3. Economic and Financial Impacts of Grid Interconnection

3.1. Introduction:

Arguably the primary reason for developing an electricity grid interconnection between countries is to reduce the overall combined economic costs of supplying electricity services in the interconnected countries—at least relative to non-interconnected systems[36]. Energy trading between nations offers significant direct economic benefits, but also in most cases requires significant economic and financial outlays. There are also potentially many indirect economic benefits of a grid interconnection for one or more of the countries involved, as well as potential indirect economic costs. Pricing of traded electricity requires careful consideration and negotiation if all parties are to benefit. Making sure that the economic costs and benefits are shared fairly between project partners (and among various stakeholder groups within nations) requires that economic and financial structures be in place before (typically) expensive interconnections can begin operation.

The "E7" Group of Utilities describes some of the economic benefits of interconnection as follows:[37]

> "The pooling of resources and the interconnection of isolated electric power systems allow optimum use of available resources. They will be instrumental in achieving reductions in the operating cost of the generation mix, increasing the generation capacity margin and, conversely, reducing the need for investment in peak capacity. Lower production costs and/or lower investments in generation, achieved through the interconnection of electric power systems, should have an impact on rates to the customers' advantage. Improved electric power systems reliability will foster an increase in quality of service and a reduction in power interruptions that too often lead to productivity losses in the commercial and industrial sectors, affecting average regional manufacturing costs and, finally, the national gross domestic product (GDP). Pooling electricity resources is crucial if the electric power systems are to fully contribute to sustainable development."

Careful planning and modeling of options—with consideration of the economic costs and benefits in each of the countries potentially involved in an interconnection—is required in order to ensure that the interconnection project provides significant net benefits to the countries concerned. In some

36 That is, the overall costs of providing electricity, and possibly even the per-unit costs of providing electrical energy and power, may well rise when an interconnection is developed—especially in developing countries where the overall demand for energy services from electricity is rising fast—but the use of an interconnection allows more efficient use of resources in each of the interconnected countries, resulting in costs that are (in theory) lower than they would have been in the absence of the interconnection.

37 Quote is from Section 5 of the "Guidelines" volume of *Regional Electricity Cooperation and Integration (RECI), E7 Guidelines for the pooling of resources and the interconnection of electric power systems*, prepared by the E7 Network of Expertise for the Global Environment, dated approximately 2000, and available from *http://www.e7.org*.

cases, this may include modeling of other energy resource transport options in addition to transport of electricity,. A report prepared by the World Energy Council, for example, compares the costs of transmitting electricity from remote gas-fired generation to electricity markets to the costs of transporting gas to generation constructed near electricity markets. This particular analysis found the overall costs of providing electricity to be less, for most combinations of variables when transport distances were above 1000 km or so, if the gas was converted to electricity at the gas field, rather than near the consuming area[38].

3.2. Potential Economic and Financial Benefits of Interconnection: Power System

The potential economic benefits of interconnection for the power systems of the interconnected countries (considered either individually or together) include fuel costs avoided by the interconnection, avoided generation capacity costs, avoided operating costs, and avoided costs for transmission system improvements. Savings in these elements come about largely because the operation of the interconnected system can (to a degree) be coordinated to optimize the use of resources on both systems to meet the loads on both systems. Income from power sales, of course, is also a key direct benefit of interconnections for exporting countries.

3.2.1. Avoided fuel costs (where country providing power is using lower-cost resources)

Grid interconnections offer opportunities to reduce generation fuel costs per unit of electricity delivered by allowing generating plants with low fuel costs to be connected to loads, and also by allowing plants with low fuel costs to run more by presenting a flatter demand load curve.

Grid interconnections, and particularly international interconnections between countries with varied resources, offer the option of siting power plants where generation resources are located, and transporting power from those areas to load centers. Key examples of such resources, particularly in regions such as Africa, Latin America, and the Russian Far East are hydroelectric resources, which are often located in areas remote from major populations. Other examples of power plants with low fuel costs, however, include mine-mouth coal-fired power plants, natural gas from gas fields where pipeline transport to markets is undeveloped or problematic (or from oil fields where gas has previously been flared), and in some countries, nuclear power. For resources such as hydroelectric power, and perhaps within a few decades, large-scale solar, wind, and tidal power, power line transport is arguably the only current method of transporting large amounts of energy from where it is converted to distant consumption centers[39]. For resources such as coal and natural gas, conversion to electricity and transport over power lines (including interconnections) must compete with other methods of transporting the fuels to end-users and/or power plants closer to load centers.

A grid interconnection, whether it is between nations or between otherwise largely isolated grid systems within one country, effectively increases the size and scope of both the electricity supply system and the electricity demand that must be met. In any power system, a "load curve" describes the relationship between the power (in MW, for example, or in fraction of peak power demand) to be supplied to meet

38 Clerici, Alessandro and Longhi, Andrea (1999), *Competitive Electricity Transmission Systems as an Alternative to Pipeline Gas Transport for Electricity Delivery*. World Energy Council publication, available as *http://www.worldenergy.org/wec-geis/publications/default/tech_papers/17th_congress/2_2_08.asp*.

39 In the more distant future, technological advances may make the use of hydrogen as an energy storage and transport medium for direct resource-to-electricity conversion methods such as hydro, solar, and wind power a large-scale reality.

overall demand and the number of hours in a year when power is at a given level. With an interconnection, the areas joined may be different enough in the mixes of consumers served and/or the timing of high and peak electricity demand so as to result in a "flattening" of the load curve, that is, an overall reduction in the ratio of annual peak hours to non-peak hours[40]. If the countries (or areas) to be interconnected have peak power demands at different times of the day, or in different seasons, the result, once the systems are interconnected, is that the baseload generation plants, typically those units with lower fuel and other running costs, can run a larger fraction of the time (at a higher capacity factor), thus allowing plants with higher fuel costs to run less. Further fuel savings can accrue because power plants are often more efficient when run at or near full capacity for more hours at a time, and, possibly, when having an interconnection allows the construction of larger power plant units, which may (up to a point) have higher efficiencies than smaller units. The "E7" Group of Utilities describes the benefits of flattening the load curve as follows[41]:

> "Once the former isolated power systems are interconnected, the overall load and the load factor increase: the load curve is flattened. Flattening the load curve will make it possible, in the short term, to maximize the use of the low fuel cost units, thus decreasing the overall fuel cost. At the same time, it will increase the capacity margin of the overall power system. In the long term, it may permit the introduction of bigger size units in the power system, thereby capturing economies of scale. Not accounting for the possible economies of scale in the generation sector, flattening the load curve is *per se* a strong incentive for interconnecting isolated networks."

Note that depending on the structure of the interconnection, and on the characteristics of the interconnected countries, generation fuel costs may be avoided on a net basis in just one or in more than one of the interconnected nations. If the interconnection is primarily an export-import arrangements, overall fuel costs will be lowered in the importing country, though fuel costs per unit electricity generated could fall in both importing and exporting countries if the interconnection allows the exporting country to use its low-fuel-cost generation more. Fuel-cost savings may also have effects "upstream" in the fuel chain in the importing country, as, for example, reduced need for generation fuel also reduces the need for fuel production (for example, coal mining) capacity, with the reduced need for fuel production capacity having its own economic and financial benefits.

3.2.2. Avoided generation capacity costs

In addition to avoiding fuel costs, a major incentive to pursue the interconnection of power systems is to avoid costs for new generation. Generation capital costs can be avoided through interconnection by a combination of replacement of domestic capacity with capacity from power imports, through reduction

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40 For example, a suggested interconnection between the Republic of Korea (ROK) and the Russian Far East (through the Democratic Peoples' Republic of Korea) might be configured for power exchanges to effectively flatten the overall load curve because the ROK system is summer-peaking, while electricity demand in the Russian Far East peaks in the winter.

41 Quote is from p. 9 of the "Module 1" volume of *Regional Electricity Cooperation and Integration (RECI), E7 Guidelines for the pooling of resources and the interconnection of electric power systems*, prepared by the E7 Network of Expertise for the Global Environment, dated approximately 2000, and available from *http://www.e7.org.*

in power plant siting costs, through economies of scale in generation, through flattening of the load curve and related capacity trade-offs between countries, and through reduction in required reserve margin.

The most obvious way that a grid interconnection can result in reduced capital costs of electricity generation capacity is by displacing the need for new domestic capacity in an electricity importing country. In this case, depending on how the capital investment in the interconnection infrastructure itself is designed, the importing country may be spared, or able to defer, the financial burden of the costs associated with new domestic power plants (needed for energy, serving peak power needs, or spinning reserves), instead making payments for electricity consumed from the interconnection[42].

Savings through economies of scale in power generation capital costs come into play in a grid interconnection when the interconnection allows the development of larger power plants than could be supported before interconnection by the demand in any one of the countries in the project. As noted by the "E7" Group of Utilities[43]:

> "At the level of the power generation unit, for a given technology (diesel engines, steam turbines, combustion turbine, wind turbine, etc.), increasing the unit size reduces the unit investment cost, increases efficiency and reduces labor cost per kWh generated by the unit. The capacity at which these economies of scale are exhausted depends on the technology: around 1,000 MW for nuclear units, 600 MW for steam turbines, 300 MW for combined cycle units, and 50 MW for diesel engines1. For a given technology, increasing the size of a unit generally entails technical barriers that will challenge the R&D department of electric plant manufacturers…..Economic gains may also arise from the operation of several units on the same site. For hydroelectric power plants, these gains arise from the fact that civil works for the dam account for most of the investment cost of the hydroelectric power plant. Spending the additional investment cost of a turbine is not commensurate with the up-front cost of civil works. Hence, the full exploitation of a hydroelectric potential is often an important incentive for interconnecting isolated networks."

"Flattening the load curve" by combining loads from two or more systems, may also allow savings in capacity costs by allowing peaking capacity in one nation to effectively serve peaking needs in another, if the times and/or seasons of peak power requirements in the interconnected service territories do not significantly overlap. The net result is that less overall peaking capacity (and perhaps less intermediate-load capacity as well) may be needed. This sort of synergy has been noted between the grids of the winter-peaking Russian Far East and that of its potential electricity trading partner, the summer peaking Republic of

42 Margaret Matinga (2005), *Pooling African Power: Challenges and Issues in a Reforming and Integrating in a Southern African Power Sector*. Dated March 10th 2005, and available as *http://www.nepru.org.na/Regional%20Intergration/Power%20sector%20integration.pdf.*

43 Quote is from p. 8 of the "Module 1" volume of *Regional Electricity Cooperation and Integration (RECI), E7 Guidelines for the pooling of resources and the interconnection of electric power systems*, prepared by the E7 Network of Expertise for the Global Environment, dated approximately 2000, and available from *http://www.e7.org*.

Korea[44]. When countries are interconnected with sufficient transmission capacity, more choices exist for the placement of new generating resources to meet the combined demand of the interconnected systems, allowing (theoretically) the more efficient use of available international investment funds for building new power plants[45].

Another aspect of connecting electricity systems is that there may be a reduced need for reserve capacity, as the larger, interconnected system, may be able to supply electricity at acceptable levels of reliability with a lower reserve margin. Having a lower reserve margin—that is, reducing the ratio between overall peak demand and total available generating capacity—means that lower investments in capacity, and in particular peaking capacity, are required.

It should be noted that reductions in capacity costs due to flattening the load curve, complementarities of peak times or seasons, and reserve margin impacts in particular, and economies of scale impacts to an extent as well, depend on there being enough capacity in the interconnection to substantially affect capacity requirements. Fully realizing these benefits also depend on there being sufficient internal transmission capacity in the interconnected countries to allow the benefits of the interconnection to flow to where peak demands are greatest. If transmission restrictions—whether physical capacity limits or restrictions on access of generators to transmission capacity—prevent power from the interconnection from flowing to some large demand centers, the overall capacity cost reduction from the interconnection is likely to be reduced[46].

3.2.3. Avoided operations costs

When the addition of an interconnection causes changes in the way that power plants within one or more of the interconnected nations are operated and/or built, a savings in operating costs will likely accompany any savings in fuel costs and/or capital costs. These costs savings, which may occur in one or more of the interconnected nations, include savings in variable operating costs—costs that vary with the amount of electricity produced, and fixed operating costs, which vary (at least somewhat) with the amount of generating capacity, but not with the amount of generation in any given year. Variable cost savings include, for example, savings on chemicals for pollution control equipment, possibly spinning reserves costs, and savings on waste disposal costs—if a coal-fired power plant is operated less due to an interconnection, the volume of coal ash to be disposed of, and the costs for transport and disposal, will be reduced. Fixed operating costs, including costs for some maintenance activities, plant labor costs, and other costs, are avoided primarily when the use of an interconnection reduces the need for capacity additions.

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44 Won-Cheol Yun (2004), *A Strategic Approach for Electric Power Cooperation in North-East Asia.* Prepared for the APEC Study Centre Conference, May 2004, and available as *http://fbweb.cityu.edu.hk/hkapec/Conference/Papers/Won-Cheol.pdf.*

45 See, for example, Michael Wolfe, Peter Donalek and Peter Meisen (1993), *The Economic, Environmental and Developmental Benefits of High-Voltage Interconnections Between South and North America via Central America and the Caribbean*. Presented at ENERLAC 93, Bogota, Columbia, June 1993. Accessed from the Global Energy Network Institute (GENI) website at: *http://www.geni.org/energy/library/technical_articles/transmission/interconnect.html.*

46 The importance of network access is noted by Francois Verneyre (2004) in a presentation entitled *European Challenges, Overcoming Challenges*, prepared for the KEEI & IEA Joint Conference "Northeast Asia Energy Security and Regional Cooperation", March, 16-17, 2004, and available as *http://www.keei.re.kr/web_keei/en_news.nsf/0/4dfb5e1e76aa3c1349256e4800150eab/$FILE/Francois%20Verneyre.pdf.*

3.2.4. Avoided costs for transmission system improvements

In some cases, international grid interconnections may avoid national investments in transmission system improvements. When an interconnection, for example, allows existing or new electricity customers living in remote areas near international borders to be provided with electricity service, the costs that would have been incurred to connect those customers directly to the national grid will be avoided. An interconnection may be able to serve towns and cities in border regions through or near which the interconnection will pass more easily than service can be provided from the main power grid of the countries. Similarly, depending on how the interconnection is configured and on the configuration of existing transmission in the nations to be interconnected, the interconnection itself may serve to take the place of needed transmission reinforcement. In either case, the calculation of the net cost of the interconnection needs to take into account the difference between the long-term costs of the electric power systems of the interconnected systems with the interconnection in place and the costs of providing the same electricity service without an interconnection.

3.2.5. Income from power sales

For power exporting countries, income from power sales is a key economic advantage of power grid interconnections. To the extent that some or all of the power sales are paid for in hard currencies (dollars or euros, for example), the sales provide foreign exchange benefits as well. Income from power sales is most useful for national accounts, particularly in developing nations, in situations where a significant portion of investments in generation can be made in local currencies and/or if investments are financed by a third party, such as a private company, rather than by the government itself.

3.3. Potential Economic and Financial Costs of Interconnection: Power System

Each of the potential direct economic benefits of grid interconnection described above has counterpart costs that must be considered in an accounting of the net benefits of interconnection. These include additional generation fuel costs, additional capital and operating costs, connection infrastructure costs, costs of operating the grid interconnection, costs of needed power system upgrades, and costs of power purchases.

3.3.1. Costs of fuel used to generate exported electricity

For interconnections built in large part to provide a means of exporting power, the costs of the fuel used to generate power for export must be considered. Fuel costs for hydroelectric, solar, geothermal, wind or (to a lesser extent) nuclear power plants may be negligible, but the costs for any additional coal, oil products, or gas used to generate export power for export must be counted against fuel costs avoided in the importing nation. Fuel costs should be calculated so as to include any fuel-chain costs related to fuel provision. These will include, for example, costs for developing coal mines and for mining itself, costs for gas extraction or for gas import facilities, and other similar costs. In instances where an open market exists for the fuels used for electricity generation, a market price may be a suitable substitute for a full accounting of fuel-chain costs of providing fuels, but in many countries, where subsidies, often hidden, obscure the true costs of fuel provision, a more detailed approach to the costing of fuel inputs to power generation may be required. A paper from the Workshop on Regional Power Trade (held in Kathmandu, Nepal, in March 2001) makes the following point about the need for careful economic analysis of projects in regions where electricity and fuel price subsidies have been common[47]:

47 Workshop on Regional Power Trade (2001), *Regional Electricity Trading: Issues and Challenges*. Paper from the Workshop on Regional Power Trade, Kathmandu, Nepal, March 2001. Available as *http://64.224.32.197/Publications/shean.pdf; quote is from page 6.*

> "Electricity prices often have been used as the vehicle to promote Government social policies through subsidies to particular classes of customers, cross subsidies between classes of customers, non-sustainable tariff levels to the benefit of all customers, fuel subsidies to generating facilities, and non-commercial capital repayment conditions. Regional trading that may appear to be economically advantageous given current prices in the sending and receiving areas may appear less attractive when such subsidies are removed or when a more commercial terms and conditions are applied with respect to the generation sector."

3.3.2. Costs for power plants used to generate exported electricity

If new power plants are constructed to generate electricity for exports as a part of the interconnection project, the capital and operating costs of those projects represent a net cost to the interconnected system, relative to the cost of the non-interconnected system. Although potentially reduced somewhat, on a per-unit basis, due to economies of scale from being able to sell electricity to a wider market, the additional costs of new generation also may represent significant financial costs to the exporting country, particularly if much of the equipment or materials for the export power plants must be imported and/or if the government of the exporting country must finance or make hard currency payments on a loan to finance the infrastructure. If the power plants are mostly built and financed by a third party, with limited input of funds or guarantees by the host government, then export power plants may constitute less of a financial burden to the government itself.

3.3.3. Costs of interconnection infrastructure

Perhaps the most obvious direct costs of an international grid interconnection is the cost of the power line joining the grid systems. Power line costs include:

- Costs of electrical conductors and insulators.
- Costs of purchasing and erecting transmission towers, and of clearing rights-of-way.
- Costs of substations and transformers to connect grids to the power line.
- Costs of power line control hardware and software.
- Costs of any special interconnection hardware, such as AC to DC and/or DC to AC converters, when the interconnection links must provide a degree of isolation between two systems with very different operational parameters, or when a long-distance DC power line is part of the interconnection.

All of these costs may vary substantially from project to project. Costs depend greatly on the terrain to be traversed, the vegetation present, the characteristics of existing rights-of-way and requirements for rights-of-way, and the hardware needed for system interfaces. As one example comparison, the "E7" Group suggests that "the unit investment cost of a combustion turbine, for instance — US$250/kW — is of the same order of magnitude as the investment cost of a 1000 kilometer-long Direct Current (DC) transmission line with a 3000 MW capacity". Economies of scale in power transmission are significant, with higher-voltage power lines costing less, per MW of power transferred, than lower-voltage lines, and with the possibility of carrying more than one set of conductors on a single set of towers and in a single right-of-way for further cost reduction[48].

The financial cost of the interconnection to the countries involved depends on arrangements for financing (for example, whether the power line connecting the countries is paid for by one or more of the interconnected countries directly, financed through an international financial institution, or is privately financed), and what the arrangements are for repaying the debt on the transmission line and related infrastructure.

One potential means of reducing the financial cost of qualifying interconnections is through the Clean Development Mechanisms (CDM) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. CDM, in theory allows countries (typically industrialized counties) to receive credit for a portion of the reduction in greenhouse gas emissions (relative to a specified "baseline" level of emissions) brought about by projects in developing countries. The "E7" Group of Utilities describe the somewhat uncertain potential for financing interconnection projects with CDM funds as follows[49]:

> "Many of the investments involving an interconnection line should qualify since either they will favor a better dispatch of the generation mix — likely to reduce the consumption of fossil fuels and, thereby, reduce CO_2 emissions of the power system — or facilitate the development of hydroelectric power plants that will replace thermal power generation."
>
> "However, the current stand among the experts devising these CDMs is project-wise, irrespective of the project's contribution to the emissions of the whole power system. For the time being, these experts have not devised anything relative to the baselines for qualifying transmission lines that would permit a better dispatch of the generation mix."

3.3.4. Costs of operation of interconnection infrastructure

An additional element of the total accounting of direct costs and benefits of a grid interconnection is the costs of operating the grid interconnection itself. Operations costs include the costs of labor and supplies to maintain the power line, the rights-of-way, and the substations and other infrastructure, as well as the costs of running control centers that dispatch power to and from the interconnection. These costs are typically relatively small relative to the power plant fuel, capital and operating costs, and to the power line infrastructure costs.

3.3.5. Costs of power system upgrades

In some cases, countries participating in interconnection projects will find that upgrades to their national power systems will be required in order to be able to accommodate—technically and economically—the interconnec-

48 Quote is from p. 14 of the "Module 1" volume of *Regional Electricity Cooperation and Integration (RECI), E7 Guidelines for the pooling of resources and the interconnection of electric power systems*, prepared by the E7 Network of Expertise for the Global Environment, dated approximately 2000, and available from http://www.e7.org. The source notes that DC power lines are "better" for transit distances of 1000 km or greater, but require DC-AC interconverters and other hardware that can be very expensive. The same source also presents a table showing economies of scale in power line costs (costs of power lines per unit capacity versus power line voltage), but the table is based on figures from a rather old (1985) source.

49 The "E7" Group of representatives of large utilities from the G7 group of industrialized nations (2000), *Regional Electricity Cooperation and Integration (RECI)* compilation. Subtitle of overall set of documents, "E7 Guidelines for the pooling of resources and the interconnection of electric power systems". These documents are available from *http://www.e7.org*. The quote provided is from page 28 of the *Module 1, RECI Feasibility* volume.

tion itself. For example, transmission systems may need to be upgraded and reinforced, and control systems (hardware and software) may need to be modernized. These changes certainly imply costs for each national transmission system, but the improved reliability and availability of power that the upgrades produce, even independent of any interconnection, will provide both direct and indirect economic benefits[50]. Last but not least, customer metering and billing systems may need to be upgraded to improve collections (so that power imports can be paid for) and to reduce or eliminate illegal consumption of electricity so as to assure that the costs of power delivered by the upgrade are compensated by payments from end-users. Each of these types of upgrades will yield dividends for the national economy—in the form of reduced electricity losses, better utility cash flow, less wastage of electricity (by consumers not paying for power), and a more equitable distribution of the benefits of electricity—but the upgrades will also require up-front investments in equipment, software, improvements in security of distribution and transmission systems, and training for network control and collections/accounting personnel[51].

3.3.6. Costs of power purchases

For a power importing country, costs of power purchased from the interconnection represent a direct cost to the power system that must be balanced against the types of direct savings described in section 3.2, above, and the indirect net benefits described below. In many cases, power purchases from an interconnection will need to be made in (or partially in) hard currencies, this could represent a significant financial burden to an importing developing country, potentially exerting a drag on a country's balance of payments.

3.4. Economic and Financial Costs and Benefits of Interconnection: National Economy

In addition to the direct benefits and costs of to the power systems of the connected countries, international grid interconnections also offer the potential for indirect economic benefits (and costs) related to the employment impacts associated with the construction of power plants and power lines, the impacts of improved power supply on local and national economies, and the impacts of net savings in power supplies.

3.4.1. Stimulation of local economies from construction and operation of transmission and generation infrastructure

As with other large infrastructure projects, such as pipelines, transport sector development, or the construction of major industrial facilities, the building of new power lines and power plants to feed them will typically result in significant short-term employment for laborers, engineers, and others in the area where the infrastructure is being built. As the workers who build a power line or power plant require support services (food, lodging, and other services), such projects also typically attract and provide employment for a community of vendors and others to serve those working on the project. While this creation of this local employment and economic may be beneficial to the area where the infrastructure is built in the short term, it may also, unless carefully planned, run the risk of creating a "boomtown"—a town that grows and bustles with activity while the project is under-

50 Michael Wolfe, Peter Donalek and Peter Meisen (1993), *The Economic, Environmental and Developmental Benefits of High-Voltage Interconnections Between South and North America via Central America and the Caribbean* (Presented at ENERLAC 93, Bogota, Columbia, June 1993. Accessed from the Global Energy Network Institute (GENI) website at: *http://www.geni.org/energy/library/technical_articles/transmission/interconnect.html* notes this requirement for the "firming up of power systems" in the context of potential interconnections between the countries of Central America with North America and South America.

51 Section 5.6.6 of this Report includes a short discussion of the closely-related political issues associated with curbing illegal consumption of power.

way, but largely fades away, often leaving economic and social dislocation as well as environmental damage in its wake, when the project is complete[52]. The "boomtown" syndrome is a clear example of non-sustainable economic development.

In the longer term, the ongoing operation of power plants and transmission lines will require a community of workers for day-to-day operation. Though the number of workers needed for ongoing operation of these types of facilities is far less than the number required during the construction phase, hundreds to thousands (for example, for a major nuclear plant) of workers may be needed, proving local employment on an ongoing and likely sustainable (if planned correctly) basis in both the operation of the facilities themselves and in the community that will be needed to provide support services for the workers[53].

3.4.2. Stimulation of local economies in importing nations through improved power supply

In nations that will import power or whose power systems will be stabilized by interconnections, a key indirect benefit of interconnections is the impact of more stable and (presumably) less costly supplies of energy on the local and national economies. To the extent that interconnections allow the electrification of areas that had previously lacked electricity, new electricity supplies can be expected to contribute to the local economy through improving the productivity of agriculture (for example, through use of electricity instead of human or animal power for milling of grains), reducing the amount of labor needed for household tasks such as water provision (thereby leaving more time for home and small businesses and other productive activities, and making possible the development of other local industries. Similar benefits may accrue if the reliability of electricity supply is markedly enhanced. The improvement from a situation where electricity supplies are intermittent to a situation where electricity supplies are always or nearly always available makes the siting of new industrial capacity more attractive and feasible, contributing to the development of the local economy. Improved power supplies also benefit existing businesses and their employees; many businesses must shut down when power is unavailable, resulting in loss of income, wastage (in some cases, such as the food industry) of products or raw materials, and loss of employment[54]. New and/or better access to electricity for communities often means improved access to educational opportunities (such as the use of electric lights for study at night), and better health care (light for examination rooms, refrigeration for medicines)

52 See, for example, Section 6.3.3 of this Report.

53 Additional, quite site-specific economic and other benefits may also accrue from the construction and operation of power plants built to feed electricity to the interconnection. Certain hydroelectric power plants—the Aswan High Dam in Egypt and the Akosombo Hydro Project in Ghana are cited as examples in 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*) —may have additional benefits, including flood control, storage of water for irrigation in dry seasons or years, improving navigation, and improving fisheries.

54 An example of the problems that can face industries dependent on uncertain electricity supplies is described in Itai Madamombe (2005), "Energy Key To Africa's Prosperity: Challenges in West Africa's Quest for Electricity", *Africa Renewal*, Vol.18 #4, January 2005, available as *http://www.un.org/ecosocdev/geninfo/afrec/vol18no4/184electric.htm*. This article also describes some of the interconnection and related power projects under consideration in Africa, as well as other potential economic benefits of interconnection.

which may reduce productive time lost due to illness[55]. Grid interconnections may also allow developing economies to access needed additional electricity supplies faster than through development of domestic electricity sources, thus avoiding (to the extent possible) temporary shortages of electricity and the negative effects of such shortages on economic growth[56].

To the extent that there are net savings in overall direct power supply costs due to the interconnection (and assuming that those costs are passed on to electricity consumers in the form of reduced tariffs), there should be a stimulation of the local economy (where prices are lowered) through the "re-spending" effect. When the amount of money that a household must spend on grid electricity (or other energy forms, such as batteries or lamp oil) declines due to tariff reductions, the household has more money to spend on other goods and services, and/or can devote a higher proportion of income to savings. In either case, the result may be enhanced local economic activity, and enhanced investment in the means of production, both potentially assisting the process of sustainable development[57].

3.4.3. Economic benefits resulting from increased competition in electricity generation.

Another possible economic benefit of grid interconnections is their role in spurring greater international and national competition in the power generation sector. Additional competition in the sector may serve the purpose of lowering both costs of electricity generation and lowering electricity prices, while improving efficiency and productivity. The economic benefits of such improved competition could accrue by allowing more domestic and foreign firms to enter the market, with the greater competition in electricity supply resulting in reduction in the price of electricity for end users (resulting in the types of economic stimulation described above). More domestic firms may be able to enter a market in a country receiving power over an interconnection due to the improved transmission access that the interconnection provides. Similarly, foreign generators will (assuming access rules allow) have improved potential to send power to markets across borders, presumably at lower transmission costs. Another possible mechanism for bringing about increased competition is that an interconnection project brings with it a level of required increased transparency in financial dealings at the utility and governmental level that makes electricity pricing and market opportunities more obvious to potential generators. Countries with relatively few domestic market actors may be able to form a fully functioning electricity market **only** if interconnections are strong. This was noted in a study describing the "Baltic Ring" interconnection project for the Baltic region of Northern Europe[58]:

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55 See, for example, Michael Wolfe, Peter Donalek and Peter Meisen (1993), *The Economic, Environmental and Developmental Benefits of High-Voltage Interconnections Between South and North America via Central America and the Caribbean*. Presented at ENERLAC 93, Bogota, Columbia, June 1993. Available from the Global Energy Network Institute (GENI) website at: ***http://www.geni.org/energy/library/technical_articles/transmission/interconnect.html.***

56 Vladislav Vucetic (2004), *South Asian Regional Energy Trade: Opportunities and Challenges*. Presentation provided at The World Bank/International Monetary Fund Annual Meetings, Washington, D.C.., October 1, 2004. Available as *http://siteresources.worldbank.org/INTSOUTHASIA/Resources/Energy_a.pdf.*

57 An example of the "re-spending" effect in the context of household savings from demand-side management is described by B. Biewald et al (1995), *Societal Benefits of Energy Efficiency in New England*, available as *http://www.cs.ntu.edu.au/homepages/jmitroy/sid101/npfdsm.html*.

58 Baltic Ring Electricity Co-operation Committee (BALTRAL, 2003), *Towards a Common Electricity Market in the Baltic Sea Region*, Report co-Financed by the European Commission, and available as *http://www.baltrel.com/Reports/Baltrel_021202.pdf.* Quote is from page 7.

> "In a number of cases, joint multi-national solutions are the only reasonable alternative for countries that want to achieve true competition, i.e. countries need one another to enable competitive solutions to perform well in practice."

Of course, an opposite effect is also possible, as having a large transmission line in place may depress local wholesale electricity prices and/or saturate (in the short or long term) the market for additional capacity, both of which would tend to reduce private entrants to local, national, or cross-border electricity markets.

A special case of the impact of grid interconnections on competition in the electricity market is their impact on distributed generation. Distributed generation refers to small generation facilities (usually kilowatts to tens of megawatts), typically owned by electricity customers (though sometimes by third parties) and located on customers premises, that allow on-site generation of electricity and sometimes heat as well, reducing transmission and distribution losses, and also reducing the need for transmission and distribution capacity (as well as for generation capacity in general). A grid interconnection can help to set up the market conditions whereby distributed generation can compete with utility resources, particularly in instances where an interconnection results in a change from a vertically-integrated, single utility structure. Conversely, on the negative side, the presence of low-cost power from an interconnection may make it more difficult for distributed generation to compete in the generation market.

Overall, the degree to which an interconnection brings with it enhanced competition in generation (for both large generators and distributed generation), and, through competition, reduces electricity prices (without compromising power quality or social or environmental qualities), depends on the degree to which the full costs of all alternatives are considered in planning the energy sector, and on the degree to which all relative costs are transparently included in market prices as much as possible.

In the European context, an observer from Electricité de France notes that though it is assumed that international electricity trade or the possibility of trade should drive down electricity prices, in practice a combination of insufficient cross-border interconnection capacity and a lack of harmonization of network access rules across the countries of Europe mean that the market for electricity remains fragmented[59]. Thus, while interconnections may ultimately help to lead to a more competitive international market and better electricity prices for consumers, there are clearly a number of other considerations that come into play in determining the impacts of interconnections on electricity markets.

3.4.4. Benefits of interconnection are dependent upon the structure of transmission capacity

It is not necessarily the case that an interconnection configured to bring lower-cost power to a country will bring significant direct economic benefits—avoided fuel, O&M, and capacity costs—to all of the regions in the countries that are interconnected. In many cases, internal transmission "bottlenecks" (points in the network where transmission capacity is inadequate) may prevent some or many regions of the interconnected countries from accruing significant benefits from the interconnection. In a detailed modeling study of the power systems of Northeast North America, Eynon and colleagues looked at the

59 F. Verneyre (2004), *European Experiences, Overcoming Challenges*. Prepared for the KEEI and IEA Joint Conference on Northeast Asia Energy Security and Regional Cooperation, March, 2004, Seoul, ROK. Available as Francois Verneyre.pdf from *http://www.keei.re.kr/web_keei/en_news.nsf/0/4DFB5E1E76AA3C1349256E4800150EAB?OpenDocument*.

economic and technical benefits from the interconnection between the United States and Canada, and concluded (in part) "...that certain bottlenecks prevent all regions [of the US Northeast] from benefiting to the same extent" from regional interconnection[60]. This result underscores the need for thorough, well-informed economic and power flow modeling of the systems to be interconnected before interconnection is begun in earnest. Making sure that domestic transmission capacity is sufficient to allow good use of the interconnection is necessary to ensure that the interconnection investment is worthwhile.

3.5. Pricing of electricity traded between nations

A key economic consideration in any grid interconnection is how the electricity that will be traded will be priced. This includes consideration of what elements of energy and capacity will be priced, what basis or bases should be used for pricing, and what arrangements may be made for changing prices paid over time[61].

3.5.1. Elements to be priced

A grid interconnection is designed to move electrical energy and power from one grid to another. Within this general mission, however, the interconnection may provide several different related services, all of which may have their own pricing structure. The services sold over an interconnection may include:

- Transmission capacity, which may be sold to generators (or bulk purchasers of power) independent of any actual deliveries of power over the interconnection.
- Electrical energy, sold by generators to purchasers (in units of cost per MWh, for example).
- Delivered power, sold by generators to purchasers (in units of cost per MW, for example).
- Ancillary services, sold by generators and/or by the operators of the interconnection to the power grid or grids, and including services, such as spinning reserve, short-term regulation of grid stability, and electricity for "black start" of power plants, that allow for the smooth operation of grid systems and maintenance of power quality[62].

3.5.2. Potential bases for pricing

There are a number of different ways that prices for the services (including energy and power) to be provided by an interconnection may be valued and priced.

Prices can be based on **production costs**, where, for example the costs of electrical energy provided via an interconnection is by agreement equal to the cost of generating the power—including fuel, operating, and capital costs expressed per unit of energy, plus the costs of delivering the energy to a designated transfer point (factoring in losses), and probably an adder for profit or return on investment. Pricing based on production costs requires a clear and transparent means for both parties agreeing to the pricing to review actual costs of production. Production cost pricing is probably more feasible for the pricing of energy, capacity,

60 Robert T. Eynon, Thomas J. Leckey, and Douglas R. Hale (2002), *The Electric Transmission Network: A Multi-region Analysis.* Published by the United States Department of Energy's Energy Information Administration, and available as *http://www.eia.doe.gov/oiaf/analysispaper/transmiss.html.*

61 Note that this discussion focuses on prices paid by utilities and others purchasing power wholesale, not on tariffs paid by retail customers.

62 Examples of markets for ancillary services exist in a number of places, including those maintained by the PJM system in the Eastern United States (see *http://www.pjm.com/markets/ancillary/ancillary.html*), and the Alberta Electric Systems Operator in Western Canada (AESO; see *http://www.aeso.ca/market/5137.html*). For a definition of ancillary services, see Chapter 2 and the Glossary to this Report.

and power delivered than for the pricing of ancillary services. This cost-based method of determining average tariffs has been used for years in many jurisdictions in the United States, especially for determining tariffs to be charged to customers by regulated utilities.

Prices for the services provided by the interconnection can also be determined by consideration of **avoided costs**. In this case, the question is not what it costs to provide electricity via the interconnection, but what the electricity will be worth to the partner purchasing the electricity services. Here the costs of fuel, operations, capital expenditures on power lines and plants, and other cost elements that are avoided by the use of energy and power via the interconnection set the upper limit on the amount that can be paid for the services provided by the interconnection. Calculation of avoided costs depends on a consideration of what the future development—often fairly long-term development—of the power system would look like in the presence and absence of an interconnection when both "scenarios" provide the same energy services. This comparison, in turn, requires both a long-term forecast of energy demand and a long-term plan, at least in skeletal terms, of how demand will be met through supply additions and other system changes. The total costs avoided by using the interconnection instead of other means of providing electrical energy, power, capacity, and ancillary services are then divided by some measure of the services provided (capacity, power, or energy delivered) to calculate a unit price. The avoided costs method of pricing has often been used in the past in the United States to provide a rate, or sometimes an upper limit on the rate, that a distribution utility will pay for electricity provided by independent power producers.

In some, probably limited, cases, the **costs of other fuels** that would compete with electricity provided by an interconnection may provide a ceiling price. For example, the cost of lamp oil or batteries for rural lighting may provide an upper bound on the value of electricity from an interconnection if rural lighting were the major intended market for electricity from the interconnection[63]. Similarly, if electricity from an interconnection were intended largely to provide power for a factory or mine, the cost of operating electric motors with energy from the interconnection would be compared with the costs of operating diesel motors. In most cases, however, electricity will serve a variety of end-uses with a variety of potential competitor fuels, and the calculation of the value of electricity based on substitute fuels is not straightforward.

A final means of developing prices for electricity services provided by an interconnection is through **negotiation**. Negotiation of the prices to be paid for electricity services requires that each party to the negotiation have an understanding of its own costs of providing electricity services—either to its own customers in the absence of the interconnection, or to export customers via the interconnection—that is as complete as possible. Negotiation, however, does not require full disclosure of costs to the other party. Prices for electrical energy, power, capacity, and ancillary services can be negotiated and agreed to through a long-term contract, or can be renegotiated periodically. For example, the Southern African Power Pool (SAPP) was originally designed as a "loose pool", with purchase arrangements between buying and selling utilities made on a bilateral basis via long-term contract[64].

63 The costs of using alternative fuels for lighting is admittedly more reasonably compared to the costs of providing electricity for lighting from individual or village-level systems (photovoltaic, wind, or diesel systems, for example) than for the larger interconnection power source, which will likely serve a much broader array of end-uses.

64 Donald O'Leary, Jean-Paul Charpentier, and Diane Minogue (1998), *Promoting Regional Power Trade – The Southern African Power Pool*, *http://rru.worldbank.org/Documents/PublicPolicyJournal/145olear.pdf.*

The extreme form of negotiated prices is an open market for electricity and electric services. Here generators—for example, those selling power through an interconnection, would offer blocks of power or energy at prices that might vary by the week, day, hour, or even minute, to be purchased (or not) by distribution utilities, groups of customers, or even individual (typically large) customers. Markets for electrical energy, power, capacity, and ancillary services have been operated for several years in a number of jurisdictions in the United States and elsewhere. For markets to operate properly, a fairly large number of electricity sellers is required, with no one seller holding undue market power. The market may operate with a single buyer or with many buyers, but must operate under clear and specific rules (including rules for open access to transmission services) and procedures, under the auspices of an independent (or government-based) market operator, and with appropriate regulation. If the number of sellers is too small, market distortion may result. As an example of such distortions, in a statistical analysis of the "California Energy Crisis" of 2000—where wholesale electricity prices in California reached extraordinarily high levels, resulting in considerable economic damage— Joskow and Kahn conclude in part that "…there is sufficient empirical evidence to suggest that the high observed prices reflect suppliers exercising market power"[65]. As a consequence, for grid interconnections in developing nations, it is probably more likely (and has been the pattern) that countries (or private entities) selling electricity through interconnections will be selling, at least initially, at prices negotiated with individual (state or private utility) buyers than on an open market, though markets may develop over time[66].

3.5.3. Arrangements for changing agreed prices over time

Once a set of base prices for the services to be provided via the interconnection have been agreed to, it may be necessary to also agree on a formula for the automatic adjustment of prices in response to external markets. An example here is the use of "fuel cost escalation clauses", which are formulae that specify how the price will change in response to changes in costs for the fuel used for generation or for competing fuels. The costs of gas-fired generation, for example, may change dramatically as natural gas prices rise and fall. Typically these changes in cost would be passed on to electricity consumers. Similarly, even when a fuel—such as fuel oil—is not used for electricity generation in the countries served by the interconnection, changes in that fuel's market price may be used as in fuel adjustment clauses as a measure of the changing value of the electricity provided via the interconnection. Fuel adjustment clauses insulate power sellers from the impacts of an uncertain fuel market, but also, by their nature, force the ultimate consumers of power to take the risk of fuel price changes. As such, fuel adjustment clauses do not provide an incentive for a generator to negotiate long-term contracts for fuel supply, or to make other arrangements to mitigate the impacts of the risk of future changes in fuel costs. Contracting for power supplies in general, and the

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65 Paul Joskow and Edward Kahn (2002), *A Quantitative Analysis of Pricing Behavior In California's Wholesale Electricity Market During Summer 2000: The Final Word*. Available as *http://stoft.com/metaPage/lib/Joskow-KahnE-2002-CA-Mrkt-Pwr-Final.pdf.*

66 A summary discussion of these market options, described as "three phases of a continuum: [1] the single-buyer model, [2] the third-party or open access model; [3] the spot market or wholesale market (power pool) mode" is provided in Enrique Crousillat (1998), *Developing International Power Markets in East Asia.* Note No. 143 in the "Public Policy for the Private Sector" series, published by the World Bank Group Finance, Private Sector, and Infrastructure Network, May 1998, and available as *http://rru.worldbank.org/Documents/PublicPolicyJournal/143crous.pdf.*

setting of fuel adjustment clauses in particular, are interconnection-related activities where economic and legal issues must be addressed simultaneously.

3.6. Case Study of Economic Costs and Benefits of Interconnection

An article by Enrique Crousillat includes the following summary of the estimated (future) net economic benefits of trade of electricity via an interconnection in the countries of Southeast Asia's Mekong region[67]:

> "Recent studies comparing scenarios of electricity self-sufficiency in each country with a full trade scenario show that full trade could yield cost savings of at least US$10.4 billion in 2001–20 and a reduction of airborne pollutants valued at US$160 million a year. (These estimates assume a significant slowing in power demand over the next few years in Thailand as a result of the current [as of the late 1990s] financial crisis.) The savings would arise from:

- [1] Lower operating costs due to economic power exchange, postponed and lower investments in generation due to least-cost development of regional energy resources, and reduced spinning reserve costs.
- Lower coincident peak load (compared with the sum of individual peak loads), mutual access to generation reserves for interconnected systems, a more robust power supply to meet such unexpected events as load growth above forecast or delayed commissioning of generation and transmission projects, and increased system reliability.
- Lower greenhouse gas emissions and other pollutants, largely due to a shift from thermal to hydro generation in the long term."

3.7. Summary and Conclusions

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. Avoided costs include costs for fuels used in electricity generation (and in the costs of producing those fuels), 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 can include the stimulation of national and local economies through employment of labor needed for construction of the interconnection power line and of the power plants that will feed it, 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-

67 Enrique Crousillat (1998), *Developing International Power Markets in East Asia, Public Policy for the Private Sector*, Note no. 143, May 1998, available as *http://rru.worldbank.org/Documents/PublicPolicyJournal/143crous.pdf.*

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, as well as improvements in education and health care, as well as the "re-spending" effect where an interconnection reduces the prices that households must pay for energy, leaving 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 buyer and sellers exist to provide for structured, fair competition. Pricing agreements between buyer and seller, particularly in long-term sales agreements, may have fuel escalation clauses used to shield sellers from the risks of increases in generation fuel costs, and/or assure that the price they receive for electricity will keep pace with the price of competing fuels.

Given the need for contracting and/or for market arrangements in the selling of power, the economic and financial costs and benefits of interconnections interact strongly with technical, legal, and sometimes political, interconnection issues. Further, the fair distribution of economic benefits among the nations involved in an interconnection, as well as among the groups within nations that are "stakeholders" in the interconnection, is an important element in assuring that the political and social benefits of an interconnection are maximized, and the political and social costs are kept low. In making sure that economic benefits are fairly distributed, one key is to 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 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 sector planning by the project participants[68].

3.8. Resources for further analysis

3.8.1. Selected references on economic costs and benefits of grid integration

"Guidelines" and "Module 1" volumes of *Regional Electricity Cooperation and Integration (RECI)*, E7 Guidelines for the pooling of resources and the interconnection of electric power systems, prepared by the E7 Network of Expertise for the Global Environment, dated approximately 2000, and available from *http://www.e7.org*.

Michael Wolfe, Peter Donalek and Peter Meisen (1993), *The Economic, Environmental and Developmental Benefits of High-Voltage Interconnections Between South and North America via Central America and*

68 An example a multi-nation economic analysis of electricity trade is described in a proposal prepared by Purdue University, in coordination with the South African Power Pool: F.T. Sparrow and William Masters (1997), *Modeling Electricity Trade in Southern Africa*, project proposal for funding under the USAID co-operative agreement on Equity and Growth through Economic Research/Trade Regimes and Growth (EAGER/TRADE), available as *https://engineering.purdue.edu/IE/Research/PEMRG/PPDG/SAPP/1998proposal.pdf*. Evaluation of the benefits of power trading should be carried out on an ongoing basis, even once grids are interconnected, to assure that the use of resources in the interconnected countries is as optimal as possible.

the Caribbean. Presented at ENERLAC 93, Bogota, Columbia, June 1993. Available from the Global Energy Network Institute (GENI) website at: *http://www.geni.org/energy/library/technical_articles/transmission/interconnect.html.*

Workshop on Regional Power Trade (2001), *Regional Electricity Trading: Issues and Challenges*. Paper from the Workshop on Regional Power Trade, Kathmandu, Nepal, March 2001. Available as *http://64.224.32.197/Publications/shean.pdf.*

Donald O'Leary, Jean-Paul Charpentier, and Diane Minogue (1998), *Promoting Regional Power Trade – The Southern African Power Pool*, *http://rru.worldbank.org/Documents/PublicPolicyJournal/145olear.pdf.*

3.8.2. Methods for analysis of costs and benefits of integration

Several of the integrated planning packages described in Table 2-2 also include functions for evaluation of the costs and market prices of electricity under different network conditions. Several summaries of other software models for computing network costs and prices under different conditions are also found at *http://www.econ.cam.ac.uk/electricity/research/comparison/groups.htm*, compiled by the Cambridge MIT Institute Electricity Project. Indirect benefits of electricity interconnections, for example, the re-spending effect, can be quantified (roughly) using tools such as "Input-Output" models (though these are not trivial to specify or run for areas where economic and employment data are difficult to obtain).