9. Conclusions and Recommendations for Follow-up

9.1. Review of Major Issues Associated with International Grid Interconnection

International electricity grid interconnections, particularly those spanning large distance, carrying large amounts of power, and/or involving several countries, 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. Some of the key elements of each of these aspects are reviewed briefly below.

Technical Aspects of Grid Interconnection

Among the basic technical issues that must be addressed early in the planning process for a grid interconnection are 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.

For AC interconnections, key design and operating issues 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. HVDC and other transmission options may be considered as alternatives or complements to traditional transmission upgrades in interconnections. Simulation software is an essential tool for planning 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.

Economic Aspects of Grid Interconnection

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 nations participating in the interconnection are “avoided costs”, that is, direct costs that are 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 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. Where significant amounts of short-term construction labor are needed, there is the risk of non-sustainable economic development in local areas—the "boomtown" effect. 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.

Legal Aspects of Grid Interconnection

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. As such, binding legal agreements between countries (and between the countries and the outside lenders, if any, providing project financing), 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 issues that must be addressed setting up a legal framework for international electricity grid interconnections include:

- Power purchase and pricing agreements, including agreements on the currency of payment, the escalation and/or indexing of prices to prices of other energy commodities over time, and penalties if sales or purchase minimums are not met.
- Agreements on siting of power lines and related infrastructure, such as routes between generating plants and consuming grids, and placement of substations and interconverter (for AC-DC-AC systems) stations.
- Agreements on power line operation, including deciding upon or constituting a joint authority to operate the interconnection, and agreeing on how the power line operator will be governed or overseen by both parties. Agreements on power line operation will also include agreements on how the interconnection right-of-way is to be maintained.

- Agreements on power line security, including agreements on which parties will be liable in the event of different types of incidents resulting in power line damage.
- Agreements on the environmental performance of the interconnection, potentially including environmental standards to be met during construction of the line, and environmental and safety (including fire safety) standards to be met during line operation.
- Agreements on liability for power line failure, including damages to third parties caused by power line failure.
- Agreements for the orderly, fair, and open selection of contractors to build and/or finance and/or operate and maintain interconnection infrastructure, including agreements on how such contractors are to be overseen by parties to the project.

Political Aspects of Grid Interconnection

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. On the other hand, in some cases, the existence of an interconnection may be used as an excuse for internal political oppression, may give one of the interconnected countries more political and economic leverage over another, may entangle countries in each others' internal affairs, may provide potential for political graft, and may entail significant political costs for power line protection.

Designing, constructing, and operating power line interconnections require political cooperation both between and within countries on a number of fronts, including:

- Agreements in principle as to sharing power resources—political agreement between the two governments that such sharing of resources would be mutually beneficial.
- Agreements on moving forward with the interconnection project, including agreements on contractor selection, power line routing, and other major decisions.
- Agreements as to how interconnection project contractors will be paid, and by whom.
- Agreements as to 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.
- Agreements as to the sharing of information necessary to plan, operate and protect the interconnection.

Social Aspects of Grid Interconnection

International grid interconnection projects may yield significant social benefits to some or many groups in the nations participating in the projects. Among these benefits are:

- An international interconnection may help to provide better power quality, more reliable power, and more widespread availability of electricity to communities. Greater availability of affordable electricity can provide more opportunities for education, improvements in health care, development

of employment opportunities, and reduction of difficult and labor-intensive tasks, all of which can contribute to sustainable development.

- If carefully and equitably distributed, and particularly when spent toward social development goals such as education, health care, housing, agricultural improvement, and creation of employment opportunities, the income to power-exporting countries from an interconnection project may have many positive social impacts.
- Successful operation of a grid interconnection may provide the experience and incentive for interconnected countries to embark on additional cooperative activities, including cultural exchanges and additional trade, resulting in improved relations between the countries.

Among the potential social costs and/or liabilities of grid interconnection are:

- The presence of a power line or other types of infrastructure used in grid interconnections may partially or totally physically separate local groups from the water, land, forest, agricultural, social and economic (local towns and markets), and other resources that they use regularly.
- The process of construction of interconnection infrastructure may bring in unwanted outside influences, causing social problems in formerly isolated local populations ranging from alcoholism to violence.
- For electricity exporting countries, the construction and operation of power plants built to feed an interconnection, and of the fuel supply infrastructure that feeds the power plants, may have significant social impacts. Displacement of populations by new facilities (particularly hydro facilities) can be considerable, and can lead to social problems such as out-migration from rural areas to the margins of cities, under-employment, and dislocation from ancestral lands.
- For electricity importing countries, use of electricity provided via an interconnection from a neighboring country can reduce the incentive to use local resources, can increase the vulnerability of communities to cuts in power supply that are outside of the control of the community and the nation, and can reduce the preparedness of the community to deal with electricity shortages.

Environmental Aspects of Grid Interconnection

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 air pollutant emissions (including pollutants of local, regional, and global significance), 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, however, can also occur as the result of the interconnection. In addition, a grid interconnection can provide net environmental benefits of one or (more likely) several types in some locations, while resulting in net environmental costs of one or (more likely) several types in other locations. A grid interconnection may, for example, reduce carbon dioxide and other emissions in a country importing power by reducing the use of coal-fired generating stations in that country, but the hydroelectric dams built to supply electricity in an exporting country may produce significant net methane emissions.

9.2. Key Attributes of Situations with Grid Interconnection is to the Mutual Advantage of Trading Parties

From the technical and economic perspectives, groups of countries where at least one partner has significant untapped, and possibly remote energy resources that can be converted to electricity, and/or where the timing of peak demand is significantly different between countries, and/or where strong load growth is expected, will make the best partners in an interconnection project. The sharing of technical grid standards, including similar nominal and actual operating parameters, is another key attribute for potential interconnection partners.

From a legal perspective, countries with existing frameworks for contract enforcement, significant human capacity in the legal and judicial professions, effective and consistent regulatory structures, stable political systems, and experience in being a party to international legal agreements will have a smoother path to success in interconnection projects.

From a policy perspective, countries sharing the political will to cooperate on a grid interconnection are most likely to reach the legal agreements necessary to run a grid interconnection smoothly and in a timely manner, and indeed most likely to attempt to enter into such arrangements in the first place. Countries sharing a culture of regional or international cooperation, having a culture of active long-term planning and clear energy policy goals, having shown a previous willingness and ability to ratify and adhere to international agreements, sharing a history of cross-border trade on key commodities, and having common membership in strong regional organizations are most likely to be able to reach political agreement on grid interconnections.

From a social perspective, countries where there is a clear commitment to allowing different social groups a voice in the planning of an interconnection project, and to making sure that the benefits (and costs) of the interconnection project are both fairly distributed and well-anticipated, are likely to benefit most from an interconnection, and find a smoother path to project implementation and operation.

From an environmental perspective, countries where the new resources that an interconnection draws upon are significantly cleaner, environmentally, than the energy resources displaced by the output of the interconnection, will benefit the most. Where interconnection infrastructure can be installed in existing rights of way and on existing power plant sites, environmental damage due to changing land uses can be minimized.

9.3. Summary of Key Strategies for Maximizing Benefits, and Minimizing the Costs of Grid Interconnections

Given the potential benefits, costs, national attributes favoring agreements, and barriers to cooperation in each of the six main issue areas covered in this Report, 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. This is an important element in assuring that the net benefits of an interconnection are maximized, and that the political, social, and other costs are kept low.
- 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 sec-

tor) planning. This means that analyses of the economics of power trade across all of the nations involved in an interconnection project (or set of projects) needs to be a part of both short- and long-term electricity and overall energy-sector planning by the project participants.

- **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. In some cases this may require building legal and regulatory capacity within the participating countries.
- 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.
- Continue **planning and assessment studies even after the grid integration project is completed**, and avoid the temptation to cease assessment studies when the project is complete.
- 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.
- Undertake a thorough **estimate of the significant environmental costs and benefits** that will flow from a grid interconnection. This will require a thorough and systematic study of all of the aspects of the interconnection, the electricity generation facilities feeding the interconnection, and the fuel chains feeding electricity generation, in all of the countries and areas within countries that may be affected by changes in energy sector activity or infrastructure brought about by the interconnection.

In a presentation at a USAID SARI/Energy Semi Annual Meeting in South Asia, Vladislav Vucetic of the World Bank lists, in the context of a "way forward" for the development of interconnection projects, a number of strategies for regional energy and grid cooperation. These strategies are summarized in Figure 9-1. Many of the approaches outlined above are explicit or implicit in the strategies recommended by Vucetic.

9.4. Full and Consistent Consideration of Interconnection Opportunities Require Integrated and Long-term Electricity System Planning

The need to embed the consideration of interconnection projects into the broader consideration of electricity system planning, and even overall energy sector planning, was noted above, but deserves special additional mention. All costs and benefits of a long-term project like an interconnection—whether they are economic, social, political, or environmental—must be measured relative to other means of providing the same energy services. As technology progresses, the number of other means of providing those energy services is growing

rapidly, including not only construction of new large power plants, but on-site renewable or fossil-fueled generation for businesses and homes, energy efficiency improvements, fuel switching, and even alternative social organizations (though this is very difficult to include in planning).

Figure 9-1: The Way Forward, Strategies for Cooperation on Energy Interconnections[150]

The way forward

- Increasing bilateral trade ("bottom up")
- Pursue simpler deals first
- Get the private sector involved (in partnership with the public sector)
- Strengthening physical infrastructure (in conjunction with specific trading deals and investment projects): gradually constructing regional electricity (and gas) transmission network, starting from bilateral interconnections
- Getting the broad framework right to open up longer term trading and investment potential ("top down"):
- Analysis of regional energy trade economics
- Addressing institutional, regulatory and policy issues
- Addressing technical issues: parallel operation of electrical grids
- Developing commercial framework for trading: framework trading agreements, model power purchase agreements
- Addressing investment issues: investment protection, regional investment planning, riparian rights, right of way for electricity transmission lines and gas pipelines, environmental and social concerns, etc.
- Using the existing (or complementing) regional forums for multi-country discussions and coordination (SAARC, ECO)

An interconnection project of significant size represents a considerable investment, not only in economic terms, but often also in political and social terms, as well as being a magnet for available human capacity. Before completing such an investment, it is critical that the societies involved examine, to the best of their ability and in multiple dimensions[151], alternatives for providing energy services for sustainable development that include, but go beyond, grid interconnection. The ability to do such studies—and indeed, to meaningfully do any of the studies necessary for grid interconnection itself—depend on the availability of human analytical and planning capacity, the collection and organization (and sharing) of robust sets of data

150 Vladislav Vucetic (2004), *World Bank's South Asia Energy Program*. Presentation at the USAID SARI/Energy Semi Annual Meeting, New Delhi, October 12-13, available as 2004 *http://sari-energy.org/DynamicPPTShow/PPTDownloads/PPT103OCT04.zip*. Figure shown is slide 24. Vucetic's presentation also provides good summaries of many other topics relevant to international grid interconnections, including market arrangements, benefits of energy trade, barriers to trade, risks of energy trade/mitigation measures to reduce risks, and the potential roles of international agencies in interconnection projects.

151 Perhaps, for example, using a method like the energy security analysis methodology outlined in Chapter 8 of this Report.

describing current conditions and recent trends (including data on energy use, topography, demographics, and the status of the environment, just to name a few), the coordination of plans between sectors, and, most importantly, the cooperation and consistent, ongoing support and encouragement of the governments that the studies will serve. It is important to stress again here that the term "planning studies" does not mean determining a detailed plan for the long-term future of an energy sector, if indeed that were possible (particularly in this age of markets). These studies are rather designed to show which energy sector strategies are clearly viable, and which are clearly not, relative to other alternatives that appear (at least at present) reasonable. The planning studies therefore point an overall direction, to be updated regularly, in which policy can guide energy sector and other actors as the future unfolds.

9.5. Recommendations

There are a many areas of activity related to grid interconnections where United Nations agencies and other international organizations could very usefully provide support and structure to assist in evaluating, and, more importantly, developing the human capacity to evaluate, international grid interconnection projects. These include (but are by no means limited to):

- **Training**. Evaluating the many complexities associated with grid interconnection will require people, preferably local to the region for which the interconnection is considered, who are trained in a number of both general and specific professional areas. These areas include:
    - Electricity transmission engineering and power flow modeling
    - Power plant engineering
    - Civil engineering
    - Utility finance and project financial analysis, including tariff setting
    - Utility (transmission, power plant, and other) project management
    - Utility law
    - Utility metering, collections, and accounting systems
    - Contracts enforcement
    - Power marketing
    - Utility regulation
    - Negotiation and arbitration (including skills for convening and management of stakeholder groups)
    - Information systems and database development
    - Energy planning and electricity systems planning
    - Policy development and facilitation of political communications
    - Energy, environmental, and social data collection and analysis
    - Social impacts assessment
    - Environmental modeling
    - Environmental sampling and damage assessment

These daunting training tasks often need not (and generally should not) start "from the ground up" (building whole new programs). Rather, they should build on existing training resources in each region, including in local colleges and universities. This approach was summarized as "Identify centers of excellence within each sub region, which serve as training centers for sharing of experience." by E.A.K. Kalitsi[152].

- **Compilation of Information**. The evaluation of grid interconnection requires many types of information. In many countries, these data are disorganized, dispersed, closely held for personal/organizational/economic or political reasons, or simply (and most often) not available at all. United Nations agencies and other international organizations could provide support and for data collection and compilation in a number of areas, including:
    - Technical parameters of national transmission systems, including an inventory of transmission and power plant infrastructure
    - Power loads and flows at all relevant points in national and regional transmission systems (as needed for power flow modeling)
    - The status of national and regional systems needed to support interconnections, such as regulatory, financial, and legal systems
    - Electricity load forecasts (if they exist)
    - Energy sector development plans (if they exist)
    - Demographic and social features of areas potentially affected by an interconnection (including collection of information on local needs for energy services)
    - Hydrologic and other data related to water resources
    - Environmental data (existing pollutant emissions and impacts, for example)
    - Data on the costs and performance of new technologies (including power plant, power transmission and distribution, demand-side energy-efficiency, renewable energy, and pollution control devices)
- **Sponsor Analytical Activities**. In many cases where the investigations of interconnections are desirable, the combination of financial resources, capability, and political trust in a convening party may not exist to underwrite necessary pre-project analysis (especially analysis open to all stakeholder parties) unless regional or international organizations act as sponsors. Some of the analytical activities that United Nations and other multi-lateral agencies might usefully sponsor include:
    - Power flow modeling of non-connected and interconnected systems
    - Analysis of market systems for power trading
    - Economic impacts analysis (pre-, during, and post-project)
    - Electricity sector planning, and overall energy planning, including forecasts of demand for electricity and for energy services

152 E.A.K. Kalitsi (2003), *Problems And Prospects for Hydropower Development in Africa*. Prepared for the Workshop for African Energy Experts on Operationalizing the NGPAD Energy Initiative 2 – 4 June 2003 Novotel, Dakar, Senegal, and available as *http://www.un.org/esa/sustdev/sdissues/energy/op/nepadkalitsi.pdf*. Quote is from page 17.

- Environmental assessment and impact analysis (pre-, during, and post-project)
- Social impacts assessment (pre-, during, and post-project)

- **Support for Engagement**. United Nations agencies and other international organizations have traditionally provide support for events and processes where counterparts from different countries, and often, regions, can meet to discuss matters of shared concern in a neutral setting. In addition, the United Nations and other organizations can help to support the engagement of sub-national stakeholders in the interconnection planning process, including stakeholders who otherwise might not have a strong voice in the process. A number of both of these types of support opportunities exist, a few of which are described below.
  - Regional study groups on the technical, economic, legal/regulatory, political/social, and environmental aspects of interconnections to serve a particular area
  - Inclusive national and regional stakeholder meetings regarding interconnection prospects in general, and/or specific interconnection options in particular
  - Meetings of those involved in interconnection projects in different regions of the world where participants can share experiences and learn from each other
  - Support—including training, expert analytical and tactical support, and project support—for the intervention of stakeholder groups (such as local indigenous groups, women's groups, environmental organizations, and other) in interconnection planning processes

Although many of the processes associated with planning and developing an international electricity grid interconnection will, appropriately, be sponsored by the governments, utilities, and other key beneficiaries of the interconnection project, there remain many initiatives that will likely go unfunded and undone without support from UN or other outside agencies. Without the types of support for engagement noted above, it is likely that the full scope of project costs (and benefits) will remain under-evaluated, and that many stakeholder groups will receive insufficient information to protect and advance their rights, and thus an insufficient voice in decisions related to the project.