Executive Summary

International electricity grid interconnections are complex undertakings, with varied, varying, and potentially diverse issues, costs, and benefits. These issues, costs, and benefits are multi-disciplinary, almost always having technical, economic, legal, political, social, and environmental aspects that must be considered.

Key **technical** aspects of grid interconnection include whether interconnected systems operate synchronously (at the same frequency) or asynchronously, what the magnitudes and directions of the anticipated power flows are to be, what physical distance and terrain will be spanned by the interconnection, and what are the key technical and operating differences are among the systems to be interconnected. Key design and operating issues in AC interconnections relate to the constraints on transmission capacity, both of the interconnection and of the grids that it connects, which include thermal limits, stability limits, and voltage regulation. Where there are liberalized electricity markets, these constraints may become more severe as systems are operated closer to capacity in order to maximize net revenues. Simulation software is an essential tool for planning, assessing the technical benefits of, and operating an interconnection. For modeling to be effective, however, extensive technical data must first be gathered and shared between systems, and personnel must be trained. Grid interconnections require a careful calculation of costs, benefits, and risks. Technical planning of a grid interconnection should be coordinated with economic, organizational, legal, and political aspects of a potential interconnection project from the outset of project consideration.

Grid interconnections may offer both *direct* and *indirect* **economic and financial** costs and benefits. Examples of *direct* economic benefits to the electricity generation systems of one or all of the interconnected nations are "avoided costs"—direct costs avoided by the use of the interconnection—including costs for purchase and/or production of fuels used in electricity generation, capital costs of generation facilities, operating costs of generating facilities, and capital and operating costs for any transmission facilities avoided by the interconnection. Another direct economic and financial benefit of an interconnection to a country is income from power sales, with payments for power made in hard currencies of particular import to many developing economies. Direct incurred costs related to the interconnection include the costs of fuels used to generate electricity for export (and of running the facilities needed to supply fuels), the capital and operating costs of generation facilities, and the costs of building and running the interconnection itself, as well as the costs of purchasing power.

The *indirect* costs and benefits of an interconnection potentially include the stimulation of national and local economies through employment of labor needed for facilities construction, and to a lesser extent, from the labor needed to operate the interconnection (and associated power plants) on an ongoing basis. Other potential indirect economic benefits of an interconnection include the impacts of improved power supplies in fostering development of local industry, improvements in education and health care, as well as the "re-spending" effect where electricity price reductions leave households with more disposable income available for other consumption, for savings, and for investment in productive activities. Depending on how the institution selling the power from the interconnection is configured,

an interconnection may spur markets for power generation in one or more of the interconnected nations, further reducing electricity prices.

Pricing arrangements are needed to specify what the buyer(s) and seller(s) will pay and receive for electricity (electrical energy and power) and electric system services (capacity and ancillary electricity system services) provided through the interconnection. Prices can be specified based on production costs or avoided costs, or through negotiation, with market-based pricing a possibility where enough buyers and sellers exist to provide for structured, fair competition.

International electricity grid interconnections, except perhaps in their very simplest forms, can be very complex **legal** undertakings, involving a variety of national, sub-national, and even international parties to the agreements required for planning, building, and operating power lines used to buy and sell electricity across borders. Binding legal agreements between countries and others involved in the project, as well as the negotiation processes that produce the agreements, must be transparent and enforceable. This requires national legal capacity to draft, review, enforce, adhere to, and in the event of a disagreement, adjudicate contract issues. Some of the key types of legal agreements needed to provide frameworks for international electricity grid interconnections include power purchase and pricing agreements, agreements on siting of power lines and related infrastructure, agreements on power line operation (and operation authorities), agreements on power line security, agreements on the environmental performance of the interconnection, agreements on liability for power line failure, and agreements for the orderly, fair, and open selection of contractors to build and/or finance and/or operate and maintain interconnection infrastructure.

International electric grid interconnections may bring **political** benefits to the interconnected countries ranging from increased experience and political comfort with international cooperation, more reasons to avoid conflict with neighbors, increased democratization (depending, in part, on how the interconnection is designed and administered), and an increase in internal political stability. The existence of an interconnection may, conversely, raise concerns about the perception of political and economic leverage of one of the interconnected countries over another, may entangle countries in each others' internal affairs, and may entail significant political costs for power line protection.

Political agreements both between and within countries are needed to underlie the types of legal agreements noted above. Political agreements are needed on sharing of power resources, moving forward with the interconnection project, how interconnection project contractors will be paid, and by whom, how the benefits and costs of the project will be shared between and within nations, agreements as to how the interconnection infrastructure will be operated and secured, including agreement on the governance of the interconnection operator, and sharing of information necessary to plan, operate and protect the interconnection.

International grid interconnection projects may yield significant **social** *benefits*, as well as *costs*, to some or many groups in the nations participating in the projects. Potential *benefits* include better power quality, more reliable power, and more widespread availability of electricity to communities, income from power exports if spent toward social development goals, and the experience and incentive for interconnected for additional cooperative activities between countries. Potential social *costs* and/or liabilities

of grid interconnection include potential physical separation of local groups from the resources that they use regularly, the importation of unwanted outside social influences to areas of infrastructure construction, the social impacts of export power plant construction, and the reduced incentive in power importing countries to use local resources, leading to increased vulnerability to supply disruptions.

International electrical grid interconnections can offer a wide range of **environmental** *benefits*, but can also cause a wide range of environmental *impacts*. Environmental *benefits*—including reduced or avoided locally, regionally, or globally significant air pollutant emissions, reduced water pollution, reduced solid and hazardous wastes, reduced land-use impacts, reduced impacts on biodiversity and wildlife, and reduced impacts on human health—can be provided by the grid interconnection, through its impact on electricity generation and/or the use of other fuels in one or more of the nations participating in the project. Net environmental *impacts* in each of these categories can also occur as the result of the interconnection. In addition, a grid interconnection can provide net environmental benefits or impacts of one or several types in different locations, requiring a comprehensive evaluation to assure that all environmental costs and benefits are accounted for.

Some of the key potential overall strategies for reaching the necessary agreements to implement an interconnection project include:

- Assure the **fair distribution of economic, social, and other benefits and costs** among the nations involved in an interconnection, as well as among the groups within nations that are "stakeholders" in the interconnection.
- Make sure that the **direct costs and avoided costs of an interconnection are specified as accurately as possible**, preferably within the context of comprehensive long-term power system (and overall energy sector) planning. This includes assessment of **environmental** costs and benefits. Continue planning and assessment studies even after the project is implemented.
- **Emphasize transparency** in all negotiations related to grid interconnections, including allowing all stakeholders access to all relevant materials.
- Include **all** (or at least all major) **potentially affected parties in the early stages of project formulation**, and continuing to solicit the input of all parties on key decisions throughout the project.
- Establish clear needs for, and protocols **for collecting and distributing, quantitative data and other information** needed for project design, as well as for the accurate estimation of project costs and benefits.
- Establish **clear legal and administrative authorities** over all aspects of the design, construction, and operation of the grid interconnection.
- Work **with and through international and regional institutions**, including international financial institutions, to help smooth the path to political agreement, as well as to assist in providing the capacity for all groups to contribute meaningfully to decisions related to the interconnection.

- Locate new power lines in **existing transmission or transport corridors** as much as possible.
- Implement **capacity building** to allow different social stakeholder groups to meaningfully participate in investigating and deciding upon grid interconnection options, and in planning for grid interconnection construction and operation.

Recommended areas of activity related to grid interconnections where United Nations agencies and other international organizations could usefully provide support and structure to assist in evaluating, and, more importantly, developing the human capacity to evaluate, international grid interconnection projects include:

- **Training** of local and regional people in a number of both general and specific professional areas, ranging from electricity transmission engineering and power flow modeling to finance, utility management, law, marketing, regulation, negotiation and arbitration, information systems and database development, planning and policy development, data collection, and environmental analysis. Training should build as much as possible on existing centers of expertise within the region.
- **Compilation of information** in a number of areas, including technical parameters of and power loads and flows in national transmission systems, the status of national and regional regulatory, financial, and legal systems, energy sector forecasts and planning results, demographic and social data, resource, hydrologic and environmental data, and data on the costs and performance of new energy and environmental technologies
- **Sponsor analytical activities** that it is hard for individual countries or private groups to sponsor (or to sponsor in an inclusive manner), including, power flow modeling of non-connected and interconnected systems, analysis of market systems for power trading, economic/environmental/social impacts analyses (pre-, during, and post-project), and electricity sector planning, and overall energy planning, including forecasts of demand for electricity and for energy services.
- **Provide support for engagement** via events and processes where counterparts from different regions and countries, and even sub-national stakeholders, can communicate, work, and learn together. Such opportunities include regional study groups on the technical, economic, legal/regulatory, political/social, and environmental aspects of interconnections to serve a particular area, national and regional stakeholder meetings regarding interconnection prospects in general, and/or specific interconnection options in particular, and support—including capacity building, expertise, and project support—for the intervention of stakeholder groups in interconnection planning processes.[1*]

1 Cover graphics from *http://www.eskom.co.za/about/Annual%20Report%202003/Enterprise/htm/2359%20Final-0081.htm* and *http://www.tva.gov/power/projects/500kv_line/*.