte Carlo simulation. For this, META runs simulation with thousands of iterations for a range of capital cost and fuel cost values. Once a simulation has been run, the results (i.e. the corresponding values for generation costs) are stored and can be analyzed using typical statistical measures, e.g., mean, standard deviation etc. This feature of the model was recently used for the World Bank's ***Mitigating the Vulnerability to High and Volatile Oil Prices in the Power Sector*** report.

- **Estimating Environmental Damage Costs.** META can be used to estimate the cost of environmental externalities from emissions of CO_2, SO_2, NO_x, and particulate matter (PM_{10}). Consideration of environmental externalities can help lead to better informed electricity supply decisions.

META Deployment

META was launched in June 2012 and has been deployed by the World Bank and selected partners since. META has been used in Dominica, Egypt, Macedonia, Morocco, Kosovo, and Vietnam as part of the World Bank's engagement in these countries, and by other organizations in Haiti and Jamaica.

Going forward, ESMAP plans to regularly update the core cost data in the tool to take account of global trends and technological developments, and add in new features and data for other countries.

Getting Started with META

The META report and User Manual are available along with the META tool on the ESMAP website at **http://www.esmap.org/META.** The META report contains information on the full suite of technology options and their costs, as well as a description of other input assumptions. It serves as an explanatory companion to the model, and is valuable as an extensive database and reference source.

Technical and operational support is available from ESMAP for teams interested in using META.

For more information, please contact **esmap@worldbank.org.**

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. It provides analytical and advisory services to low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.

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