Opportunities for Power Trade in the Nile Basin
Final Scoping Study

January 2004

Joint UNDP/World Bank Energy Sector Management Assistance Programme
(ESMAP)

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Preface

Recognizing the scope and urgency of their shared problems, the Nile riparian countries have taken a historic step toward cooperation in the establishment of the Nile Basin Initiative (NBI). Formally launched in February 1999, the NBI is a transitional mechanism that provides an agreed framework to fight poverty and promote economic development. The initiative is guided by a shared vision "to achieve socio-economic development through the equitable utilization of, and benefit from, the common Nile basin water resources" and a set of policy guidelines that provide a basinwide framework for cooperative action.

Within the framework of the NBI, since 1991, ESMAP has supported Nile riparain efforts to build consensus for coordinated development of the Nile Basin's potential for electric power. This scoping study, completed in November 2000, is the first major output of that effort and reviews the opportunities for power trade in the Nile Basin countries.

Under the NBI, the riparian countries have identified regional electricity trade as an important component of their strategy to promote economic development and cooperation in the region. This study represents an initial overview of the opportunities for power trade among the Nile Basin countries. Based on experience from other regions of the world, the potential benefits of power trade at different stages of market development and barriers to regional power trade are identified. This experience, coupled with a review of the energy resource endowment and the power supply demand pattern of the Nile Basin countries, has provided the basis for identifying opportunities for power trade in the Nile Basin presented in this study. The study also proposes that a more focused and coordinated process for discussing the expansion of power trade in the Nile Basin would advance the development of power supply facilities. The study recommends that this objective be realized through the creation of a basinwide forum of national power experts to facilitate continued dialogue in the region.

The scoping study is structured in four chapters: (i) an overview of the power sectors of the 10 Nile Basin countries and different types of power trade; (ii) potential for power trade based on the characteristics of the Nile Basin in terms of resource endowments, energy balances, existing generation and transmission facilities, and present and future demand and supply; (iii) scope for power trade in the Nile Basin; and (iv) framework for developing power trade.

Acknowledgments

This report was prepared by Norconsult and Statnett under the guidance of a World Bank team comprising John Besant-Jones, Lead Energy Economist and Task Team Leader; Barbara Miller, Senior Water Resources Management Specialist; Mangesh Hoskote, Senior Power Sector Specialist; and Diane Minogue, Consultant. The authors would particularly like to thank the Nile Basin Council of Ministers, the NBI Technical Advisory Committee, and the NBI Secretariat for their guidance and support. Our gratitude also goes to the national power experts[1] from the Nile Basin countries for providing key power sector data and information, and for their useful comments.

The authors also would like to acknowledge Mark Tomlinson, Sector Manager of the Africa Energy Unit (currently Country Director for Nigeria); Praful Patel, Sector Director of Africa Infrastructure (currently Vice President, South Asia Region); and David Grey, Senior Water Advisor, for their guidance in the design and development of this study.

The report was edited by Grammarians, Inc. Marjorie K. Araya, from the Energy Sector Management Assistance Programme (ESMAP) supervised its publication, printing, distribution, and dissemination. The maps were edited by Gregory Prakas, Cartography Section of the World Bank.

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Abbreviations and Acronyms

CEPGL	*Communauté économique des pays des grands lacs* (Great Lakes Economic Community)
ESMAP	Energy Sector Management Assistance Programme
HVDC	High voltage direct current
KPLC	Kenya Power and Lighting Company
NBI	Nile Basin Initiative
SADC	Southern African Development Community
SADCC	Southern Africa Development Co-ordination Conference
SAPP	Southern African Power Pool
SINELAC	*Société Internationale d'Electricité des Pays des Grands Lacs*
TANESCO	Tanzania Electric Supply Co. Ltd.
UEB	Uganda Electricity Board

Units of Measure

Bcm/y	Billion cubic meters per year
GWh	Giga-Watt
h	hour
kgoe	kg oil equivalent
kV	Kilovolt
kVA	Kilovolt-Ampere
MTOE	Million tons of oil equivalent
MW	Mega-Watt
TWh	Tera-Watt

1

Overview of the Study and Types of Power Trade

Overview and Background

1.1 Ten countries share the Nile River: Burundi, Democratic Republic of Congo,[2] Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The Nile Basin countries are fundamentally interconnected through their common interest in the stewardship of the river and its tributaries. The Nile is the link that has brought the countries together to seek mutually beneficial goals through concrete action under the Nile Basin Initiative (NBI).[3] The NBI provides a framework for fighting poverty and promoting economic development in the region, based on the basin countries' shared vision "to achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin Water Resources." Under the NBI, the basin countries have identified development of regional electricity markets as an important component of their strategy to promote economic development and cooperation in the region.

1.2 The Nile Basin's rich resource endowment for electricity generation remains largely untapped. Most of the potential is in hydropower that could be provided by the Nile and its tributaries; there are several important gas fields as well. Power trade is occurring at modest levels among several basin countries and many are either discussing increased power trade or considering developing power trade in the near future. The Nile basin countries' interest in increasing power trade is part of a global trend, as regional electricity markets continue to grow in emerging markets for three reasons:

- Power sector reform—globally, the pace of liberalization of the power sector has considerably increased in recent years leading to greater regional cooperation;

[2] Only the eastern part of Democratic Republic of Congo is evaluated in this report in relation with the power subsector. This part includes South-Kivu, North-Kivu, Maniema, and the Oriental province. There is also a power grid jointly operated by Burundi, Democratic Republic of Congo, and Rwanda in Kivu province, which is not interconnected to Democratic Republic of Congo's national grid.

[3] Eritrea attended its first NBI meeting in August 2000 and has indicated it will start participating in an observer capacity. The country was not, however, involved in the NBI during the preparation of this report.

- Partnerships—regions that share a single natural resource are finding it difficult to harness the energy potential individually, leading to project development with public-private partnerships; and
- Complementarity—the location of supply in one country and demand center in other countries provides complementary and mutually beneficial trading arrangements.

1.3 This scoping study represents an initial effort to provide an overview of the opportunities for power trade among Nile Basin countries. Based on experience from other regions of the world, the potential benefits of power trade at different stages of market development and barriers to regional power trade are identified. This experience, coupled with a review of the energy resource endowment and the power supply demand pattern of the Nile Basin countries, has provided the basis for identifying opportunities for power trade in the Nile Basin in this study. The study also proposes a framework for developing regional power markets.

1.4 This preliminary assessment is presented to promote dialogue among the Nile Basin countries and to provide a sound conceptual basis for these countries to assess the benefits of pursuing regional power trade and the framework for moving forward.

1.5 Detailed analysis of existing information on the present and likely future development of the energy and power sectors of the Nile Basin countries has been conducted. This information has been summarized in a series of country-specific draft data reports. Except in the case of Eritrea, these have been reviewed and updated using information provided by national power-sector experts from each of the Nile Basin countries.

Approach of the Study

1.6 This assignment was undertaken as a desk study, based on existing available information; the Nile Basin countries were not visited. Almost all information initially used was taken from World Bank documents. A few exceptions were studies, articles, and information gathered from the Internet or otherwise obtained by the Consultant on his own initiative. A draft scoping study was prepared using these and presented at the Power Trade Working Group meeting in Entebbe, Uganda, in December 1999. This meeting was held under the auspices of the NBI and included two national power-sector experts appointed from each country, one representing the Ministry responsible for the power sector and the other the primary utility in the country.

1.7 The parties agreed during that meeting to update the draft scoping study—producing a draft final scoping study, which was presented and discussed during a second Power Trade Working Group meeting held in Addis Ababa, Ethiopia, from June 29 through July 1, 2000. The updating of the study was achieved by further work related to information and data relevant for the energy sector and power subsector in each Nile Basin country, with the exception of Eritrea. This work was undertaken by national experts in each country who submitted country-specific data to Norconsult International. Using this background information Norconsult International worked out the revised country-specific draft data reports, which constituted the starting point for the draft final scoping study. With regard to Eritrea, all data and information used in the draft were the same as those applied in the draft scoping study. As already indicated, the draft final scoping study was presented and discussed during the working group meeting in Addis Ababa. Some adjustments and clarifications to the study were agreed on; a few additional study options were also indicated. These modifications have been included in this final scoping study, prepared by Norconsult International after the Addis Ababa working group meeting. This final scoping study is also being translated into French. A complete list of documents used is given in appendix 1.

1.8 The only reference document available for Eritrea was a proposed generation and transmission master plan prepared by a consultant in 1993. The quality of the data for Eritrea is consequently poor, leading Norconsult International to come up with its own estimates when necessary. The data received for other countries are of good quality; however, there have been communication problems with Democratic Republic of Congo-East during recent years and as a result, some estimates regarding power production and consumption were undertaken by Norconsult International using information provided by the Democratic Republic of Congo national expert.

1.9 The revised draft data reports for each Nile Basin country were handed over to the respective national experts at the working group meeting in Addis Ababa. The third of these reports includes reviews of the energy resource endowment, energy markets, and the institutional framework of the energy sector. This represents the first step of the approach in analyzing the energy sector for the final scoping study and is performed at an aggregate level primarily to establish the importance of the energy sector in the overall socioeconomic development of the country, the relative importance of the various energy subsectors, and the potential for energy substitution and conservation and energy imports and exports. Based on available information, an energy balance for each country is also established.

1.10 The fourth chapter of the draft data reports includes a detailed analysis of the power subsector. Existing generation and transmission facilities, present supply and demand, current level of power import and export, and institutional framework are summarized in the final scoping study, based on available information and updated data provided by the national experts. Future development is then outlined, including a discussion of the power demand and generation and transmission projects.

1.11 The main findings from the energy sectors and power subsectors at the national level are aggregated to the regional level and presented in chapter 2. They provide general economic indicators, energy resources and balances, demand forecasts, and important present and future power demand and supply characteristics. A map of the region with a single line diagram showing existing generation and transmission facilities is also presented. A possible division of the region into subregions is discussed with regard to the demand–supply situation and power transmission distances.

1.12 Types and basis for trade, including subregional perspectives, are discussed in chapter 3 in terms of the assessment of the energy resource endowment, existing generation and transmission facilities, and demand and supply characteristics. This chapter also includes generic descriptions of study options that could promote power trade. It should be emphasized that these options are tentative as they are based on a desk study. A screening and discussion of these options, as well as other options and ideas brought forward by the Nile Basin countries, is now pertinent.

1.13 In chapter 4, a discussion framework for developing power trade among the Nile Basin countries is presented. This includes various considerations of a technical, policy, and institutional nature. Water resources and environmental matters are discussed. Future activities within the NBI are also covered in chapter 4.

1.14 The framework for moving forward assumes that power trade will evolve incrementally and will be designed to be mutually acceptable to Nile Basin countries. The discussion framework includes the establishment of a power form, concepts for the development of power trade in the region, and generic project proposals at basin and subregional levels. Consensus was reached on key elements of a proposed Nile Basin power form during the working group meeting in Addis Ababa. It was also agreed that an initial task of this power form would be to advance this final scoping study.

Current Situation in the Nile Basin

1.15 There is only a low level of power trade among some of the Nile Basin countries at this time, including export from the national grid in Uganda to the national grid in Kenya and to isolated load centers in Rwanda and Tanzania. The average power export from Uganda to Kenya, Tanzania, and Rwanda during the period 1997–99 was 167 GWh per year, whereas the figure for 1999 was 174 GWh, or about 20 percent of the total sales in Uganda. A 132 kV transmission line connects the Kenya system to the Uganda system at Tororo substation, where sales from Uganda to Kenya are metered. Uganda has been exporting power to Kenya since 1958, when the Owen Falls Power Station and the Tororo-Nairobi 132 kV transmission line were completed and commissioned. This power export is carried out under the Kenya-Uganda Electricity Agreement, signed in 1955, according to which Uganda Electricity Board (UEB) is supposed to supply 30 MW of electrical power to Kenya Power Company for 50 years. Four supplemental agreements to this one have since been signed to determine the tariff at different times. This export has, however, been below the agreed level for long periods owing to capacity constraints in the power system in Uganda.

1.16 In 1993 UEB entered into an agreement with Tanzania Electric Supply Co. Ltd. (TANESCO)—the UEB–TANESCO Electricity Agreement, 1993. Under this agreement, UEB will supply 9 MW of electrical power to the Bukoba region of Northern Tanzania for 30 years. An agreement between UEB and ELECTROGAZ of Rwanda was entered into in 1995. Under this agreement, UEB will supply 5 MW of electrical power to

Rwanda, delivered at the Rwanda–Uganda border. Uganda is engaged in negotiations with its three neighbors to increase power trade.

1.17 Power is also imported from Nakonde in Zambia through a 33 kV line to supply Tunduma, Mobozi, and Ileje in Tanzania. There is also export from Democratic Republic of Congo-East to Rwanda and Burundi, because the three countries have jointly developed two hydropower plants in Democratic Republic of Congo. These are the Ruzizi I and Ruzizi II power plants, which have an aggregate installed capacity of 55 MW and a mean annual production of about 289 GWh, comprising 148 GWh from Ruzizi I and 141 GWh from Ruzizi II. During 1999 Rwanda received approximately 70 GWh whereas the import to Burundi was 50 GWh.

1.18 The Ruzizi II power plant is jointly operated and each of the three countries is entitled to an equal production share. The Ruzizi I power plant is operated by SNEL, the power company in Democratic Republic of Congo. According to an agreement with Democratic Republic of Congo, Rwanda can import 3.5 MW from this power plant. Burundi imports power from Ruzizi I based on payment of SNEL's debts to Burundi. The remaining credit at the end of 1999 was about 180 GWh.

1.19 Rwanda also exports power to the Kisoro border region in Uganda.

1.20 Finally there are interconnections from Egypt to neighboring Libya and Jordan. A 220 kV link between Egypt and Libya commenced operation in December 1998; the Egypt-Jordan interconnection, at 500 kV and 400 kV levels through the Sinai and Aqaba Gulf, respectively, was commissioned in September 1998.

Scope for Power Trade

Introduction

1.21 This section sets out the conceptual framework for power trade with reference to international experience. Conditions of particular importance to obtain the benefits of power trade are presented. The benefits of cooperation among different power systems are also described.

1.22 Current trade in electricity among Nile Basin countries is characterized by bilateral trade between state-owned utilities. This trading pattern was also the case in other regions of the world until recent years. Traditionally, most electricity utilities around the world were vertically integrated entities performing simultaneously the three primary functions of generation, transmission, and distribution. Most of them were more or less self-sufficient in terms of generation in their respective geographical areas. Interconnections with neighboring countries were developed mainly for short-term, non-firm power exchange based on complementarities among generation systems. A reduction in operating reserves and mutual support during emergencies was achieved as an additional benefit. Despite the development of interconnections, self-sufficiency in supply and capacity reserve margins were usually maintained.

1.23 The benefits that may be gained from utility-to-utility trade are sufficient reason to examine the possibilities of exploiting the hydropower potentials of the Nile for the mutual benefit of its riparians. Furthermore, power sector reform, with its unbundling of power utilities and establishment of competition in the electricity markets, has moved power trade to new dimensions during recent years in some regions. Additional economic as well as environmental benefits are realized through more efficient use of the combined energy resources and demand of larger markets than represented by one nation. The scope for such benefits and exploitation of variations in hydrological regimes and topography appear substantial for the Nile Basin too, not least if the development of larger low-cost hydropower potentials of the Nile could become viable through the creation of larger power markets. This feature is addressed in more detail in chapters 2 and 3, which present the regional energy situation and options for future power trade among the Nile Basin countries.

1.24 There are, however, a number of conditions that need to be considered in order to advance power trade in the Nile Basin area. Experience from other regions of the world[4] may illustrate some of them.

Power sector reforms

1.25 The sophistication of international power trade differs from region to region, and depends greatly on the level of industrialization and power sector reforms. A common experience is that power trade cannot be seen in isolation from the overall socioeconomic development in general and the power sector restructuring process in particular. Environmental benefits also add substance to power trade initiatives.

1.26 As a rule of thumb, development of international electricity trade is seen as a direct consequence of the ongoing power sector restructuring efforts. This involves vertical unbundling, which unties the distribution function from production and combines transmission with an independent system operation. Regulated third-party access or open access to transmission is introduced. Horizontal unbundling, meanwhile, promotes competition in generation and in distribution. A direct consequence of such restructuring is the search by actors in the market for the cheapest way to access electricity, including imports, if the infrastructure is available.

1.27 It is expected that in the Nile Basin countries, as in other regions of the world, power sector reforms will influence the development of power trade. The framework for power trade in the region, as defined by the institutional framework of the electricity sector including the status of power sector reforms, is presented in chapter 4.

1.28 A particular challenge for the Nile Basin countries is exploiting ways to create regional markets in power, and specifically, deciding whether to establish separate and

[4] Reference regional markets in power trade include Nordic countries (Nordel); Western European countries (UCPTE); England/Wales-Scotland area; different U.S.-pools such as the New England area (NEPOOL) and the Mid-Continent Area Power Pool (MAPP); the Southern African Power Pool (SAPP); the Greater Mekong area; and the Mercosur area (Argentina, Brazil, Paraguay, and Uruguay).

regulated transmission entities. The lack of independent transmission system operators is likely to become a barrier to power trade in the region at some later stage in development.

Infrastructure

1.29 Development of power trade requires interconnectors of sufficient capacity. To this end, projects identified in chapter 3 include studies of new interconnectors. In addition, technical standards acceptable to generators and consumers have to be established to ensure acceptable supply security in a regional network. Therefore coordination among national operators is of utmost importance. A power form with representatives from all of the Nile Basin countries could provide the institutional setting for developing such coordination.

Institutional requirements

1.30 Bilateral or limited trade of economy energy, such as in the Nile Basin at present, does not require sophisticated institutional frameworks. For greater short-term energy and capacity trade, government support may play a driving role, particularly in the case of government-owned utilities. Development of intensive regional trade could be boosted by pooling arrangements including transit (that is, wheeling) agreements. Where pooling arrangements are set in place, appropriate management structures are required and voting rules need to be introduced to ensure a high degree of consensus on the operation of the pool. Consequently there is a need to develop leadership in regional network development.

1.31 Transmission of electricity, sometimes across national borders, remains a major bottleneck in many regions. Three major conditions seem to be required to overcome this bottleneck. First, transmission should only be a "service" with a specific tariff structure independent from energy prices. Second, as transmission will remain a monopoly within given areas, it should be regulated and international agreements should be discussed among concerned countries so that the transmission regulatory regimes allow international transit. And third, close international coordination between the national control centers of the different transmission companies must be put in place to ensure the technical feasibility of such international transfers of electrical energy.

1.32 Contracts in power trade specify the conditions for supply of energy and transmission services. They can be short-term, affecting the dispatch decisions of the purchaser, or long-term, in which case they also affect investment decisions. The sophistication of trading contracts will depend in part on the ability to monitor trading arrangements. Trade will not develop if contracts cannot be enforced, ensuring payment and reliability.

1.33 Long-term contracts for the supply of bulk power may become a barrier to the introduction of competitive trade in either or both the importing or exporting power market, and approval of such contracts should take account of the cost of foregone competition. For example, a lack of flexibility to reassign part of the generation purchased under a long-term power purchase agreement will limit the scope for introducing more competition when desirable.

Investment climate

1.34 Power trade can develop only in response to overall development requirements in the region—hence a supportive macroeconomic environment is an important element. Financially viable and creditworthy power utilities are required to back investments in a regional grid. Within this framework, the development of regional power markets among the Nile Basin countries presents opportunities to exploit economies of scale when it comes to the development of hydropower resources.

Pricing

1.35 Traditionally, the approach to pricing of traded power has been based on the avoided-cost principle with a split of cost savings relative to a situation with no trade. This is typically applicable to bilateral trade arrangements and represents negotiated contracts. The cost of such an administered approach tends to grow with the complexity of trade. A more recent and quite common approach to price setting relies on bids based on marginal cost, as illustrated by cases in England, Chile, and Argentina.

1.36 Nord Pool, the Nordic Power Exchange, represents the most advanced form of power trade. The spot market trade is based on sales and purchase bids from the players. A balance price between purchase and sale bids is established hour by hour. In addition to the spot market trade via Nord Pool, there is a lot of direct bilateral trade between companies. The Nordic case is described in more detail at the end of this chapter.

1.37 It should be noted that England changed its price setting from the marginal cost approach to the Nord Pool bid approach in 2000. The big consumers in Continental Europe also demand the establishment of spot markets according to the Nord Pool approach.

1.38 In many cases of power trade, sophisticated pricing of energy, capacity, and transmission does not exist, though improvements in sophistication are taking place in most regions of the world. Where transmission has not yet been unbundled, transmission services, as a general rule, have not been separately priced. This does not appear to constrain trade in cases of limited exchanges by integrated companies. However, if power sector reforms proceed, the lack of transmission pricing will become a constraint and a system of transparent tariffs for transmission services will have to be introduced to facilitate trade.

Cost of power generation

1.39 Whether trade develops will depend on the relative costs of power in neighboring countries. However, comparison of the unit cost of generation and transmission by candidate projects in the region is difficult for a host of reasons, including difficulties in establishing comparable cost estimates, nonconvertibility of currencies, and the need to redesign projects so that their focus shifts from national to regional needs. In order to establish the potential for power trade among the Nile Basin countries, there appears to be a great need to carry out new studies together, in order to establish a common understanding of the cost of alternative supply options. This should also take into account internalized environmental costs and credit for multipurpose benefits accruing to external downstream parties.

Environmental concerns

1.40 Environmental and water resource considerations regarding hydropower development in the region are addressed in chapter 4.

Potential Benefits

1.41 The potential benefits of power trade among the Nile Basin countries are rooted in cost savings in the supply of power from cooperation as opposed to independent expansion of national power systems. Specifically, such savings may be realized through the following: a reduction in operation costs due to economic power exchange; lower investment costs in additional supply due to least-cost development of energy resources from a regional—as opposed to a national—perspective; spinning reserve requirements as a proportion of peak load; and coincident peak load relative to average load. In addition, these factors enhance robustness in dealing with unexpected events.

1.42 Significant environmental benefits could emerge in this region if regional power trade were developed on a least-cost basis. Such benefits could result from water conservation and land protection effects, and from a reduction in greenhouse gas and other pollutant emissions caused by a shift from thermal to hydropower-based generation.

1.43 Certain power system considerations in relation with these indicated cost savings and environmental benefits are discussed in the following subsections.

Hydro-hydro complementarity

1.44 Two (or more) hydropower-based systems are complementary to each other (or one another) in the following cases:

- There is a difference in the distribution pattern of water runoff over the year.
- There is a difference in hydrology over the years.
- There is a difference in reservoir capacity between the systems.

1.45 Such differences often exist when two or more river basins are in question. They result in differences in the marginal cost of power generation by season and by year. From these cost differentials, benefits from power trade can emerge. For example, a system operator can avoid spilling water during wet periods if it can release water as power export. And during dry periods the operator will be able to import power and consequently avoid load shedding or save water.

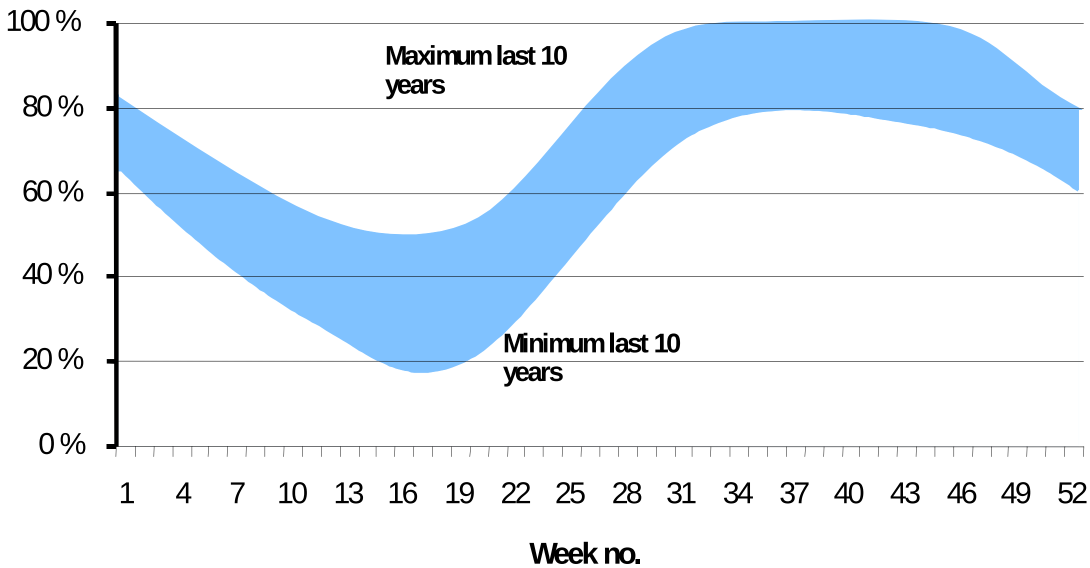
Hydro-thermal complementarity

1.46 A hydropower-based system has marginal costs of generation based on hydrological parameters. This means that inflow varies over the course of the year and from dry to wet years. Consequently, when the hydropower-based system in some periods has a surplus of energy, water is spilled. In other periods, an energy deficit may in the worst case prevent the hydropower-based system from meeting demand.

1.47 Thermal generation has high variable operating costs relative to a hydropower scheme. Savings in variable operations costs can therefore be achieved by using hydropower when available.

1.48 Figure 1.1 shows typical weekly variations in a year and over a 10-year period for maximum and minimum reservoir volumes in a hydropower plant or system (illustrated by the shaded area). These variations can be exploited through trade for the mutual benefit of the exporter and importer, if the other country has a thermal unit whose output can be replaced when water is available at the hydropower plant.

Figure 1.1: Reservoir Volumes in Hydropower Systems



1.49 Figure 1.2 shows the operation of a thermal power system with a hydropower system and how the operation is optimized during a wet period. As the marginal cost of power in the hydropower-based system is virtually zero during a wet period, it is profitable to replace comparatively expensive thermal power with cheap hydropower (illustrated in the diagram as “hydro import”) during periods of peak load.

1.50 Figure 1.3 shows the same situation during a dry period. In this case, the short-run marginal cost (avoided cost) of hydropower is high (the availability of hydro-energy is relatively low) and it will be profitable to sell some thermal power to the hydropower-based system during off-peak periods. The producer of thermal power will be able to reduce unit-variable operating costs by maintaining the same level of output throughout the 24-hour period.

Figure 1.2: Combined Hydro-Thermal Generation for Wet Period

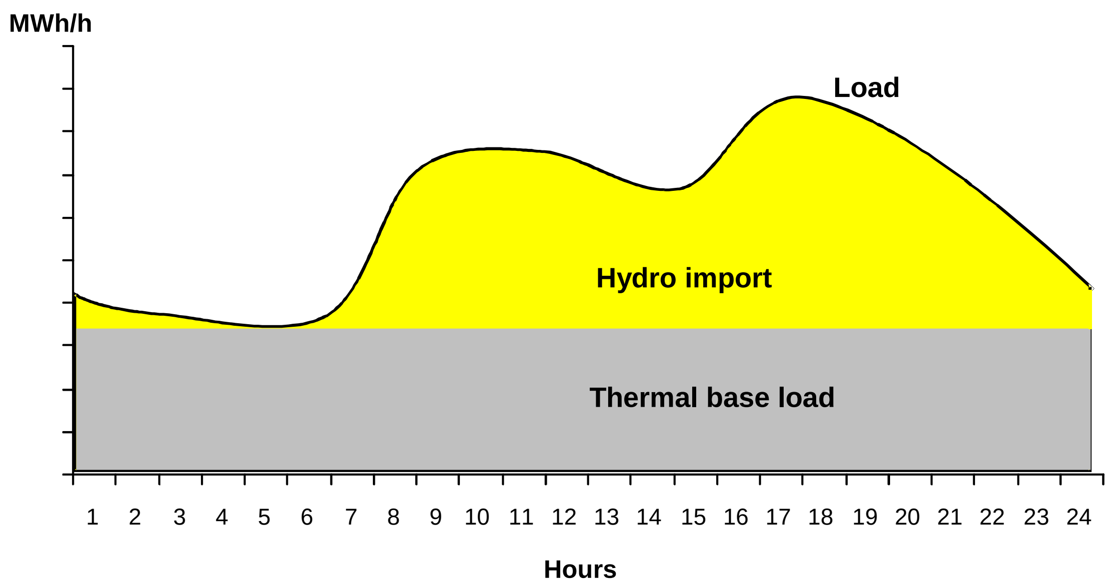
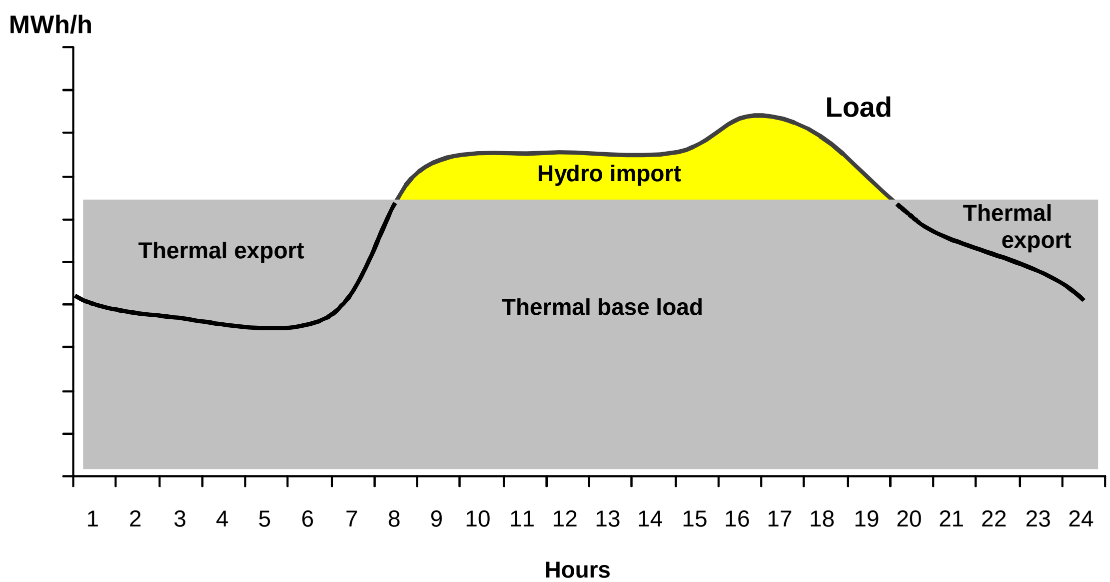


Figure 1.3: Combined Hydro-Thermal Generation for Dry Period



1.51 Some thermal plants have high start-up costs, while hydropower-based plants or systems have comparatively low start-up costs. To cover a short-term increase in demand, it will often be less expensive for an operator of a thermal-based system to purchase power from a neighboring hydropower-based system than to start up another thermal unit.

Mutual assistance in case of disturbances and maintenance

1.52 In case of short-term maintenance or forced outages a system operator can buy power from a neighboring system instead of applying load-shedding or starting generators out of merit order.

Reduced reserve capacity

1.53 In an environment without any trading of power, each system has to be self-sufficient. Consequently the combined investments in capacity are higher and system reliability lower than if both systems could benefit from trade. An interconnected system with trading capabilities improves the possibilities for mutual assistance during extreme situations such as an exceptionally dry year, shortage of fuel, or forced outages of units in one system, and thus reduces the need for combined reserve capacity.

Economies of scale in new generating capacity

1.54 A small power market cannot benefit from economies of scale in large-scale power generation alternatives because there is not sufficient purchasing power to exploit the full capacity of the project. In other words, a low capacity-utilization factor results in a low return on capital invested—at least in the early years until demand picks up. By combining two or more small power systems through interconnection, the combined power demand can become sufficient to make an investment in a relatively large low-cost hydropower plant economically viable.

Ways to Trade Power

1.55 In most regions of the world, power trade has gone through phases, from bilateral trade to third-party access and open access, to fully competitive markets, often termed power pools. Models of power trade in use around the world are outlined in box 1.1

1.56 The Nordic power trade experience could provide valuable lessons for the Nile area. Norway and Sweden opened their electricity markets but maintained public majority ownership in the sector. This proves that a key to successfully increasing electricity trade is to establish an appropriate market structure rather than changing to private ownership. However, creating effective competition among generators is difficult where one or few hold significant market power. Trade, and where possible, a joint marketplace across borders, can reduce the control of large generators.

Box 1.1: Models of International Power Markets

Vertical Integration (Single Buyer). In a single-buyer market, a single entity, for instance a government utility, purchases power from all producers on a contractual basis. This approach does not require a radical separation of integrated utilities or significant power sector reform. The Southern African Power Pool began operations using this framework.

Vertical Integration with Bilateral Wheeling Contracts (Negotiated Third-Party Access). This model implies that the transmission system is open to independent power producers so that they can wheel power directly to distributors and large consumers. Under the negotiated third-party access model, most exchanges would still be based on long-term contracts.

Open Access. An open access market is a regional competitive market in generation and distribution allowing any producer to sell directly to any distributor or bulk consumer. Generation, transmission, and distribution are unbundled. Access to transmission needs to be regulated, and pricing policies compatible, transparent, and efficient. Nord Pool is an example of such a competitive power exchange.

1.57 When Norway introduced a new energy act in 1991 and opened its market to free competition (as the first Nordic country to do so), this unilateral reform affected the electricity exchanges among the countries of the network, especially with Sweden. Trade resumed and even expanded upon implementation of a similar reform in Sweden. Apparently, parallel developments in power sector reform of countries with power trade are preferable to maintain balance. The development of competitive markets in the region took a long time and went through all the phases mentioned. (Box 1.2 describes Nordel, the Nordic body of cooperation for energy system operators.)

1.58 The same lesson is being experienced in the Southern African Power Pool (SAPP), which was established in 1995 through the Inter-Governmental Memorandum of Understanding signed by 7 of the 11 members of the Southern African Development Community (SADC). The members of SAPP are all vertically integrated national utilities undergoing various degrees of power sector reform. This power pool is the product of a long-term, coordinated regional approach to the power sector in southern Africa under the sponsorship of the SADC and its predecessor, the Southern Africa Development Co-ordination Conference (SADCC), established in 1980.

1.59 International power markets do tend to evolve over time as economies grow and demand increases, and as reforms in the power sector facilitate infrastructure and national market development. In addition, trading partners build confidence in working together to gain benefits and solve problems. However, there is no rule that says a regional market has to go through all phases as experienced in most regions.

Box 1.2: Nordel

Nordel is a body for cooperation among system operators in the Nordic countries. The association also serves as a forum for technical cooperation and coordination among these countries' system operators and actors. This informal organization has paved the way for the competitive market now in operation.

Nordel's primary goal is to create prerequisites for and develop an efficient Nordic electricity market. It gives advice and recommendations.

In August 1998, the association adopted new bylaws, which were accommodated to the new conditions that prevail on the joint Nordic market.

Nordel's tasks fall mainly into the following categories:

- System development and rules for network dimensioning;
- System operation, reliability of operation, and exchange of information;
- Establishing principles of pricing for network services;
- Fostering international cooperation; and
- Maintaining contacts with other actors, organizations, and the authorities within the power sector.

Nordel's highest decisionmaking body is the annual meeting, which encompasses leading individuals from the Nordic system operators as well as representatives of other participants in Nordel's work.

The association has no budget. Its executive body is the Executive Board, composed of one representative of the system operators in each country, as well as two representatives of the other actors. The Executive Board makes initiatives and decisions on topical issues and implements the decisions taken at Nordel's Annual Meeting.

Much of Nordel's work is carried out by committees and working groups made up of technical specialists from the various sectors involved in cooperation within Nordel.

No trading

1.60 This scenario is characterized by a monopolistic system, in which the power subsector in each country is organized in one or a few vertically integrated companies. There is either no interconnection or only weak interconnections among the power grids of these companies. The customer can only obtain electricity from one utility. There is no national or international trading among the utilities, all of which are self-contained, and all costs can be passed to the end user or are covered by government funds.

Trading with occasional (non-firm) power from utility to utility

1.61 This variation is also characterized by a monopolistic system, in which the power subsector in each country is organized in one or a few vertically integrated companies. There may also be some independent power producers.

1.62 Power may be traded among utilities occasionally, on a national as well as international basis. The transaction is often approved over the phone and can be started and concluded at any time. The utilities responsible for trade across national borders often apply the "mean price principle," which means that the average of the marginal costs calculated for an hour of operation in the various systems forms the basis for the price of power transmitted over the border. In such a monopolistic system, consumers and power producers can only do business with one utility.

Trading with firm power from utility to utility

1.63 This one is also characterized by a monopolistic system in which the power subsector in each country is organized in one or a few vertically integrated companies. There is a monopoly market where consumers and power producers can only do business with one utility. There may also be some independent power producers.

1.64 Firm power can be traded from major utility to major utility. Important parameters are price, quantity, and time of use, and the trade is regulated by long-term contracts. There will often be a mix of firm power contracts and non-firm power contracts of varying duration. Mutual support contracts related to operating reserve, emergency energy, control area services, and scheduled outage energy are also possible. The latter will often be based on "gentleman's' agreements"—that is, the support is reimbursed in energy and not in cash. In case of transmission limitations, firm power contracts have priority over non-firm contracts.

Eligible third-party access

1.65 This scheme has an environment in which large independent power producers and large consumers can trade with others and not only with the utility. The power subsector in each country is still organized in one or more vertically integrated companies. Transmission facilities are open to negotiated or regulated third-party access for large producers and consumers. Vertically integrated companies have to keep separate accounts for these players.

1.66 This market structure is typical in an early stage of sector unbundling, including privatization and competition in the power subsector.

Decentralized trading—open access trading

1.67 Decentralized trading is characterized by a system with open access both for consumers and producers. Within their franchise areas, distribution companies have the obligation to connect all end-users and to offer distribution services on nondiscriminatory terms. Thus the consumers are free to buy power wherever and from whatever supplier they want. Consumers and power producers are allowed to trade, and they buy transmission capacity from a grid company. This gives open access on equal terms to everyone to transmit power through all transmission and distribution networks. Power can be traded bilaterally, in a common spot market or a combination of those.

Experience of the Nordic countries

History

1.68 The Nordic countries have cooperated in the area of electricity for more than 80 years, in the early years in a very limited fashion through bilateral trade mostly between Norway and Sweden.

1.69 Since 1963, when Nordel was established, the Nordic countries have cooperated more closely to exploit their combined energy resources and thereby ensure that the supply of electricity is environmentally friendly, efficient, and reliable.

1.70 The cooperation faced a new challenge when, in 1991, Norway adopted a new, market-oriented energy act. Norway was the first of the Nordic countries to deregulate its electricity market, open it for competition, and establish a power exchange. Sweden and Finland followed, and in Denmark the electricity market opened fully for all customers in 2002.

1.71 In 1995, the Nordic ministers of energy agreed to increase cooperation to develop a common electricity market. One area of concern was the dominant position of some of the generating companies of these countries. A common electricity market would significantly reduce their dominance and guarantee better competition. Following the deregulation and development of a regional power market, experience shows that unbundling of the electricity sector is taking place faster than most experts expected beforehand.

Process of deregulation

1.72 A first step in Norway’s deregulation process was to separate the grid activities from the electricity production. The grid thus became a “neutral, natural monopoly” subject to regulation by public authorities. This established a neutral and nondiscriminatory transmission grid, which is available to all players—in other words, open access.

1.73 By opening the entire network (also the regional and local distribution networks) and introducing a separate network tariff (point of access tariff) for grid supply and consumption, competition among players in the electricity market is established.

1.74 A system operator is appointed for each electricity system in the Nordic grid: Statnett in Norway, Svenska Kraftnet in Sweden, and Fingrid in Finland and Denmark. Eltra and Elkraft (since 1998). The transmission system operators bear the responsibility for ensuring the physical framework for a well-functioning electricity market and own and operate the high-voltage grid and the main interconnections to neighboring countries. The transmission system operators do not own generating plants themselves, excluding some capacity for emergency use.

1.75 The transmission system operators have to ensure that the system always is in balance—that is, that production plus import corresponds to consumption plus export at any second around the clock. Accordingly, the transmission system operators must make sure that the system disposes of sufficient regulating power and reserve capacity, which can eliminate imbalances due to forced outages, unexpected fluctuations in consumption, and fluctuations in, for instance, the production of wind and solar energy.

1.76 Normally the transmission system operators purchase reserve capacity and regulating power directly from the market players or on a special regulating power market. The transmission system operators may require that certain units be regulated up or down in case of system imbalances.

1.77 The transmission system operators also plan and carry out the necessary expansion of the transmission network, including the connections to neighboring areas, in time and in accordance with market requirements. Thus the transmission system operators must ensure that the number of transfer constraints in the system are as low as possible.

1.78 The transmission system operators treat all players neutrally and in a nondiscriminatory way. They make information available to all the players on transport capacity in the network, as well as transfer bottlenecks, forced and scheduled outages, and the prices of transport services (tariffs).

Market

1.79 The Nordic electricity market combines direct trading between players (bilateral trade) and trading via the Nordic Power Exchange, Nord Pool (see box 1.3). The trade, which takes place via the power exchange, is still increasing.

1.80 The primary source of electricity production differs considerably among the Nordic countries, as it does in the Nile Basin countries. In Norway, nearly all electricity is generated from hydropower. Sweden and Finland use a combination of hydropower, nuclear power, and thermal power. Denmark mainly uses conventional fossil fuel–based thermal power, but wind power is increasingly used.

1.81 Several interconnections (overhead lines or submarine cables) link the Nordic countries to one another as well as to other countries in continental Europe. In the years ahead, several planned cable projects are expected to bring the Nordic countries even closer to the continent.

Box 1.3: Nord Pool

Nord Pool—the Nordic Power Exchange—is the world's only multinational exchange for trading electric power. Established in 1993, Nord Pool is owned by two national grid companies: Statkraft SF in Norway, Svenska Kraftnet in Sweden. It is intended that Fingrid of Finland become part owner as well.

The main products of the power exchange are spot trading, financial contracts, and clearing services.

The physical market offers trade in power contracts for physical delivery during the next 24-hour period.

The spot market's system price is the reference price for settling power trade on Nord Pool's futures market and also serves as a price signal in the Nordic countries.

The futures market is a purely financial market for price hedging, risk management, and trade in forward and future power contracts. Increasingly, the trend is that both Nordic and European financial institutions trade forward contracts on the power exchange.

Conclusion

1.82 The scope for power trade in the Nile Basin countries appears to be significant. Experience from other regions of the world, however, indicates that the extent to which such trade will materialize depends on a number of factors including the region's general economic development, existing power sector infrastructure, energy resource endowment, and institutional framework, including power sector restructuring.

1.83 The potential for power trade as defined by the existing infrastructure, the energy resource endowment, candidate power projects, and expected growth in electricity demand are addressed in the next chapter.

2

Potential for Power Trade in the Nile Basin

Introduction

Contents of the chapter

2.1 This chapter presents characteristics of the Nile Basin that are relevant to identifying the potential for power trade in the region. To this end, the country-specific information in the draft data reports has been combined to show regional totals. The regional data and analysis are presented in this chapter as well as chapters 3 and 4. The draft data reports also contain an overview of the water resources and the environmental and physical development features of the Nile River and its basin. The geographic setting was briefly described in those reports and will not be repeated here.

2.2 This chapter starts with a brief overview of the economic setting of the 10 Nile Basin countries, followed by a description of energy resource endowments, with emphasis on the potential for power production. The regional energy balance is then presented with comments on the structure of energy consumption and energy supply/conversion by energy carrier.

2.3 The power sector presentation includes a description of existing generation and transmission facilities. Map IBRD 32740 showing power plants and the transmission network for the region is presented at the end of the chapter for easy reference and overview of existing facilities. A summary of available supply costs has also been included, along with a discussion on future demand and supply and the scope for power trade. Interesting study options are outlined here and further discussed in chapter 3. Finally, possible groups of countries or natural subregions within the Nile Basin in the context of the power subsector and power trade specifically are also outlined.

Economic setting

2.4 The Nile Basin countries vary in size, demographic characteristics, and topography—and to some extent, economy. Most, however, have a very low production level of goods and services in common, and consequently are classified as least-developed countries. Table 2.1 shows the countries' land area, population, GDP per capita, access to electricity, and electricity use in 1999. Data for all countries except

Eritrea are up to date. The data for Eritrea are old and the electricity use figure is estimated by Norconsult International. The table's figures for Democratic Republic of Congo represent the whole country; however, only the eastern part of the country and the power grid common with Burundi and Rwanda are relevant for this study. It has not been possible to find representative figures only for this part of the country.

Table 2.1: Key Economic Indicators of the Nile Basin Countries

Country	*Land area (1,000 km^2)*	*Population (million)*	*GDP per capita (USD)*	*Access to electricity (%)*	*Electricity Use (kWh p.c.)*
Burundi	28	6.3	140	2	17
Congo, Dem. Rep.	2,350	50.3	100	1-6	110
Egypt	1,000	63.5	1,200	98	900
Eritrea	94	4.0	230	—	43
Ethiopia	1,222	61.7	124	10	21
Kenya	583	28.7	279	9	153
Rwanda	26	8.0	230	2	25
Sudan	2,506	33.0	263	15	70
Tanzania	945	30.5	130	10	75
Uganda	241	22.0	330	5	36

—. Not available.

Source: Power experts of the Nile Basin countries.

2.5 Egypt is more developed than the other countries of the Nile Basin, both in terms of the economy in general and access to and use of electricity specifically. Another difference is the size of the countries, both in terms of land area and population. GDP per capita, electricity use, and access to electricity are shown in figure 2.1.

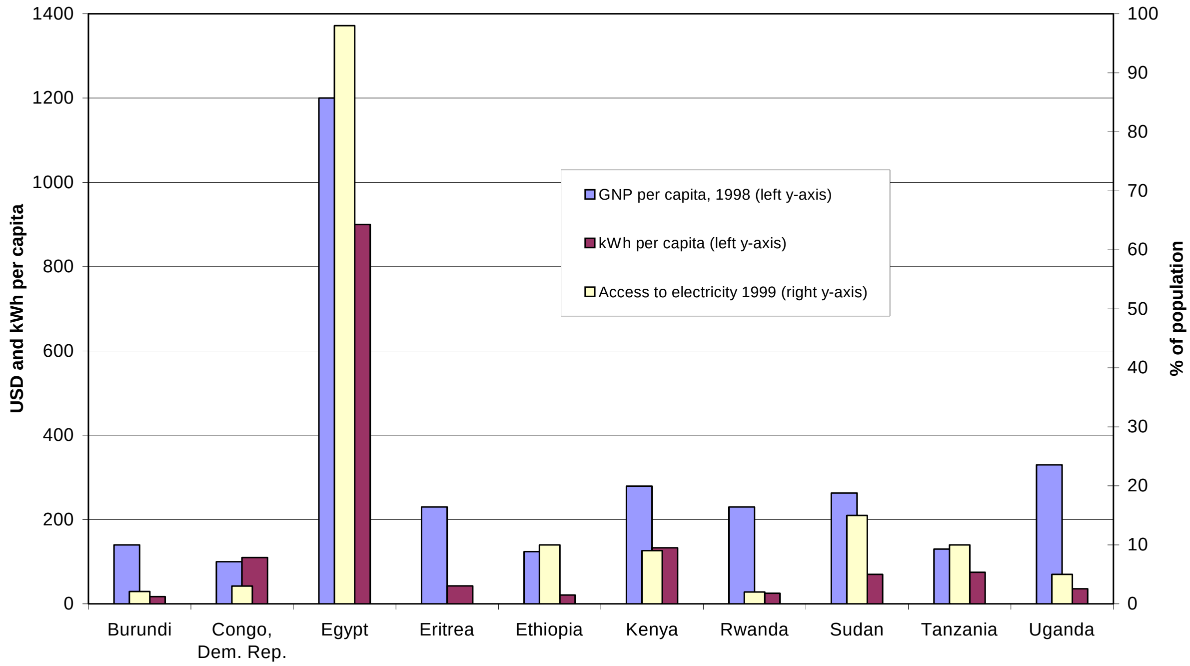
Resource Endowment

Regional overview

2.6 The energy resource endowment of the region is largely undeveloped, but has the potential to create supply far in excess of its current energy needs. These sources include biomass, hydropower, hydrocarbons, and geothermal resources as shown in the tables in Appendix 2.

2.7 Data on the reproductive capacity of the forests in the region are incomplete and do not provide a representative picture. Information available on forest reserves indicates a stock of wood fuel in excess of 30 billion m^3, with Democratic Republic of Congo accounting for about 80 percent of the total.

Figure 2.1: Key Economic Indicators of Nile Basin Countries



Source*: Power experts of Nile Basin countries.*

2.8 The technically exploitable hydropower potential is estimated at about 150,000 MW, with Democratic Republic of Congo accounting for 100,000 MW. Excluding Democratic Republic of Congo, the total hydropower potential of the region is more than 46,000 MW.

2.9 Reserves of crude oil have only been discovered in Democratic Republic of Congo, Egypt, and Sudan, with a total resource endowment of 624 million tons of oil equivalents (MTOE).

2.10 The region appears to be gas prone, with proven reserves of natural gas in Democratic Republic of Congo, Egypt, Sudan, Ethiopia, and Tanzania. The estimated recoverable reserves of natural gas are 1,475 billion cubic meters or approximately 1,300 MTOE. The gas reserves are to an increasing extent being exploited, notably in power generation in Egypt. In Tanzania, the Songo-Songo field off-shore of Dar es Salaam is being developed and will eventually feed installed thermal capacity in the capital. Recent studies for development of the Calub field in Ethiopia have also been made. The region also has proven reserves of methane, found in Lake Kivu. There are indications of coal bed methane as well, but information on proven reserves is not available in the source material of this study.

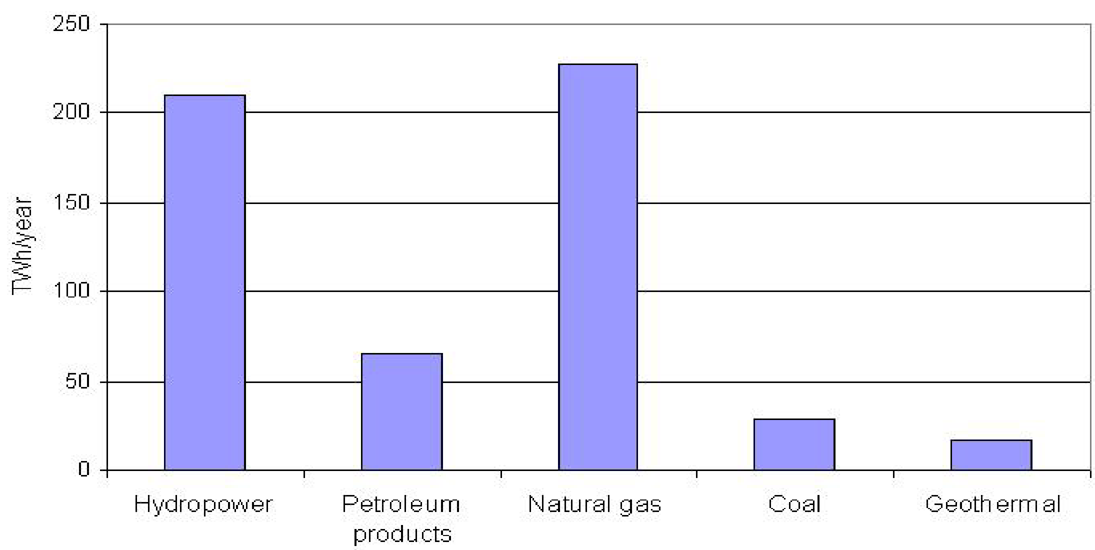
2.11 Coal reserves have been identified in Democratic Republic of Congo, Egypt, Ethiopia, Kenya, and Tanzania, with a combined total of somewhat less than 500 million tons. The coal reserves are in many cases of a low grade, with high ash content.

2.12 Geothermal resources are available primarily in Ethiopia and Kenya, with commercially exploitable potentials in some of the other Nile Basin countries. The region's total identified exploitable potential of geothermal resources is estimated at 2,540 MW.

Electricity generation potential

2.13 In order to indicate the potential of electricity generation by the primary sources of energy in the region, the commercial resource endowment has been converted to a possible annual power generation by applying a set of assumptions. For the hydropower potential, estimates from country reports have been applied when available. Otherwise, a load factor of 50 percent has been assumed, except Egypt for which 75 percent has been used. For all hydrocarbon resources—that is, crude oil, natural gas, and coal—a depletion period of 40 years of the reserves has been assumed and thermal plant efficiencies of 35, 58, and 33 percent for oil, gas, and coal, respectively, have been applied. Geothermal generation is based on resource estimates available and a load factor of 0.75. Resulting from the above exercise, the energy potential for electricity generation in the region is 1,000 TWh/year, or equal to a sustainable generation for the next 40 years of almost 15 times the present generation in the area. Excluding Democratic Republic of Congo, the power generation potential of the Nile Basin countries for about half a century is probably about 550 TWh/year, of which natural gas and hydropower represent approximately even shares of 40 percent each (figure 2.2).

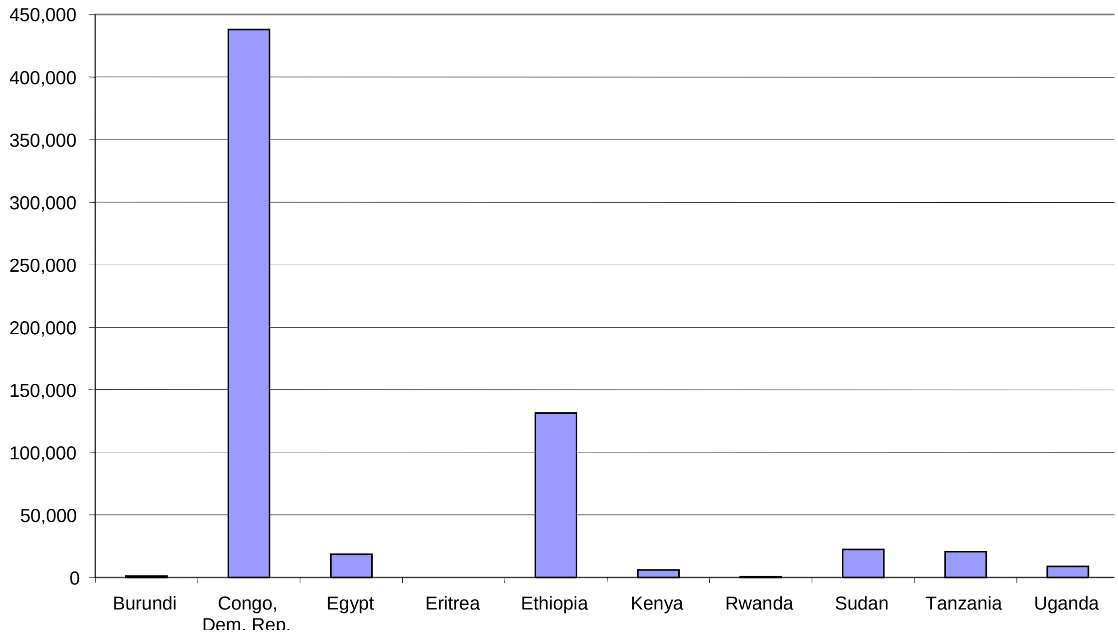
Figure 2.2: Power Generation Potential by Energy Source in the Nile Basin Countries Excluding Dem. Republic of Congo



Source: Power experts of Nile Basin countries.

2.14 The long-term sustainable potential of hydropower alone (excluding Democratic Republic of Congo) is calculated at 209 TWh/year (see figure 2.3, which shows the share of Democratic Republic of Congo as well).

Figure 2.3: Total Hydropower Potential in the Nile Basin Countries (GWh/year)



Source: Power experts of Nile Basin countries

Energy Balances

Energy use

2.15 Energy consumption of Nile Basin countries is about 85 million tons of oil equivalents (MTOE) per year.[5] On average, this is equivalent to an annual consumption of only 300 kg of oil per person for the entire population of some 300 million people in the region.

2.16 Most of the energy consumed is from traditional fuels—wood fuel, peat, crop residues, and dung used for cooking and heating by households. The technologies applied are open fire and primitive stoves. As a result of this consumption pattern, the usage efficiency of energy content in the fuels is probably only about 10–20 percent in most cases. And since two-thirds of the total energy used in the region is from traditional fuels, the energy use among the Nile Basin countries is extremely inefficient. Since commercial

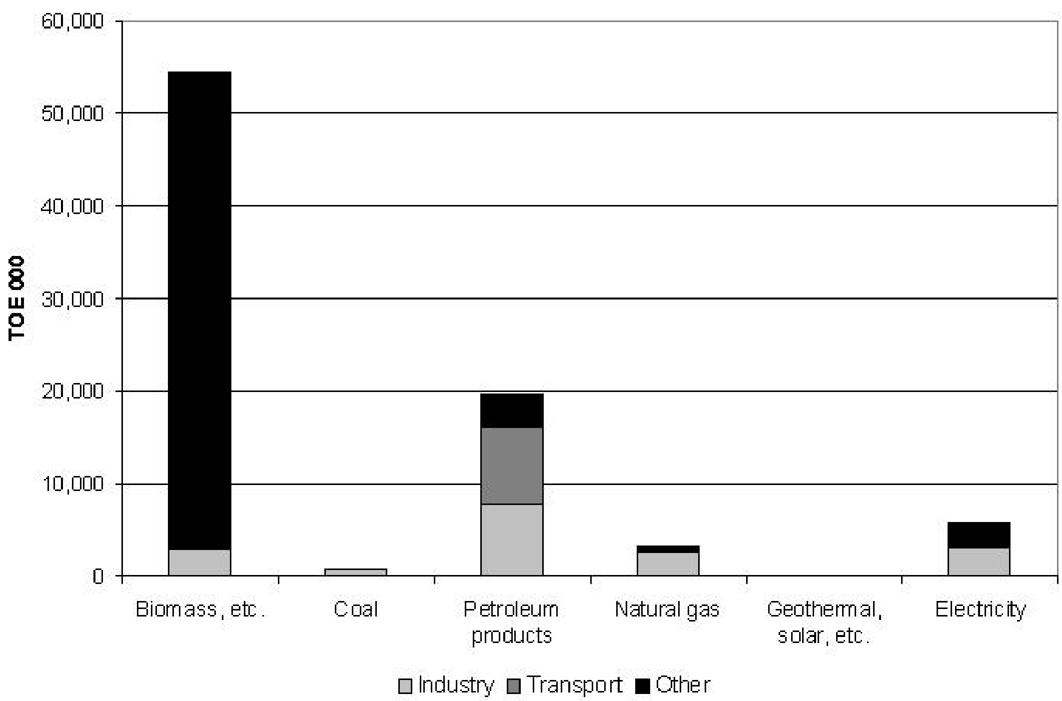
[5] Energy data for the region combined are only tentative. See the table note in appendix 2.2.

fuel use is inefficient as well,[6] the usage efficiency of energy in the Nile Basin countries is on average not more than 100 kg oil equivalent (kgoe) per person.

2.17 With the exception of Egypt, traditional energy consumption patterns have by and large been maintained by people moving from rural to urban areas. Consequently the pace of forest resource consumption around urban areas, either directly as wood fuel or indirectly as charcoal to reduce transportation costs, has exceeded the forests' reproductive capacity. Exacerbated by forest clearing for the growing population in need of arable land, deforestation is taking place around many of the urban centers in the region. Switching fuel use to commercial energy carriers, notably electricity, could save the forests and would in many cases prove economically feasible, but is not taking place to a great extent owing to lack of cash income and affordable financing.

2.18 The annual consumption of commercial fuels by the Nile Basin countries is about 30 MTOE. Petroleum products account for 70 percent of this total, electricity 20 percent, and natural gas 10 percent. The use of energy by sector is illustrated in figure 2.4.

Figure 2.4: Final Consumption in the Nile Basin Countries by Fuel and Sector



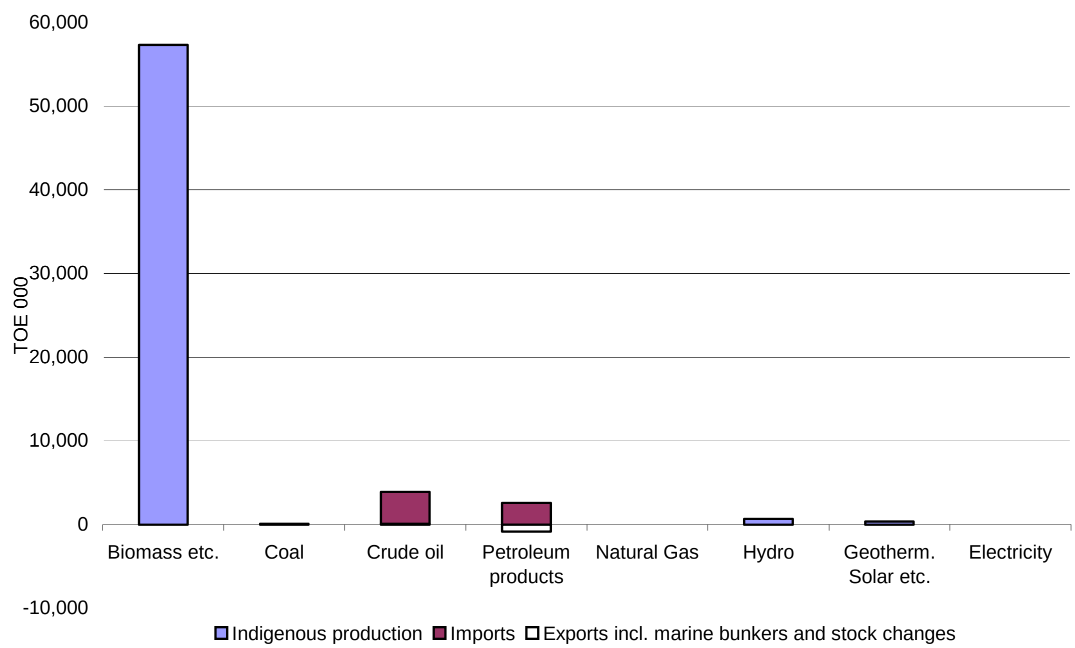
Source: *Power experts of Nile Basin countries*

[6] Measured in terms of useful energy, the relative importance of commercial fuels increases substantially, as the efficient use of energy in traditional fuels is much lower than for commercial fuels. For petroleum products (mostly used in transportation and industry) efficient use typically ranges from 30 to 40 percent and reaches 100 percent for efficient electricity use.

2.19 Traditional fuels are almost entirely consumed by "other sectors" including rural and urban households. Only 6 percent of traditional fuels are used by industry. The main users of petroleum products are transportation, industry and residential households, with 40 percent, 35 percent and 15 percent of total petroleum products consumption, respectively. Electricity is consumed by industries with 50 percent and households with 45 percent. Natural gas is only used in Egypt, where around 60 percent of total production from domestic natural gas fields are supplied for power generation, and the remaining are either 20 percent for industry, 10 percent for transformation losses or 5 percent for households.

2.20 Egypt's energy situation is quite different from that of the other Nile Basin countries. Ninety-five percent of all energy the country consumes is from hydrocarbons and hydropower—in other words, commercial fuels. Furthermore, the consumption of commercial fuels by Egypt accounts for more than 75 percent of total commercial fuels used in the region. The country's energy pattern thus dominates the regional picture of commercial energy consumption. Adjusting for this, and also excluding Democratic Republic of Congo (as the energy balance available is outdated and is for the country as a whole and not for the Kivu Province with which this study is concerned), the representative consumption pattern of the Nile Basin countries excluding Egypt and Democratic Republic of Congo are shown in figure 2.5.

Figure 2.5: Primary Energy Use of Nile Basin Countries (Except Democratic Republic of Congo and Egypt) by Resource



Source: *Power experts of Nile Basin countries.*

2.21 The figure clearly demonstrates that the Nile Basin countries, except Egypt, are predominantly subsistence agrarian societies with a small industrial sector often located in enclaves around urban areas. Excluding Egypt and Democratic Republic of Congo, traditional fuels represent close to 90 percent of total energy consumed (88 percent in 1996), petroleum products account for 10 percent, and electricity only 1 percent. Measured by usage efficiency, the relative importance of petroleum and electricity increases as the efficient use of the energy content in these resources is higher than for traditional fuels. Particularly for electricity, usage efficiency is high. The energy balances data thus easily can mislead one to underestimate the importance of electricity in the region. Nonetheless, in all the Nile Basin countries except Egypt, the extent of electrification is very modest: Less than 10 percent of the population—and in the least electrified country, Burundi, only 2 percent—has access to electricity.

Energy supply and conversion

2.22 The primary energy supply of the region was 112 MTOE in 1996, breaking down as follows: indigenous production (129 MTOE) and imports (9 MTOE) minus exports, which included marine bunkers (26 MTOE). The bulk of the region's energy exports are exports of crude oil and refined products from Egypt. Excluding Egypt and Democratic Republic of Congo for reasons explained above, the energy supply picture of the region is as presented in figure 2.5.

2.23 Typically, biomass is harvested locally for domestic use. The traditional fuels in biomass represent 60 percent of total primary energy supplied in the region. When Egypt and Democratic Republic of Congo are excluded, the share increases to 90 percent.

2.24 Among commercial fuels, petroleum and petroleum products dominate the picture, representing more than 80 percent of total modern fuels supply. Hydropower represents 10 percent and geothermal 5 percent. Coal is a primary source of energy in the region to a very little extent.

2.25 Petroleum products are provided directly through imports or through imports of crude oil refined locally. A small portion of petroleum products is re-exported. The dependence on imports of petroleum and petroleum products by the Nile Basin countries, except Egypt, exposes the region to fluctuations in the international oil price. The landlocked countries in the interior also face a long on-shore haul for their supplies of petroleum products, which adds cost and insecurity in supplies. This exposure is a reason for Nile Basin countries to exploit possibilities of indigenous energy production so that they can secure supplies and minimize impacts of external decisions beyond their control.

2.26 Hydropower represents a small portion of primary energy supplied (only 1 percent), but dominates generation of electricity. Out of a total electricity production in the Nile Basin countries (excluding Egypt and Democratic Republic of Congo) of some

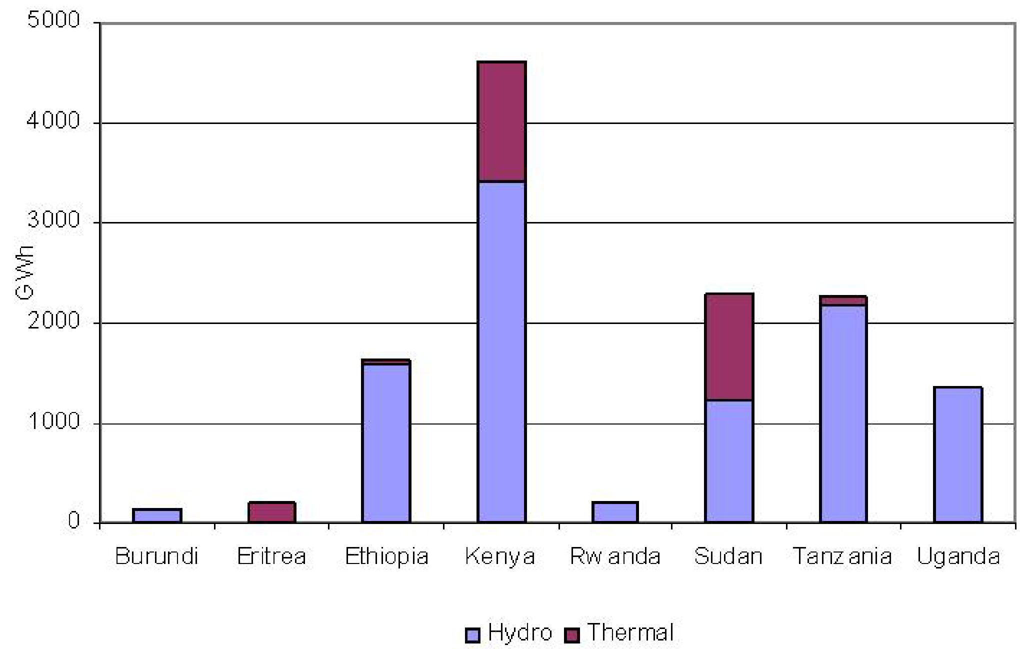
12.7 TWh in 1997, approximately 75 percent was from hydropower. The rest was from conventional thermal power plants (20 percent) and geothermal generation (5 percent).[7]

Existing Generation and Transmission Facilities

Power generation

2.27 Figure 2.6 shows how much electricity is produced in the Nile Basin countries excluding Egypt and Democratic Republic of Congo. Inventories of existing generation facilities are presented in the country-specific draft data reports. These include information on installed capacity, type of generation, year of commissioning, and so on. Annual energy production is also given for hydropower generation facilities. For most countries or projects this is average or mean annual production, but for some countries only firm energy production was given, and these data were used in such cases. All information is updated and refers to 1999 (except for Eritrea as previously mentioned). The Ruzizi II power plant in Democratic Republic of Congo is run jointly by Burundi, Democratic Republic of Congo, and Rwanda, and installed capacity and annual energy production are shared equally. Table 2.2 summarizes thermal and hydropower for each country and total installed capacity for the supply of isolated networks (insignificant for most of the countries).

Figure 2.6: Production of Electricity in the Nile Basin Countries, except Egypt and Democratic Republic of Congo, by Energy Source, 1997



Source: Power experts of the Nile Basin countries.

[7] National data from country reports combined with energy balance data. The energy balance data underreport the electricity generated—10 TWh in 1996 compared to 12.7 TWh in 1997 from national data.

Power transmission

2.28 Information related to power transmission has also been updated. Brief descriptions of transmission facilities are given in the country-specific draft data reports.

Table 2.2: Generation Facilities

Country	*National network Installed capacity (MW)*			*Isolated networks installed capacity (MW)*	*Total country installed capacity (MW)*	*Annual production national network hydro (GWh)*
	Thermal	*Hydro*	*Total*			
Burundi	6	37	43	4	47	160
Congo, Dem. Rep. East	0	37	37	55	92	195
Egypt	12,047	2,810	14,857	484	15,341	12,210
Eritrea	30	0	30	0	30	0
Ethiopia	26	372	398	59	457	1,822
Kenya	282	595	877	9	886	2,826
Rwanda	2	34	36	0	36	145
Sudan	331	307	638	135	773	1,443
Tanzania	203	557	760	29	789	2,698
Uganda	0	196	196	2	198	1,275
Total	12,927	4,945	17,872	777	18,649	22,774

Source: Norconsult International Study

Nile Basin power grid and regional overview

2.29 All existing generation and transmission facilities are indicated in map IBRD 32740 at the end of this chapter. This map gives an overview of the structure of the existing transmission and generation facilities in the Nile Basin countries. It is digitized and can easily be updated if desired.

2.30 There is at present an interconnected network covering Democratic Republic of Congo-East, Burundi, and Rwanda. As indicated in table 2.2, this represents less than 1 percent of the generating capacity in the region. There is, however, a long tradition for common operation of this network. The major part of the generating capacity in this grid is hydropower; thermal facilities are used for emergency purposes for the most part.

2.31 The national power grid in Tanzania, which represents about 4 percent of the installed capacity in the region, is isolated from all other basin countries. It contains both hydropower and thermal facilities; hydropower is the most important source, with about 73 percent of the total installed capacity.

2.32 There is a comparatively strong interconnection between Kenya and Uganda, whose grids are interconnected between Tororo and Lessos substations through a 132 kV transmission line. These two countries account for about 7 percent of the total installed capacity in the region. The distance from the Kenya-Uganda system to the grid in Tanzania is about 200 kilometers and somewhat more to the Democratic Republic of Congo-Kivu–Burundi–Rwanda grid. Uganda supplies the Bukoba region in northern Tanzania. The peak load is up to 9 MW, according to the supply agreement between UEB and TANESCO. There is also power exchange between Uganda and Rwanda. The national grid in Uganda is almost entirely based on hydropower, whereas the grid in Kenya contains both hydropower and thermal generation facilities, of which hydropower is the most important with approximately 68 percent of the total.

2.33 The Ethiopian grid represents about 2.5 percent of the installed capacity and is isolated. Almost all generation facilities are hydropower. Distances to the grids in Sudan and Eritrea are about 500 kilometers, whereas the distances to the grids in Kenya and Uganda are approximately double that.

2.34 The grid in Sudan is also isolated with a distance to the Egyptian grid of approximately 800 kilometers. The grid in Eritrea is simple and is about 300 kilometers from the Sudanese grid. The Eritrean grid is entirely based on thermal generation, whereas the generating facilities in Sudan are almost equally divided between thermal and hydropower generation.

2.35 The grid in Egypt represents more than 80 percent of the installed capacity in the region and is well developed with a strong 500 kV transmission line from Aswan to Cairo. The hydropower generating facilities in this grid make up about 19 percent of the country’s total generating capacity.

Current Demand–Supply and Supply Costs

Historic and current demand

2.36 Table 2.3 provides the following information on a country-by-country basis: the period for which statistics were available for the first desk study, average annual growth rates during the same periods, and consumption in the national network for 1999 (the figures for Egypt and Kenya represent fiscal year 1998/99). The historic consumption figures for the period covered by the first desk study have been updated to include information for 1997, 1998, and 1999. The data for Democratic Republic of Congo-East is also far from satisfactory, owing to communication problems in that part of the country as previously mentioned. Additional consumption in isolated networks is also indicated as a percentage of the consumption in the national grid.

2.37 The consumption in Democratic Republic of Congo-East for the centers covered by the main grid has been estimated at approximately 100 GWh for 1999 based on statistics from 1997 and 1998. The generating facilities not that do not belong to the main grid in this part of Democratic Republic of Congo are significant in size; their corresponding generation is therefore of importance, but the statistical data do not allow any quantification.

2.38 The calculation of the 1.5 percent consumption in isolated networks for Ethiopia is based on average annual generation in these networks.

Table 2.3: Consumption

Country	*Years with statistics*	*Average growth (%)*	*Domestic consumption in national network, 1999 (GWh/yr)*	*Consumption in isolated networks (%)*	*Each country's share (%)*
Burundi	85–97	2.5	102	6.9	0.15
Congo, Dem. Rep. East	80–88	17.4	100	n.a.	0.15
Egypt	88/89–97/98	5.7	56,504	1.0	85.36
Eritrea	83–92	1.0	171	n.a.	0.26
Ethiopia	80–95	7.2	1,306	1.5	1.97
Kenya	92/93–97/98	4.0	3,695	0.6	5.58
Rwanda	85–92	6.2	131	0.0	0.20
Sudan	85–91	2.7	1,510	12.0	2.28
Tanzania	80–97	7.0	1,960	3.0	2.96
Uganda	86–97	11.2	714	0.1	1.08
Total			66,193		100.00

Source: Norconsult International Study

2.39 Consumption figures for Sudan and Tanzania were not available for 1999. Production figures were, however, available for both countries for 1999 and consumption has been calculated based on these, assuming the same percentage of losses as for 1998.

2.40 An important aspect is each country's share of the total consumption. Egypt alone has more than 85 percent, whereas Burundi, Democratic Republic of Congo-East, Eritrea, and Rwanda together have less than 1 percent of the total. Kenya is the second-largest with 5.58 percent.

Current demand/supply situation

Current situation

2.41 The year 1999 was chosen to represent the "current situation" in this study. Production and consumption figures were available for all countries except Eritrea for this year, with the insignificant reservation about the figures for Sudan and Tanzania (already explained). The figures for Eritrea were estimated by Norconsult International using weak data. For Kenya and Egypt the figures refer to fiscal year 1998/99. Table 2.4 lists the figures for all Nile Basin countries.

Table 2.4: Demand–Supply Situation in 1999 (Excluding Egypt)

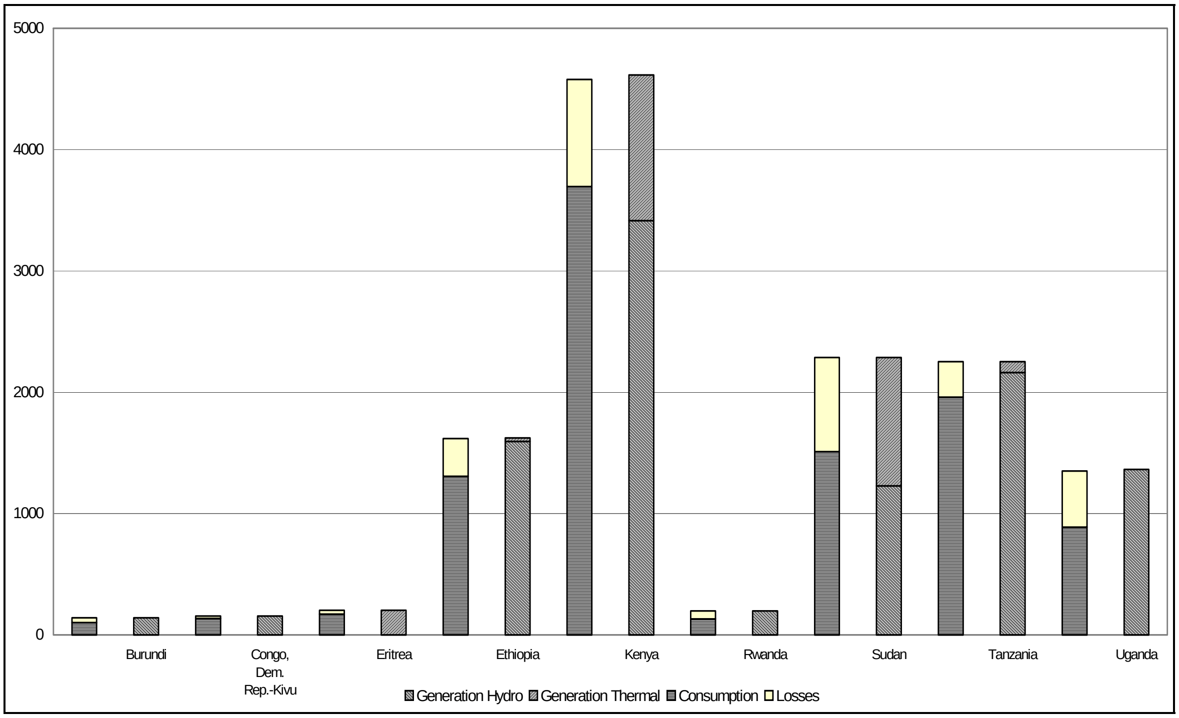
Country	*Thermal Generation (GWh/ year)*	*Hydro Generation (GWh/ year)*	*Losses (GWh/ year)*	*Domestic consumption (GWh/ year)*	*Export (GWh /year)*	*Import (GWh/ year)*
Burundi	0	121	39	102	0	20
Congo, Dem. Rep. East	0	156	20	100	36	0
Egypt	52,694	15,287	9,015[a]	56,504	0	0
Eritrea	202	0	31	171	0	0
Ethiopia	29	1,595	313	1,306	0	0
Kenya	1,201	3,274	884	3,695	0	140
Rwanda	0	182	66	131	1	16
Sudan	1,059	1,227	776	1,510	0	0
Tanzania	90	2,162	292	1,960	0	0
Uganda	0	1,364	463	714	174	1
Total	55,275	25,368	11,899	66,193	211	177

a. This figure does not include auxiliaries consumption

Source: *Power experts of Nile Basin countries.*

2.42 The table's figure for hydropower supply of 121 GWh for Burundi is composed of 91 GWh of generation by domestic facilities and 30 GWh of production from Ruzizi II. The figure for import of 20 GWh to Burundi is production from Ruzizi I, whereas the figure of export of 1 GWh from Rwanda represents export to Kisoro in Uganda. The figure for export for Democratic Republic of Congo of 36 GWh is export from Ruzizi I to Burundi and Rwanda. The figure for import to Kenya of 140 GWh is import from Uganda. The figure for hydropower supply of 182 GWh for Rwanda is composed of 128 GWh of generation by domestic facilities and 54 GWh for production from Ruzizi II. The figure for import to Rwanda of 16 GWh represents production from Ruzizi I. The figure of 174 GWh for export from Uganda is export to Kenya, Tanzania, and Rwanda. (The export and import figures do not correspond because the export is partly to isolated areas, whereas all imports given in the table are to the main networks only.) This information is also shown in figure 2.7 for all countries except Egypt.

Figure 2.7: Demand and Generation in 1999, Excluding Egypt (GWh)



Source: Power experts of Nile Basin countries.

2.43 It is important to note that Burundi, Democratic Republic of Congo-East, Rwanda, and Uganda had only hydropower generation in 1999. Eritrea had only thermal generation. Kenya had about 75 percent hydropower generation, whereas Egypt had approximately 78 percent thermal generation. Sudan and Tanzania had 54 percent and 96 percent, respectively, of hydropower generation in their national networks.

Demand–supply balances

2.44 With regard to demand–supply balances, the Democratic Republic of Congo-East, Burundi, Rwanda grid should (based on 1999) need a total supply of 458 GWh, composed of domestic consumption of 333 GWh and losses of 125 GWh. The annual average production from the hydropower facilities in this grid is exactly the same (458 GWh) and this consequently indicates a deficit in generating capacity. Rwanda has at present insufficient supply and it can be assumed that this is also the case for Democratic Republic of Congo-East. This indicates that supply in the near future may be insufficient even with the addition of the third unit of Ruzizi II, which is scheduled for commissioning in 2001.

2.45 Tanzania has experienced several periods of load shedding during recent years. With the commissioning of the new thermal generation facilities of Ubungo and the Kihansi power plant this situation has improved and the current supply should be sufficient during a normal hydrological year.

2.46 Uganda has faced capacity problems in connection with the export to Kenya during recent years. This indicates that there has been a deficit in generating capacity in Uganda. The energy production in 1999 of 1,364 GWh was also higher than the firm annual energy production from the existing facilities, which currently is estimated at 1,275 GWh. The ongoing rehabilitation of Owen Falls will improve the situation from 2001 onward.

2.47 The 1999 consumption and losses for Ethiopia are about 1,600 GWh, whereas the annual energy production for the hydropower facilities is estimated at about 1,700 GWh. There is consequently no surplus at present. Commissioning of new hydropower facilities in 2001 and 2003 with annual productions of 331 GWh and 624 GWh, respectively, will improve the supply situation considerably.

2.48 Peak demand for the Sudan grid has been between 350 MW and 375 MW for the last few years, with the available capacity somewhat below 420 MW. This indicates that there is no significant surplus when reserve margins are taken into consideration.

2.49 The information received also indicates that neither Kenya nor Egypt have any significant surplus capacity, at least when reserve margins are taken into consideration. With regard to Eritrea, the information in the documents studied is too outdated to be used for an assessment of possible surplus or deficit.

2.50 Based on the material available for this study, the main conclusion is that there is either reasonable balance or deficit in generating capacity in all of the power systems. It should be kept in mind that this conclusion has been reached through a desk study at scoping level and without any detailed power system analysis, including detailed studies of energy and capacity requirements, reserve margins, and the like. This reservation is of particular relevance for the more comprehensive power systems, especially Egypt.

Cost of generation

2.51 The cost of supplying additional power in the Nile Basin countries varies considerably in the estimates available in the source material. Egypt has the lowest cost of incremental bulk supply based on cheap natural gas from domestic sources. Uganda and Tanzania can also provide competitive candidate hydropower projects for supply of electricity, if a sufficiently large market can be established. The unit cost of generation for Ethiopia’s hydropower potential needs to be reevaluated as the range of costs available to the Consultant varies greatly. Also, the redesign of schemes to multipurpose needs in a regional context might lead to a reduction in the cost of electricity generation compared to that in the current single-purpose designs. The cost of electricity generation in the region’s landlocked countries relying on thermal power is high because of long transportation distances. Thermal generation based on imported fuels is also sensitive to world market fluctuations in the oil price.

2.52 The variation in electricity supply cost among candidate projects in the Nile Basin countries represents a significant potential for power exchange that, if developed, can greatly benefit two or more countries in the area compared to the no-trade scenario.

2.53 The candidate projects' unit cost of generation was studied and used when assessing the options for power trade presented later in the report. These cost estimates need to be updated to become comparative across countries, however. They need, for instance, to refer to a common base year, apply comparable assumptions of cost estimates, and use a discount rate that reflects the opportunity cost of capital in a regional setting. Further work on these unit costs is recommended and is an integral part of the study options detailed in chapter 3.

Electricity tariffs and average sales prices

2.54 The average sales price of electricity to consumers in the Nile Basin countries, as reported by the national energy experts, shows variations that, by and large, reflect the differences in the cost of generation. Egypt has by far the lowest sales price, 3.7 USc/kWh (1998). Burundi, Ethiopia, and Sudan sell electricity to their consumers at an average price of about 6 USc/kWh. Somewhat higher prices, around 8 USc/kWh, are prevalent in Uganda and Kenya. The highest electricity prices are found in Tanzania and Rwanda—on average 10 USc/kWh or higher. (See table 2.5.)

2.55 The tariffs applied in the region are in most cases below what is required to cover the cost of supplies and own-financing of expansions, with the possible exception of Rwanda and Tanzania.

Table 2.5: Average Sales Price of Electricity per kWh for Consumers, Nile Basin Countries

Country	*U.S. Cents (Local Currency)*	*1997*	*1998*	*1999*
Burundi	USc (FBU)	8 (28.77)	7 (30.5)	6 (32.1)
Congo, Dem. Rep.	USc	3.9		
Egypt	USc (PT/kWh)	3.7 (12.8)	3.7 (12.8)	
Eritrea				
Ethiopia	Usc			6
Kenya	Usc			7.94[a]
Rwanda	USc (FRW)	12.7 (42)	(42)	10.9 (42)
Sudan	USc (LS)		5.3 (105)	
Tanzania	USc	9.8	10.1	
Uganda	Usc (Ushs)		7 (88.3)	7.9

a. 1998/99; KPLC Annual Report.

Note: Blank cells indicate that data have not been reported.

Source: Power experts of Nile Basin countries.

2.56 Additional information, broken down by country, on tariffs and electricity prices was gleaned from the source material of this study and is presented below. Data available are not necessarily consistent across countries, as assumptions made in calculations may vary. (This caveat could, for instance, apply in the definition of average sales prices.)

2.57 In Burundi, the average sales price of electricity was about 27 FBu/kWh in 1999. Measured in fixed prices, the average sales price dropped from 15 FBu/kWh on average during 1990–95 to 6 FBu/kWh in 1999. The tariff is far below what is required to recover the cost of supplies. Consequently the operations of REGIDESO generate a substantial financial deficit.

2.58 In Egypt, about 78 percent of the Egyptian Electricity Authority's (EEA) sales in fiscal year 1996/97 were to the distribution companies at an average price of 2.9 USc/kWh, with an overall average sales price including EEA's sales to the industrial users at about 2.8 USc/kWh. The average consumer retail tariff, by comparison, was about 4.2 USc/kWh in 1999. Commercial consumers are paying the highest tariffs compared to residential customers and large industries. The average tariff for commercial customers is about 8.4 USc/kWh as compared to 2.5 USc/kWh for residential consumers and 1.9 USc/kWh for large industries.

2.59 Ethiopia embarked on a stepwise adjustment of electricity tariffs in the early 1990s in order to bring sales prices toward Long-Run Marginal Cost (LRMC). However, even with the stipulated program, average sales prices would not reach more than 72 percent of LRMC.

2.60 In Kenya the average sales price by the existing 1996 tariffs was calculated at about 8.7 USc/kWh, while the financial tariff that would meet specified financial requirements for KenGen and Kenya Lighting and Power Company (KPLC) is 9.1 USc/kWh—that is, a tariff increase of 5 percent is required to meet financial targets. The actual average sales price, as reported in the update of this study, is 8 USc/kWh.

2.61 In Tanzania, the low voltage sales tariffs range from 5.5 USc/kWh for consumption up to 450 kWh per month, and to 18 USc/kWh for consumption above 5,000 kWh per month.

2.62 In Uganda, the low voltage sales tariffs are between 9.0 USc/kWh (up to 450 kWh per month) and 8.4 USc/kWh (for consumption above 5,000 kWh per month). The average sales tariff was 7.9 USc/kWh in 1999.

2.63 The negotiated tariffs for supply of power by Uganda Electricity Board to Kenya Power Company in effect since July 1993 and valid until October 13, 1999 are 8.0 USc/kWh for supplies during the day and 6.0 USc/kWh for night supplies.

Future Demand and Supply

Demand forecasts

2.64 Table 2.6 shows demand forecasts for the years 2005, 2010, 2015, and 2020. Some average growth rates are also shown. The forecasts below are relevant for the main grids in the respective countries. The forecasts have been provided by the national experts and are in most cases up to date. With regard to Egypt, it is only the 2005 forecast that has been provided by the national expert and the Consultant has prepared his own forecasts for 2010, 2015, and 2020. The forecast for Democratic Republic of Congo-East is outdated. With regard to Eritrea, Norconsult International has prepared forecasts using rather weak data, as previously described.

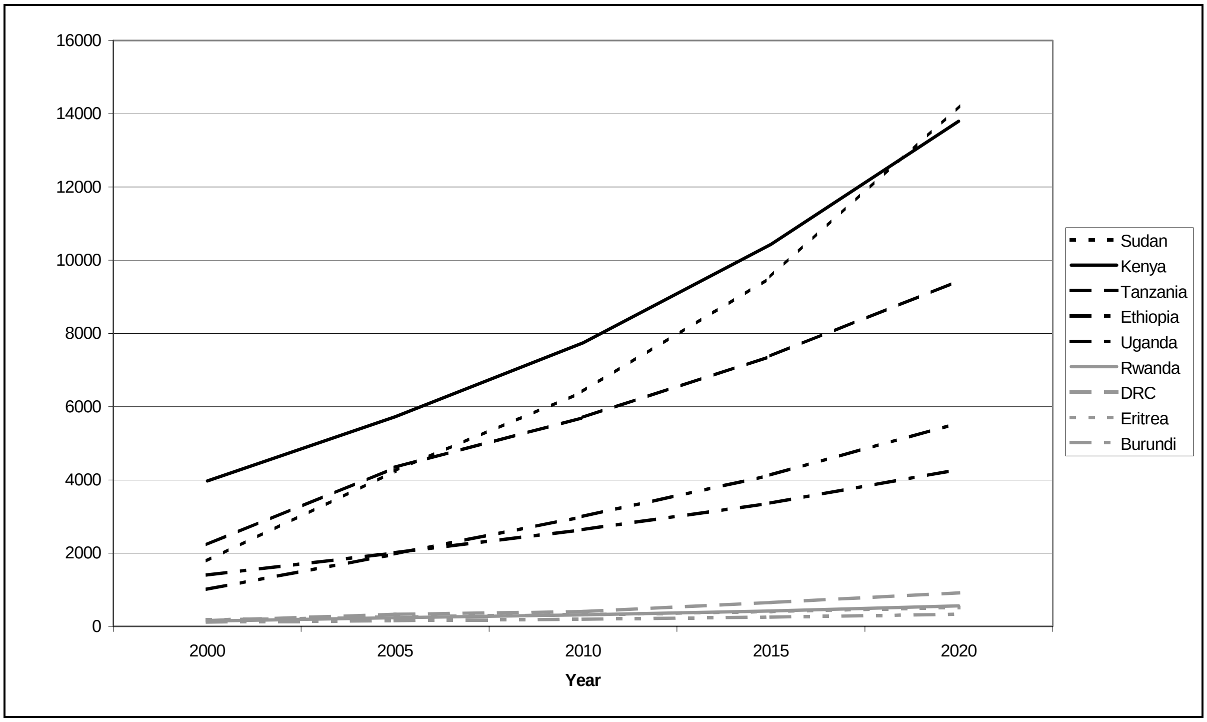
Table 2.6: Demand Forecasts for 2005 through 2020

.Country	*Forecast 2005 (GWh)*	*Avg. incr. 2005 (%)*	*Forecast 2010 (GWh)*	*Forecast 2015 (GWh)*	*Forecast 2020 (GWh)*	*Avg. incr. 2020 (%)*
Burundi	156	6.0	195	253	335	5.0
Congo, Dem. Rep. East	331	16.0	405	653	917	8.7
Egypt	86,333	8.5	109,000	145,000	191,220	5.7
Eritrea	251	6.7	320	407	518	4.9
Ethiopia	2,011	7.5	2,640	3,367	4,285	5.3
Kenya	5,724	7.6	7,747	10,435	14,007	5.3
Rwanda	234	10.0	314	420	562	6.5
Sudan	4,246	18.8	6,417	9,550	14,212	10.2
Tanzania	4,346	14.2	5,709	7,384	9,442	7.1
Uganda	1,975	14.3	3,003	4,134	5,559	8.3
Total	105,607		135,750	181,603	241,057	

Source*: Norconsult International Study*

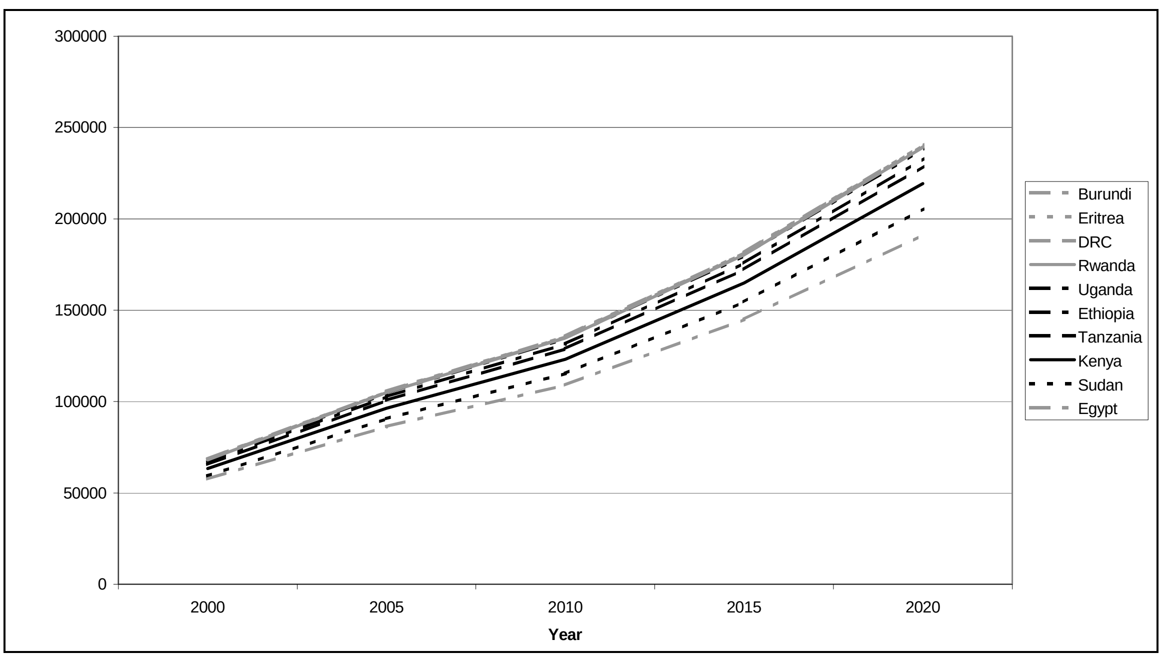
2.65 The demand forecasts for each country, except Egypt, are also shown in figure 2.8. Total demand for the entire region is shown in figure 2.9.

Figure 2.8: Electricity Demand Forecast per Country (Excluding Egypt) (GWh/year)



Source*: Power experts of the Nile Basin countries*

Figure 2.9: Total Electricity Demand Forecast in Nile Basin Countries (GWh/year)



Source*: Power experts of the Nile Basin countries*

Future demand–supply balances

2.66 National power subsector generation expansion plans form the basis for the information used in this subsection. These plans assume only power exchange among the countries at current levels. Consequently balances between demand and supply, including reserve margins, are essentially envisaged to be covered by indigenous generating facilities. The only exception is Tanzania, which has included some import from Zambia during the planning period. This shows that all of the Nile Basin countries plan future development of the power subsector in the traditional way, without any major new interconnections enabling increased exchange and trade of power.

Democratic Republic of Congo-East–Burundi–Rwanda grid

2.67 Burundi, Rwanda, and Democratic Republic of Congo-East all envisage hydropower generation for their future development. Their master plans include indigenous projects. Rwanda has also one thermal power station. As previously stated, there are indications of a deficit in available energy from the hydropower-based generation facilities. As the demand for the three countries in year 2005 is estimated at about 700 GWh, this will require additional energy generation in the order of 400 GWh, when the committed commissions of the third unit of Ruzizi II have been done in 2001.

2.68 The expansion plan for Rwanda indicates a deficit until 2005, when there is expected to be a reasonable balance if the Nyabarongo hydropower project is commissioned.

2.69 The reference scenario expansion plan for Burundi indicates reasonable balances of energy and capacity if the envisaged hydropower projects are implemented. There is some surplus in the years in which the new projects are commissioned. This is definitely the case for the high-expansion scenario, if the 90 MW hydropower project, Singuvyaye, is commissioned in 2004. This will result in a significant surplus during the first few years thereafter.

2.70 The Democratic Republic of Congo has possible hydropower projects in the eastern regions of the country. All three countries have comparatively small power markets and power exchange among them in conjunction with the development of the domestic projects could be advantageous. This could, for example, turn out to be the case for the Kabu 16 project in Burundi or the Nyabarongo project in Rwanda.

2.71 Two regional projects have also been studied for the purpose of joint development according to the reference documents. These projects are the Ruzizi III and Rusumo Falls with indicated installed capacities of 82 MW and 60 MW, respectively. (These are proposed as study options 1 and 2 in chapter 3.) It is obvious that increased exchange of power is economic in the development of both regional and domestic projects.

2.72 The Consultant's information on the operation and dispatch capabilities of this network is limited. It is known, however, that it has been in operation for a number of years, starting with the development of the Ruzizi I and Ruzizi II power plants. These power plants are operated by Société Nationale d'Electricité du Congo (SNEL, Democratic Republic of Congo's power company) and Société Internationale d'Electricité des Pays des Grands Lacs (SINELAC), respectively. The operation of Ruzizi I and II and the power exchange are based on their implementation agreements. With the increased importance of the efficient operation of this grid in the future, a study of this exchange could be useful. (This is defined as study option 3 in chapter 3.)

2.73 A general strengthening of the Democratic Republic of Congo-East/Burundi/Rwanda grid is definitely of importance. There are some plans for a new interconnection between Rwegura in Burundi and Kigoma in Rwanda. (This is noted as study option 4 in chapter 3.)

2.74 An interconnection between the Democratic Republic of Congo-East/Burundi/Rwanda grid and the Tanzanian grid might have operational advantages and also enable more optimal planning, taking the size of some of the projects in this area into consideration. Another advantage of this is that some of the load centers in northern Tanzania would end up closer to the source of generation. This would be of particular relevance if the Rusumo Falls project is developed. (This proposal is study option 5 in chapter 3.)

2.75 Another interesting matter to pursue is the possibility of supplying isolated centers in Tanzania from the Democratic Republic of Congo-East/Burundi/Rwanda grid or from Uganda, which is explored as study option 6 in chapter 3.

Tanzanian grid

2.76 As already indicated, there is a reasonable balance in generating capacity in this grid with the commissioning of the Ubongo and Kihansi projects. The demand forecasts, however, require a generation of more than 5,000 GWh already in year 2005 and the balance is supposed to be covered by new and existing thermal generating facilities as well as import from Zambia.

2.77 The demand supply balances indicate reasonable margins, if the projects in the generation expansion plan are implemented. In addition to thermal facilities, two comparatively large hydropower developments—the Ruhudji and Rumakali projects with 358 MW and 222 MW, respectively—are envisaged for the years 2010 and 2014. There is, of course, some surplus during the first years after these have been commissioned, which could be used for net export of power in a normal hydrological year if transmission facilities were available. Net export and/or reduced reserve margins might also be possible in other years, if transmission facilities to neighboring countries were developed.

2.78 Tanzania has a considerable hydropower potential. Projects with an aggregate installed capacity of about 2,400 MW and an average annual production of more than 10,000 GWh have been studied at least to master plan level. Only two of these, representing 580 MW, are included in the current national master plan, as the rest is supposed to be covered by import from Zambia and thermal generation. The unit cost of generation for these candidate hydropower projects is competitive and there is consequently a potential for net exports to neighboring countries, for instance Kenya or the Democratic Republic of Congo-East/Burundi/Rwanda grid, if the development of some of these projects is advanced. Transmission distances from the Tanzanian grid to these two power grids are also reasonable. Further studies with the objective of assessing benefits and ranking candidate hydropower projects in Tanzania with a view to increasing power export could be of interest. (This is indicated as study option 7 in chapter 3.)

Kenyan grid

2.79 For this power system there is also a balance between demand and supply, both in the near future and throughout the planning period, if the projects in the generation expansion plan are implemented. This plan has only a small part of indigenous hydropower projects envisaged for future development. Kenya is supposed to add 1,600 MW of generating capacity up to year 2017, of which 15 percent is hydropower. The generating facilities in the national power system will consequently become more and more thermal-based in the future. About 900 MW of this planned thermal generation expansion is based on diesel.

2.80 There is, consequently, a scope for increased import of hydropower from neighboring Uganda or Tanzania, if the price is competitive, with the result of reduced oil-based thermal generation. This is the case in the short term, owing to the nature of the existing generating facilities. This option may be even more important in the future because a significant part of the new generating facilities is diesel-based.

2.81 Hydropower production in Kenya is at present planned with the purpose of avoiding spill and maximizing energy production in the country's system. A result of this is that hydropower production is evenly distributed over the year and that the reservoirs are almost empty at the start of the rainy season during a normal hydrological year. Interconnection with Tanzania or more reliable supply from Uganda might allow a different operational strategy. The monthly distribution of flows, given in chapter 2 of the draft data reports, shows that the projects in Tanzania and the existing hydropower plants in Kenya to some extent are complementary as the latter have two annual peaks—that is, high flows during October–December—when Tanzania is in its dry season. The distribution of flows for the power plants in Uganda is also most favorable to trade. This is important from the point of view of power system operation. A possible interconnection of the power grids in Kenya and Tanzania could therefore be of interest as the distance between the two power systems is reasonable if sufficient amounts of power are being transmitted. (This is proposed as study option 8 in chapter 3.)

2.82 The current plan of deregulation in Kenya stipulates that KenGen will provide generation from its own installations and power purchase agreements with independent power producers. A transmission company, KPLC, will buy power from KenGen and supply it to consumers. In this set-up, there is a scope for greater competition in distribution and thereby more efficient supply to consumers. (This appears as study option 9 in chapter 3.)

Ugandan grid

2.83 As previously indicated, the Ugandan grid has faced capacity problems during recent years. This will be improved in the near future, when the first phase of the Owen Falls extension, which comprises units 11 and 12, is commissioned. According to the generation expansion plan, this was supposed to take place in 2000. The installed capacity at Owen Falls power station will then be 260 MW. The second phase of the extension, which comprises another 120 MW, was scheduled for 2001. The total addition will then be 260 MW of capacity and 750 GWh of power generation. The total energy generation will then be about 2,000 GWh. Even with this expansion, there is a deficit both in energy and capacity during the years 2000–03.

2.84 The construction of the Bujagali hydropower plant is still under discussion. If the project is implemented, this will add another 250 MW and approximately 1,600 GWh of firm power to the system. A surplus of about 800 GWh and 140 MW can occur when Bujagali is commissioned. There could consequently be some scope for increased power export, depending on the hydrology. This export potential will be significantly increased if the Karuma hydropower project is commissioned in 2005, as indicated in the generation expansion plan, as the surplus then would be about 1,800 GWh and 320 MW. Another comparatively large hydropower development, the Kalagala project, is scheduled for commissioning in 2008. There will, consequently, be reasonable margins and/or some scope for net export during the years 2004 through 2015, if the generation expansion plan is implemented.

2.85 Other new hydropower projects have also been studied to master plan level in Uganda. These represent an installed capacity of approximately 800 MW and an annual firm energy generation of about 5,000 GWh. There is, consequently, a significant scope for increased export to Kenya and other neighboring countries also in the medium to long term, if some of these projects are implemented, as their unit cost of generation is competitive.

2.86 An important characteristic here is that the monthly distribution of flows from existing and future projects in Uganda is favorable to power exchange between Uganda and Kenya. The flow of the Victoria Nile in Uganda is evenly distributed over the year, whereas the flow in the Tana River in Kenya has two typical peaks, March through May and October through December.

2.87 A study to assess possible advantages and ranking of hydropower projects in Uganda with a view to increase export to neighboring countries could be of interest. (This is proposed as study option 10 in chapter 3.)

2.88 Given this background, it is likely that increased power export from Uganda to Kenya could be favorable and that investments in increased transmission capacity between the two countries could be feasible. (This is proposed as study option 11 in chapter 3.)

Ethiopian grid

2.89 As previously stated, there is a balance, without any significant margins, in the Ethiopian interconnected network. According to the country's future generation expansion plan new hydropower projects with an installed capacity of about 250 MW and annual generation of almost 1,000 GWh have been committed and are scheduled for commissioning before 2004. The generation required in 2003 is, according to the previously presented forecast, about 2,100 GWh and there is a reasonable margin or a small surplus both in energy and capacity in that year. The Tekeze Stage 1 hydropower project is scheduled for commissioning in 2006, which would result in a surplus of about 800 GWh and 350 MW in the interconnected system in that year.

2.90 In the power subsector development master plan, it is envisaged that hydropower projects will only cover future supply. Ethiopia has a considerable hydropower potential. Projects studied at least to master plan level represent around 1,900 MW of installed capacity and an average annual energy production of 8,000 GWh. This is above the needs for the national power system in this planning period and consequently there is a scope for power export to neighboring countries, if the implementation of some of these projects is advanced. There are also other candidate hydropower projects.

2.91 A proper assessment of the unit cost of generation for potential power projects in Ethiopia for possible export of power is very important in relation to indicating the scope for power export and trade. Some of the data currently available to the Consultant indicate a relatively high cost of generation, whereas other data show much more favorable costs. Given the wide range and conflicting nature of these data, it is not possible to adequately assess the relative cost of generation without further study, which is proposed as study option 12 in chapter 3.

2.92 Additionally, the unit cost of generation from the candidate hydropower projects in Ethiopia is purely based on hydropower development. Multipurpose use of the water resources would add other benefits, reduce the power generation cost and possibly justify development of transmission facilities and power trade in the future. (This is proposed as study option 13 in chapter 3.)

2.93 There may be advantages of interconnection between the power systems in Ethiopia and Sudan. Sudan has a combined hydropower and thermal-based system, whereas the system in Ethiopia is hydropower-based. Interconnection of Roseires in Sudan with the power system in Ethiopia has been studied and found technically feasible without major reinforcements of existing transmission facilities. According to that study, the advantages would be better utilization of surplus hydropower energy and flexibility in the timing of new generation capacity. An update would be of interest in terms of power trade. (This is proposed as study option 14 in chapter 3.)

2.94 The idea of interconnecting the Ethiopian power system with the grids in Kenya and Uganda was discussed during the working group meeting in Entebbe, Uganda. Transmission distances will be about 1,000 kilometers, which is considered relatively long. However, studies for the assessment of technical characteristics, costs, and benefits at prefeasibility level could be worth considering. (These are proposed as study options 15 and 16, for Kenya and Uganda, respectively, in chapter 3.)

Eritrean grid

2.95 The statistical information made available to the Consultant for Eritrea is outdated and does not allow any assessment of the demand/supply balance. Eritrea will continue to rely on thermal power. There could consequently be a scope for power export from Ethiopia to Eritrea, thereby substituting comparatively expensive thermal power in Eritrea with hydropower from Ethiopia in the future, even if the current power market most likely is too small to justify any major investments in such transmission facilities.

2.96 There are proven gas reserves in Eritrea, which could be used for export to Sudan or Ethiopia.

Sudanese grid

2.97 As previously mentioned, there does not seem to be any surplus in the Sudanese power system. According to the development plan from 1999 to 2005, there is a certain deficit in generating capacity during the first part of this period.

2.98 Different generation expansion plans have been worked out. As for all other countries these are for the purpose of supplying the national power systems only. There are plans to add about 2,000 MW up to the year 2013. These expansion plans all include one large hydropower project, the Merowe project with a capacity of 1,250 MW.

2.99 The various expansion plans include different thermal alternatives—that is, combined cycle and steam, steam turbines, and gas turbines—with installed capacity of about 800 MW. An option with combined cycle and steam has been chosen. Different stages of the Merowe hydropower project are, according to this plan, scheduled for the period 2007–11. Tender documents for the Merowe project have been worked out. The project, however, is still awaiting financing and a final decision on project implementation has not yet been taken. A study of the importance and effect of the Merowe project in a regional perspective could be of interest. (This is proposed as study option 17 in chapter 3.)

2.100 Sudan has a technically feasible hydropower potential of about 5,000 MW. A significant part of this is located in the southern part of the country, and the estimated potential of the White Nile between Juba and Nimoli is approximately 2,000 MW. Hydropower projects in this area could, if developed, be considered for interconnection with the Nile Equatorial Lakes power grid in the future. (This is proposed as study option 18 in chapter 3.) There are also considerable hydropower potentials in the other parts of the country, which could be considered for interconnection with Egypt and development of the Eastern Nile grid in general. (This proposal is presented as study option 19 in chapter 3.)

2.101 The operation of hydropower projects in Sudan is to a great extent dependent on irrigation requirements. The distance between existing Roseires, in the Sudanese grid, and the Ethiopian grid is about 500 kilometers and an interconnection is not unrealistic in terms of power transmission. This possible power exchange should be based on the advantage of combining the hydropower-based system in Ethiopia with the mixed system in Sudan. (This refers to study option 14 in chapter 3, mentioned above).

Egyptian grid

2.102 As mentioned earlier, the Egyptian power system is well developed and represented about 84 percent of the total generation in the region in 1999. A generation expansion plan up to the year 2010 was provided for this study. The total new generating capacity in this period is 12,439 MW, of which 3,370 MW is before the year 2004. This is composed of 450 MW of wind energy, 750 MW of solar/gas energy, 1,464 MW of hydropower/pumped storage, and various types of thermal generation. The addition of new generating capacity is somewhat higher than the corresponding load growth.

2.103 A 220 kV interconnection between Egypt and Libya commenced operation in December 1998. Another project, the Egypt-Jordan interconnection, was commissioned in September 1998. These developments indicate that Egypt is oriented toward power exchange with Mediterranean countries and perhaps with Europe.

2.104 Interconnections with the grids in Sudan and/or Ethiopia could, however, materialize in the medium to long term. With the distances in question, Direct Current (DC) connections are possible options. (These are proposed as study options 20 and 21 in chapter 3, for Ethiopia and Sudan, respectively.)

Summary

2.105 To recap, there are two areas in the Nile Basin where power trade is currently undertaken. The first of these comprises Democratic Republic of Congo-East, Burundi, and Rwanda. The second area includes Uganda and Kenya. Uganda also supplies small isolated centers in Rwanda and Tanzania. It was discussed in the previous section that there also is a scope for Tanzania to be interconnected to Kenya in view of transmission distances, hydropower complementarity, and power markets.

2.106 Studies for the interconnection of the grid in Tanzania and the Democratic Republic of Congo-East–Burundi–Rwanda grid have been undertaken in connection with the possible development of the Rusumo Falls hydropower plant. According to this study, such an interconnection is technically feasible. It is also possible that other isolated centers in the northwestern part of Tanzania could be served, either from the Democratic Republic of Congo-East/Burundi/Rwanda grid or from Uganda. Consequently the grid in Tanzania could be interconnected with grids in Kenya/Uganda and with the Democratic Republic of Congo-East/Burundi/Rwanda grid. If these views materialize, power trade could be undertaken in this whole area—which could be referred to as the Nile Equatorial Lakes region and include Burundi, Democratic Republic of Congo/East, Kenya, Rwanda, Tanzania, and Uganda.

2.107 The remaining countries—Ethiopia, Eritrea, Sudan, and Egypt—could be called the Eastern Nile region. The power grids in these countries are all isolated, except that of

Egypt, which recently has established interconnections with other Mediterranean countries. The uncertainty with regard to the unit cost of generation for the Ethiopian candidate hydropower projects has already been mentioned. A proper assessment of this is of vital importance for the evaluation of the economic viability of power system interconnections and trade in the Eastern Nile region. In view of transmission distances and power markets, the power grids in Ethiopia and Sudan could be interconnected and thereby enable power trade between the two countries.

2.108 The calculation of unit cost of generation for the Ethiopian candidate hydropower project does not include benefits arising from multipurpose water use further downstream in Sudan and Egypt. This is also important for the assessment of power trade benefits in the Eastern Nile region. The power market in Eritrea is small and the study related to power export based on indigenous gas reserves is important to assess its position.

2.109 Another possibility for power exchange and trade is the interconnection of the grids in Ethiopia and Egypt. This will most likely evolve gradually by first interconnecting Sudan either to Egypt or to Ethiopia. Interconnection of Ethiopia and Egypt could also be done directly. In any case, this is a more medium-term development and has to be evaluated in a broader perspective, also including multipurpose water use.

2.110 A long-term scenario that has been discussed from time to time is a power transmission line from Inga Falls, in Democratic Republic of Congo, to Egypt and Europe.

Conclusion

2.111 An important finding of this study is that all of the development plans analyzed here assume power exchange between the countries at current levels. Consequently, balances between demand and supply, including reserve margins, are envisaged to be covered by indigenous generating facilities. This shows that the region’s countries plan future development of the power subsector in the traditional way, without any major new interconnections, including increased exchange and trade of power.

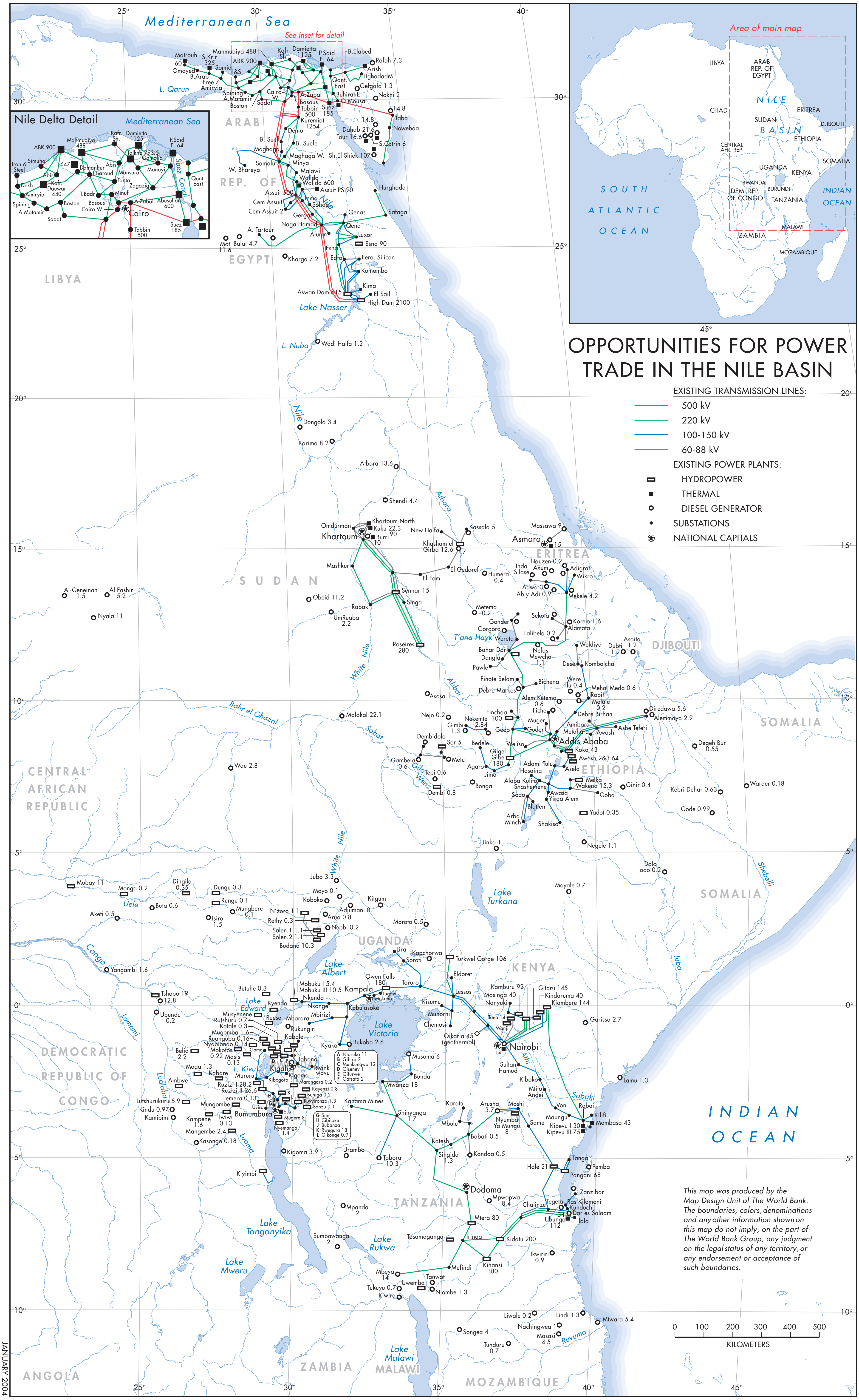
2.112 Another important characteristic observed in the plans is that there is either balance or deficit in generating capacity and/or energy generation in almost all of the power systems. The future generation expansion plans normally envisage reasonable reserve margins and some surplus at points in time when comparatively large power plants are commissioned.

2.113 Four countries—Uganda, Tanzania, Sudan, and Ethiopia—have considerable indigenous hydropower resources which are well above the domestic needs of these countries in their present long-term subsector planning periods. If some of the planned projects are advanced or other projects are introduced, there could be a scope for net export to neighboring countries with resulting reduction of thermal generation. Another interesting finding is that there is hydrological complementarity between different parts of the Nile Basin, which is advantageous for the operation of hydropower generation facilities in neighboring power systems.

2.114 Transmission distances in the Nile Equatorial Lakes in general, and also between Ethiopia and Sudan, are acceptable for the transfer of reasonable amounts of power. Transmission facilities between the power systems are, however, not sufficiently developed and this presents a severe constraint to increased trade of power.

2.115 In light of all this, basinwide trade is unlikely in the near future. However, in the Nile Equatorial Lakes some limited power trade is currently undertaken and could develop significantly in the short term. In the Eastern Nile, power trade potential exists, but needs to be evaluated in the context of a broader multipurpose approach to water resources development and management.

2.116 Several study options were mentioned in this chapter for the purpose of enabling a better evaluation of the findings and the preliminary conclusions given. These are explored further in chapter 3.


OPPORTUNITIES FOR POWER TRADE IN THE NILE BASIN
EXISTING TRANSMISSION LINES:
500 kV
220 kV
100-150 kV
60-88 kV
EXISTING POWER PLANTS:
HYDROPOWER
THERMAL
DIESEL GENERATOR
SUBSTATIONS
NATIONAL CAPITALS
Nile Delta Detail
Mediterranean Sea
See inset for detail
Area of main map
NILE BASIN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
ARAB REP. OF EGYPT
LIBYA
SUDAN
ERITREA
DJIBOUTI
ETHIOPIA
SOMALIA
KENYA
UGANDA
TANZANIA
CENTRAL AFRICAN REPUBLIC
DEMOCRATIC REPUBLIC OF CONGO
ANGOLA
ZAMBIA
MALAWI
MOZAMBIQUE
Khartoum
Asmara
Addis Ababa
Nairobi
Kampala
Kigali
Bujumbura
Dodoma
Cairo
Lake Nasser
Lake Victoria
Lake Tanganyika
Lake Turkana
Lake Albert
Lake Malawi
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JANUARY 2004
IBRD 32740

3

Scope for Power Trade in the Nile Basin

Types and Bases for Trade Including Subregional Perspectives

3.1 The data presented in chapter 2 indicate several potential opportunities for near-term investment that warrant further investigation. However, most of these opportunities were identified on the basis of a desk study, not on country visits or in-depth discussions with basin country power sector representatives. Some options were proposed by representatives from the Nile Basin countries during the working group meetings in Entebbe in December 1999 and in Addis Ababa in July 2000.

3.2 The options below are provided to initiate discussions among the Nile Basin countries regarding alternative paths to promote power trade in the region. The options presented in this chapter focus primarily on incrementally improving trade between two or more countries or on a subregional basis. There are several activities that could be carried out basinwide. These activities are oriented toward creating an enabling environment for power trade in the region and are discussed in chapter 4.

Eastern Nile region

Current situation

3.3 At present there is no international power trade in the Eastern Nile region comprising Ethiopia, Eritrea, Sudan, and Egypt. This is partly because there are no transmission facilities in these countries to enable such trade.

Future perspectives

3.4 With regard to power generation, this subregion is characterized by considerable hydropower potentials in Ethiopia and Sudan and low-cost thermal generation in Egypt. The generation expansion plan for Sudan envisages the development of one large hydropower resource, the Merowe project, with an installed capacity of 1,250 MW. Project financing is not concluded and a decision on this would be of great importance for the development in Sudan and also in the region. There is a potential for thermal generation in Eritrea. Transmission distances between Ethiopia and Sudan and also Eritrea will work to promote power trade where the amounts traded are sizeable.

Distances from Egypt to Ethiopia are longer and will therefore require higher benefits on the generation side to justify trade.

3.5 Any of the sources of generation mentioned above could in principle be regarded as a source for net export of power. Currently the power subsector in Egypt is more oriented toward other Arab countries and possibly Europe. The power markets in the other Eastern Nile countries are far too small to justify investments in transmission facilities for the purpose of power export from Egypt in the near future—and the power market in Eritrea will most likely be too small to justify any interconnections in the near future.

3.6 Hydropower generation from Ethiopia could be an important element of power trade. However, unit cost information on generation available to the Consultant varies greatly and is purely based on hydropower development. Multipurpose use of the water resources would add other benefits that offset the power generation cost and could justify the development of transmission facilities and power trade. Hydro-thermal complementarity would add further benefits to potential trade. These issues need to be further examined.

3.7 Interconnection and power trade between Ethiopia and Sudan could develop in the near future. This trade could be based on hydro-thermal complementarity, as the power system in Sudan may become more thermal-based in the future, and Ethiopia will in all likelihood develop indigenous hydropower resources. Net export from Ethiopia to Sudan or from Sudan to Ethiopia, depending on the future of the Merowe hydropower project, is also possible. This trade could be in the form of bilateral trading between national utilities or decentralized or open access trading, depending on the development of the power subsectors in the two countries.

Nile Equatorial Lakes region

Current situation

3.8 The Nile Equatorial Lakes region includes Democratic Republic of Congo-East, Burundi, Rwanda, Tanzania, Uganda, and Kenya. In this subregion power trade exists, but is rather modest. The technical and contractual characteristics of this trade were described in chapter 1.

3.9 Hydropower from Uganda is an important element of this trade, which comprises export to Kenya and some small amounts to isolated centers in Tanzania and Rwanda. This trade is characterized as bilateral trade between state-owned utilities. Referring to designations in chapter 1, the trade could be classified as "Trading with Occasional (Non-Firm) Power from Utility to Utility," even though the agreement originally could be classified as "Trading with Firm Power from Utility to Utility."

3.10 There is also export from Democratic Republic of Congo-East to Rwanda and Burundi, because the three countries have jointly developed two hydropower plants in the Kivu province of Democratic Republic of Congo. It is understood from the reference documents that this export is based on agreements related to the implementation of the

Ruzizi I and Ruzizi II projects. According to these agreements, the three countries each have contractual rights to a certain part of the production, which means the proper classification for this arrangement is cooperation through joint ownership ("unit participation"), rather than power trade. However, the three countries have considerable experience in the operation of a common network, which is advantageous in developing future power trade.

Future perspectives

3.11 This subregion is characterized by considerable hydropower potential in Tanzania and Uganda. There are candidate hydropower projects in both countries that are not included in the national development plans and that have generation costs that most likely will be competitive. Some hydropower potentials in Rwanda, Democratic Republic of Congo-East, and Burundi are also of interest. These projects could all be used for net export. Future indigenous generation in Kenya is based on geothermal and hydropower resources. These are most likely required for domestic needs and are consequently not considered for net export based on the information made available for this study. Transmission distances among the three power systems in the subregion are not a barrier to power exchange and trade if the amounts in question are deemed significant.

3.12 It is likely that interconnection and power trade between Tanzania and Kenya will develop in the future. The main element of this trade could be the net export of hydropower from Tanzania, and hydro-thermal and hydro-hydro complementarities could add further benefits. Power trade between Uganda and Kenya would most likely increase significantly, if new generation projects in Uganda were advanced and the supply were made more reliable. This increase could also be based on net export from Uganda to Kenya with hydro-thermal and hydro-hydro complementarities as additional benefits. Supplies from Uganda to isolated centers in Tanzania and Rwanda may also increase.

3.13 The specific trading regimes that are conducive to the above power trade perspectives could possibly start with bilateral trade among the state power utilities. As power sector reforms materialize in the region, they could mature into a loose pool with close cooperation among independent state-owned transmission system operators. Coordination in dispatch and regulation of transmission prices should be included in the development strategy. Eventually, a competitive market in regional power trade may materialize.

3.14 Power exchange internally among Democratic Republic of Congo-East, Burundi, and Rwanda in their common grid will most likely increase. There is a need for new generating capacity in this grid and, with the comparatively small domestic power markets, increased power trade among the three would result in better prospects for the new generation projects.

3.15 As mentioned above, the operation of these power plants and their power exchange are based on agreements related to their implementation and do not involve power trade per se. It would definitely be advantageous if more commercial trade were introduced into the equation. Interconnections between this grid and the power systems in

Tanzania and Uganda could also be envisaged, justified by general power system advantages such as flexibility in operation and development planning. If these perspectives materialize, the whole Nile Equatorial Lakes region will have one interconnected network and the physical generation and transmission facilities will allow any form of power trade.

3.16 Significant environmental benefits, such as a reduction in greenhouse gas and other pollutant emissions caused by a shift from thermal to hydropower-based generation, could emerge if regional power trade is developed on a least-cost basis.

General Descriptions of Study Options to Promote Power Trade

3.17 Several study options were mentioned in chapter 2. It is the consultant's hope that the options presented in more detail below could serve as a basis for a constructive discussion of promoting power trade in the region (with the caveat cited earlier that the options are based on a desk study with national experts' suggestions added subsequently). Further discussion of these options can, of course, bring forward additional options or possibly question the ones mentioned here.

3.18 The options presented at this stage are all studies and have been organized under the following categories:

- Power generation;
- The power transmission/system;
- Operation/communication; and
- Other studies.

3.19 Study options 1, 2, 7, 10, 12, 18, and 19 concern power generation; 4, 5, 8, 11, 13, 14, 15, 16, 17, 20, and 21 concern the power transmission/system; 3 and 22 concern operation/communication; 6 and 9 are "other" studies. It is obvious that generation projects also should be evaluated in the context of supplying the relevant power system in combination with other sources of supply. Specific projects or studies related to operation/communication have been difficult to identify, however, as part of a desk study. Therefore discussions with utility officials would improve the selection of the proper projects in this area considerably.

Power generation

Study Option 1—Evaluation of the Ruzizi III Hydropower Project for Future Supply of the Democratic Republic of Congo-East–Burundi–Rwanda Grid

- **Background:** The Ruzizi I and Ruzizi II are projects jointly developed by Democratic Republic of Congo, Burundi, and Rwanda to serve their common power grid. There are indications that the Ruzizi III hydropower project could be a feasible project for the same purpose and previous studies indicate an installed capacity of about 80 MW. A steering committee is now finalizing the terms of reference for a feasibility study for the project.

- **Scope:** Conducting feasibility study for the Ruzizi III hydropower project.
- **Result:** Assessment of technical feasibility and economic viability for the project.

Study Option 2—Evaluation of the Rusumo Falls Hydropower Project for Future Supply of the Democratic Republic of Congo-East–Burundi–Rwanda Grid

- **Background:** Feasibility study and detailed engineering study of the Rusumo Falls hydropower project are complete. A likely size of the installed capacity is estimated at 60 MW and interconnection points in Tanzania, Rwanda, and Burundi have been determined.
- **Scope:** Reviewing previous studies and conclude technical feasibility and economic viability for the project. Defining options for project financing and implementation.
- **Result:** Confirmation of technical feasibility and economic viability as well as determining possible ways to finance and implement the project.

Study Option 7—Assessment of Benefits and Ranking of Hydropower Candidate Projects in Tanzania to Increase Power Exports

- **Background:** Tanzania has considerable hydropower potential. Projects with an aggregate installed capacity of about 2,400 MW and an average annual production of more than 10,000 GWh have been studied at least to master plan level. Only two of these, representing 580 MW, are included in the current national master plan. The unit cost of generation for these candidate hydropower projects is promising and there is consequently a potential for exports to neighboring countries, for example to Kenya or to the Democratic Republic of Congo-East/Burundi/Rwanda grid. Transmission distances from the Tanzanian grid to these two power grids are also reasonable.
- **Scope:** Conducting studies with the objective of assessing benefits and ranking hydropower candidate projects in Tanzania with a view to increasing power exports.
- **Result:** Indication of unit cost of energy and ranking hydropower candidate projects in Tanzania taking into account increased power exports.

Study Option 10—Assessment of Benefits and Ranking of Hydropower Candidate Projects in Uganda to Increase Power Exports

- **Background:** In addition to projects already committed, there are five other new hydropower projects discussed in the master plan study for

Uganda. These projects represent an installed capacity of approximately 1,300 MW and an annual firm energy of about 8,000 GWh. Only some of these projects will be needed in the planning period until 2020 to cover domestic needs and exports at present levels. There is consequently a scope for increased export to Kenya and other neighboring countries in the medium to long term, as the unit cost of generation for these hydropower candidate projects is competitive and the annual distribution of river flows is favorable.

- **Scope:** Studies with the objective of assessing benefits and ranking hydropower candidate projects in Uganda to increase power exports.
- **Result:** Determining the unit cost of energy and ranking hydropower candidate projects in Uganda taking increased power export into account.

Study Option 12—Assessment of Unit Cost of Generation for Hydropower Candidate Projects in Ethiopia

- **Background:** A proper assessment of the unit cost of generation for potential hydropower development projects for possible export is extremely important in determining the scope for power export and trade in Ethiopia. While some data available to the Consultant indicated relatively high costs, other data showed more favorable unit costs of generation. These conflicting data are not adequate to allow assessments to be made at this time. Study option 12 is therefore essential to the evaluation of power trade potential in the Eastern Nile subregion.
- **Scope:** Studies with the objective of assessing unit cost of generation for hydropower candidate projects to initiate power export.
- **Result:** Determining unit cost of generation for hydropower candidate projects to initiate power export.

Study Option 18—Evaluation of Hydropower Potential in Southern Sudan in Terms of Export to the Nile Equatorial Lakes Region

- **Background:** There is significant hydropower potential totaling about 2,000 MW on the White Nile between Juba and Nimoli. These have previously been studied at master plan level and both small-scale and larger projects have possible. These could be considered for development and supply of the Nile Equatorial Lakes region.
- **Scope:** Studies to define and assess the potential of hydropower projects suitable for development with the purpose of supplying the Nile Equatorial Lakes region.
- **Result:** Determining the technical feasibility and economic viability of hydropower projects in Southern Sudan in terms of export to the Nile Equatorial Lakes region.

Study Option 19—Evaluation of Hydropower Potential in Sudan in Terms of Export to Egypt

- **Background:** There are numerous sites with significant hydropower potential in Sudan; these could be developed to export power to Egypt.
- **Scope:** Studies to define suitable hydropower projects and evaluate their potential for power export to Egypt.
- **Result:** Determining the technical feasibility and economic viability of hydropower projects in Sudan in terms of export to Egypt.

Power transmission/system

Study Option 4—Power Transmission between Rwegura and Kigoma

- **Background:** A new 110 kV transmission line between Rwegura in Burundi and Kigoma in Rwanda has been proposed and terms of reference for a feasibility study have been prepared. If implemented, this project would result in a general strengthening of the Democratic Republic of Congo-East/Burundi/Rwanda grid, in which Rwegura is an important source of generation. This study option is illustrated in map IBRD 32744 at the end of this chapter.
- **Scope:** The scope can include the preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation of the project.
- **Result:** Determination of the technical feasibility and economic viability of the project.

Study Option 5—Interconnecting the Democratic Republic of Congo-East–Burundi–Rwanda Grid and the Tanzania Grid

- **Background:** As indicated in the previous chapter, an interconnection between these two grids might have operational advantages as well as enable more optimal planning of future generation projects, taking the size of some of these candidate projects into consideration. Another advantage could be that some of the load centers in northern Tanzania would be closer to the source of generation. A technical study for this interconnection was done in 1995 by Tractebel, which assessed its technical feasibility. This study was done in connection with the Rusumo Falls hydropower project and envisages interconnection among the Rusumo Falls power plant and Mwanza in Tanzania, Rwinkwavu in Rwanda, and Gitega in Burundi. This interconnection is illustrated in map IBRD 32744.
- **Scope:** The scope can include a reassessment of transfer capacity and voltage level, update of cost estimate, and an evaluation of technical

feasibility including system stability considerations and updated economic evaluation of the project.

- **Result:** Confirmation of technical feasibility and updated economic viability of the project.

Study Option 8—Power Transmission between Tanzania and Kenya

- **Background:** As indicated in the previous chapter, the generation expansion plan for Kenya is based largely on thermal power, including considerable diesel generation. Consequently net import of hydropower from Tanzania could be feasible if the price were competitive. The monthly distribution of river flows shows that the projects in Tanzania and the existing hydropower plants in Kenya to some extent are complementary, as the latter have two annual peaks—that is, high flows during October–December—when Tanzania is in its dry season. This is also important in terms of power exchange. The fact that the power markets of the two countries are the largest in the Nile Equatorial Lakes region could add extra benefits. A possible interconnection of the power grids in Kenya and Tanzania could therefore be of interest. This study option is illustrated in map IBRD 32744.
- **Scope:** The scope can be the preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the prefeasibility level.
- **Result:** Determining the technical feasibility and economic viability at the prefeasibility level.

Study Option 11—Increased Power Transmission Capacity between Uganda and Kenya

- **Background:** The generation expansion plan for Kenya includes, for the most part, thermal power including considerable diesel generation. Consequently net import of hydropower from Uganda might be feasible if the price were competitive. An important factor that makes it advantageous to have power exchange between Uganda and Kenya is the favorable monthly distribution of river flows from existing and future projects in Uganda. The flow of the Victoria Nile in Uganda is comparatively evenly distributed over the year whereas the flow in the Tana River in Kenya has two typical peaks, March through May and October through December.

  At present there is a 132 kV transmission line between the Tororo substation in Uganda and the Lessos substation in Kenya. With possibly increased future export from Uganda to Kenya the transmission facilities would need to be strengthened. This could apply to either the distance between Tororo and Lessos or more generally the facilities between Owen

Falls in Uganda and the Nairobi area in Kenya. This is illustrated as study options 11a and 11b in map IBRD 32744.

- **Scope:** The scope can be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the prefeasibility level.
- **Result:** Determination of technical feasibility and economic viability at the prefeasibility level.

Study Option 13—Benefits of Multipurpose Use of Reservoirs in Ethiopia

- **Background:** The unit cost of generation from the candidate hydropower projects in Ethiopia needs to be fully reevaluated. The costs are currently evaluated purely in terms of hydropower development and these cost data made available to the Consultant vary greatly. Multipurpose use of the water resources would add other benefits, offset the power generation cost, and possibly justify development of transmission facilities and power trade in the future.
- **Scope:** The study would analyze the economic value that can be assigned to a reservoir system that provides multiple benefits. These benefits could include flow regulation, hydropower; increased water availability for irrigation, water supply, and minimum flows; flood management; drought mitigation; and sediment management.
- **Result:** The analysis would provide economic input required for reassessing the upstream power projects in a multipurpose context.

Study Option 14—Power Transmission between Ethiopia and Sudan

- **Background:** Interconnecting the power systems in Ethiopia and Sudan may have its advantages. Sudan has a combined hydropower and thermal-based system, whereas the system in Ethiopia is hydropower-based. Interconnecting Roseires in Sudan with the power system in Ethiopia has been studied and found technically feasible without requiring major reinforcements of existing transmission facilities. It is, however, possible that the comparatively weak transmission line between Roseires and Khartoum also would need to be strengthened depending on the amount of power to be transmitted. An alternative could also be to have the connection point in Khartoum.

  According to that study, the advantages would be better utilization of surplus hydropower energy and flexibility in the timing of new generation capacity. An update of the study would be of interest for power trade. This is illustrated in map IBRD 32742 at the end of this chapter.

- **Scope:** The scope could be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the prefeasibility level.
- **Result:** Indications of technical feasibility and economic viability at the prefeasibility level.

  The unit cost of generation for the Ethiopian candidate hydropower project is very important for possible power trade in the Eastern Nile region and three study options have been proposed: Study option 12, which would assess these costs per se; study option 13, in which multipurpose aspects are regarded; and finally study option 11, in which power system advantages, which also may include hydro-thermal complementarity and possible redesign, are explored. These issues and studies are, of course, all related.

Study Option 15—Power Transmission between Ethiopia and Kenya

- **Background:** The transmission distance between these power systems is relatively long and a high voltage direct current (HVDC) transmission is likely. Preliminary analysis indicates that the project is not viable in given current power markets. If the amounts of power to be transferred are significant, however, this project could be economically viable in the future. Benefits could derive from net export of power from Ethiopia to Kenya, hydro-hydro complementarities, and general power system advantages. The project is illustrated in map IBRD 32743 at the end of this chapter. The connection points in the two power systems will, of course, be determined by power system analysis.
- **Scope:** The scope could be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the scoping level.
- **Result:** The economic viability is questionable in view of the current power markets. The study could, however, give indications of technical feasibility and economic viability with regard to future power markets.

Study Option 16—Power Transmission between Ethiopia and Uganda

- **Background:** The transmission distance between these power systems also is relatively long and a HVDC transmission is likely. Preliminary analysis indicates that the project is not viable given the current state of the power markets. If the amounts of power to be transferred are significant, however, this proposal could be economically viable in the future. Benefits could come from net export of power from Ethiopia to

Uganda, hydro-hydro complementarities, and general power system advantages.

The project is illustrated in map IBRD 32743. The connection points in the two power systems will, of course, be determined through an analysis of the power system.

- **Scope:** The scope can be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the scoping level.
- **Result:** The economic viability is questionable given the present power markets. The study could, however, determine technical feasibility and economic viability for the future.

Study Option 17—Evaluation of the Merowe Hydropower Project in a Regional Context

- **Background:** The Merowe hydropower project, which has a capacity of 1,250 MW, is included in the Sudanese generation expansion plan. The development and implementation of this project may have consequences for other power systems in the region. A preliminary evaluation of this impact could be of importance also in relation with the development of power systems in neighboring countries and future interconnections and power trade. A possible scenario could be that Merowe is interconnected first to the Egyptian grid and at a later point in time, to Khartoum. The project may also influence the possible Ethiopia-Sudan interconnection as described in study option 14.
- **Scope:** Studies to do a preliminary assessment of the possible effect of the Merowe hydropower project on power systems in neighboring Egypt and Ethiopia.
- **Result:** Determination of the effect of the Merowe hydropower project on the power systems in Egypt and Ethiopia.

Study Option 20—Power Transmission between Ethiopia and Egypt

- **Background:** This project would most likely be a HVDC transmission line, with a substation in Sudan included for the interconnection of this grid. With the current low-cost gas-fired power generation in Egypt, the profitability of this option would need to be illustrated. The analysis of this option would benefit from being evaluated in the context of multipurpose use of reservoirs in Ethiopia (see study option 13). The project is illustrated in map IBRD 32741 at the end of this chapter.
- **Scope:** The scope can be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic

evaluation at the scoping level. Multipurpose use of reservoirs in Ethiopia should also be taken into consideration.

- **Result:** Determination of technical feasibility and economic viability at scoping level.

Study Option 21—Power Transmission between Sudan and Egypt

- **Background:** This project, whose economic viability would depend on the development of the power system in northern Sudan, would most likely be a long HVDC transmission line from this area to, for example Aswan, in Egypt. The connection point in Egypt has to be determined through transmission system studies, however. The Merowe hydropower project is of specific importance in this regard. The project is in map IBRD 32741.
- **Scope:** The scope can be a preliminary assessment of transfer capacity and voltage level, preliminary cost estimate, evaluation of technical feasibility including preliminary system stability considerations, and economic evaluation at the scoping level. Several scenarios of power system development in Sudan and Egypt should be considered.
- **Result:** Determination of technical feasibility and economic viability at the scoping level.

Operation and communication

Study Option 3—Operation of the Democratic Republic of Congo-East/Burundi/Rwanda Grid

- **Background:** The Consultant's information on the operation and dispatch capabilities of this network is limited. It is known, however, that it has been in operation for a number of years, starting with the development of the Ruzizi I and Ruzizi II power plants. The operation of these power plants and the power exchange are based on their implementation agreements.

  Possible future generation projects such as the Rusumo Falls and Ruzizi III could be developed jointly. Another observation is that some of the possible future national development projects in the three countries may be somewhat large for development on a national basis, taking the sizes of their power systems into consideration. This need to increase power exchange between the three countries in the future emphasizes the importance of efficient operation of their common grid. Possibilities to complement a more flexible trade (rather than just a fixed sharing of the generating power) should be part of the project focus.
- **Scope:** The scope of work should include an assessment of the network's current status of operation and dispatch capabilities. This relates both to

technical facilities and the background and knowledge related to power exchange and trade of the operators in the national utilities. After this assessment further activities should be proposed. The potential benefits of introducing a more flexible trade should be evaluated.

- **Result:** The outcome would be a more suitable operational environment for power trade in the region. Thereafter power trade could be introduced and more economic use of existing facilities could be achieved. The same relates to the development of future generation projects in the subregion.

Study Option 22—Basinwide Assessment of Dispatch, Control, and Communication Capabilities

- **Background:** Specific projects or studies related to operation/communication have been difficult to identify given the limitations of a desk study. A more general assessment of such capabilities is therefore proposed for the entire region as this is an important step in laying the groundwork for efficient power trade.
- **Scope:** An assessment of the current status of operation and dispatch capabilities for the entire region. This relates both to technical facilities and the background and knowledge related to power exchange and trade of the operators in the national utilities. After this assessment further activities should be proposed.
- **Result:** The outcome would be a better understanding of the current status of dispatch, control, and communication capabilities for the Nile Basin countries in general. Thereafter further studies or activities could be proposed to possibly improve said capabilities, as more interconnection is developed among the countries and thereby brings the region closer to power trade.

Other studies

Study Option 6—Identification of Isolated Centers in Northern and Western Tanzania to Be Supplied from the Democratic Republic of Congo-East/Burundi/Rwanda Grid or from Uganda

- **Background:** UEB has recently started to supply one center in northern Tanzania. There are also plans to supply load centers in western Tanzania such as Kigoma, Uvinza, Kasulu, and Kibondo from the network in Burundi. The proposed transmission facilities for the supply of these centers are shown in map IBRD 32744. This proposal will also require new transmission facilities in Burundi; a study on this was completed in 1998.

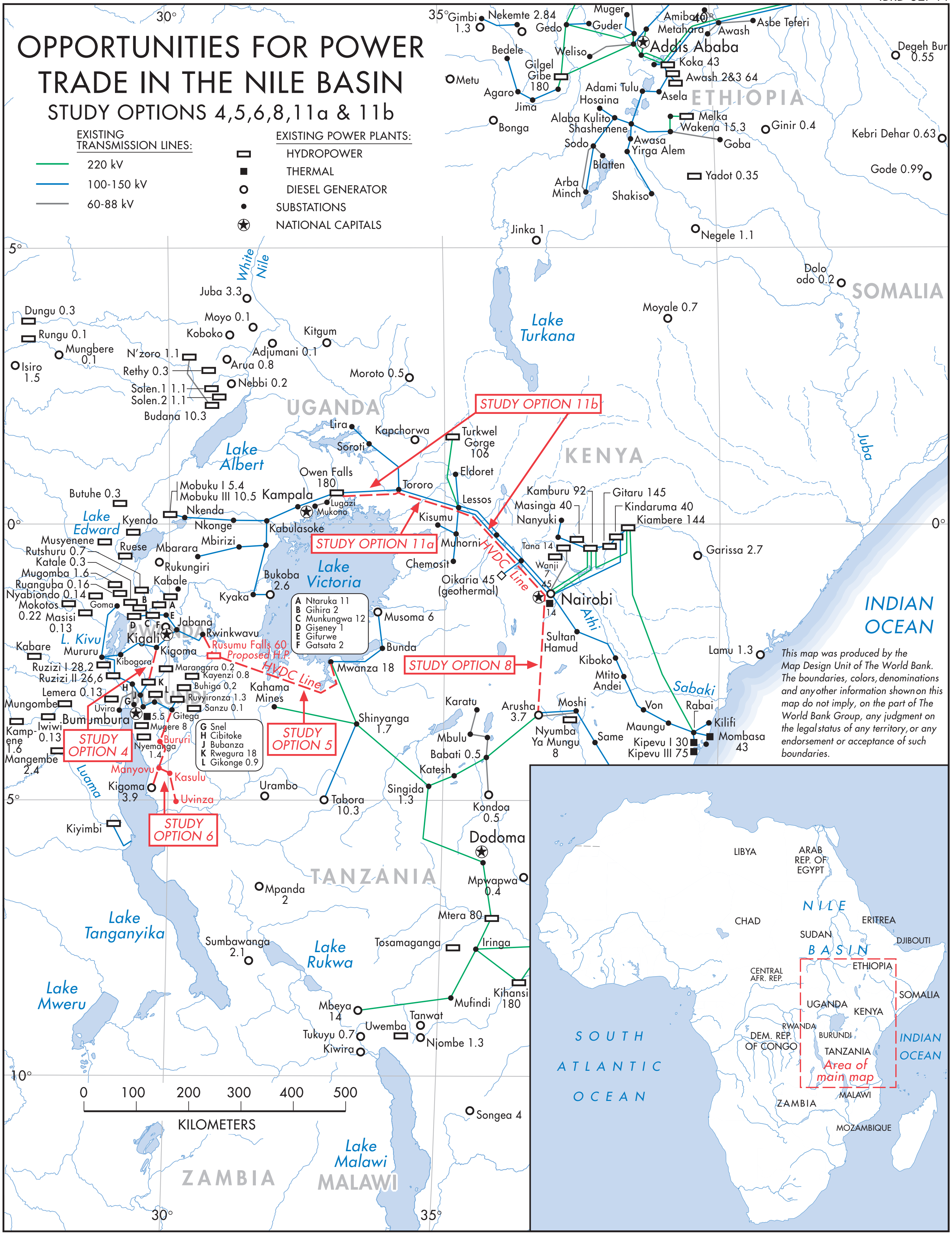
  If other isolated centers in northern or western Tanzania were served either by Uganda or from the Democratic Republic of Congo-East/Burundi/Rwanda grid, the network in the region would gradually develop. Future interconnection of the national grids might then be implemented at an earlier point in time, thus removing a barrier to power trade.

- **Scope:** Identifying isolated centers that could be supplied from the main grids mentioned above.
- **Result:** Possible replacement of diesel-generated power with hydropower and increased quality of supply for the centers. Another anticipated outcome is the development of transmission facilities in the area and better conditions for future power trade and general economic development.

Study Option 9—Market-Based Trade between Uganda and Kenya

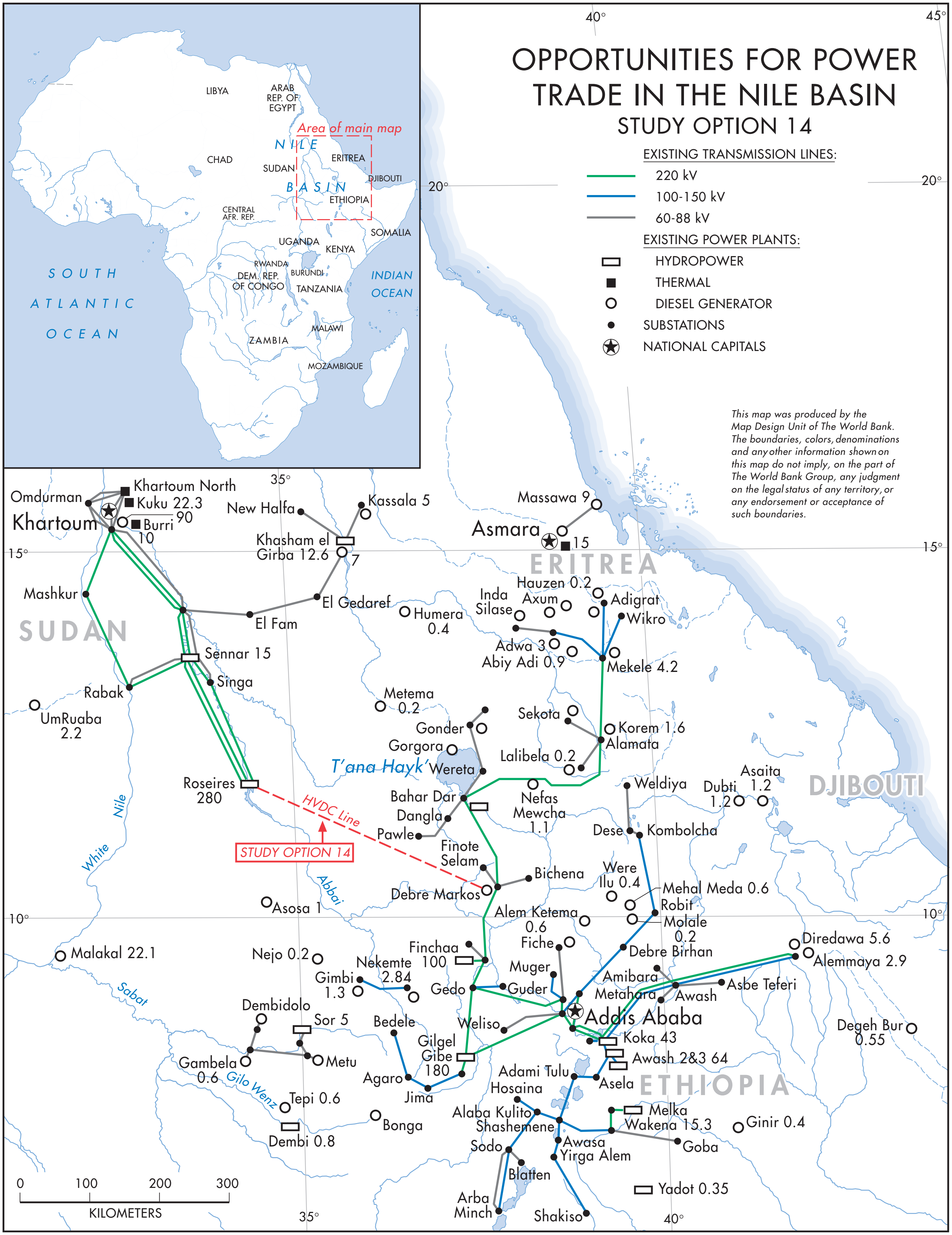
- **Background:** The current plan of deregulation in Kenya stipulates that KenGen will provide generation from its own installations and from power purchase agreements with independent power producers. A transmission company, KPLC, will buy power from KenGen and supply it to consumers. In this set-up there is scope for greater competition in distribution and thereby more efficient supply of electricity to consumers. In order to identify whether this proposal would contribute to trade, large industrial consumers of power in Kenya could be approached to assess their supply needs.
- **Scope:** A market survey is proposed to identify the willingness by large consumers in Kenya to buy power through directly negotiated supply contracts from neighboring countries. The survey would include the design of a survey and interviews with representatives of large-scale industries, KenGen and KPLC. A market mechanism with trading arrangements suitable for the local conditions should be worked out.
- **Result:** A report presenting the possibilities of developing a power market in which large-scale industries represent the early entrants. An outline of a possible framework for the market will be included with information on policy decisions, laws, and regulations required to implement greater competition in power supply through trade.

IBRD 32744



JANUARY 2004

IBRD 32742



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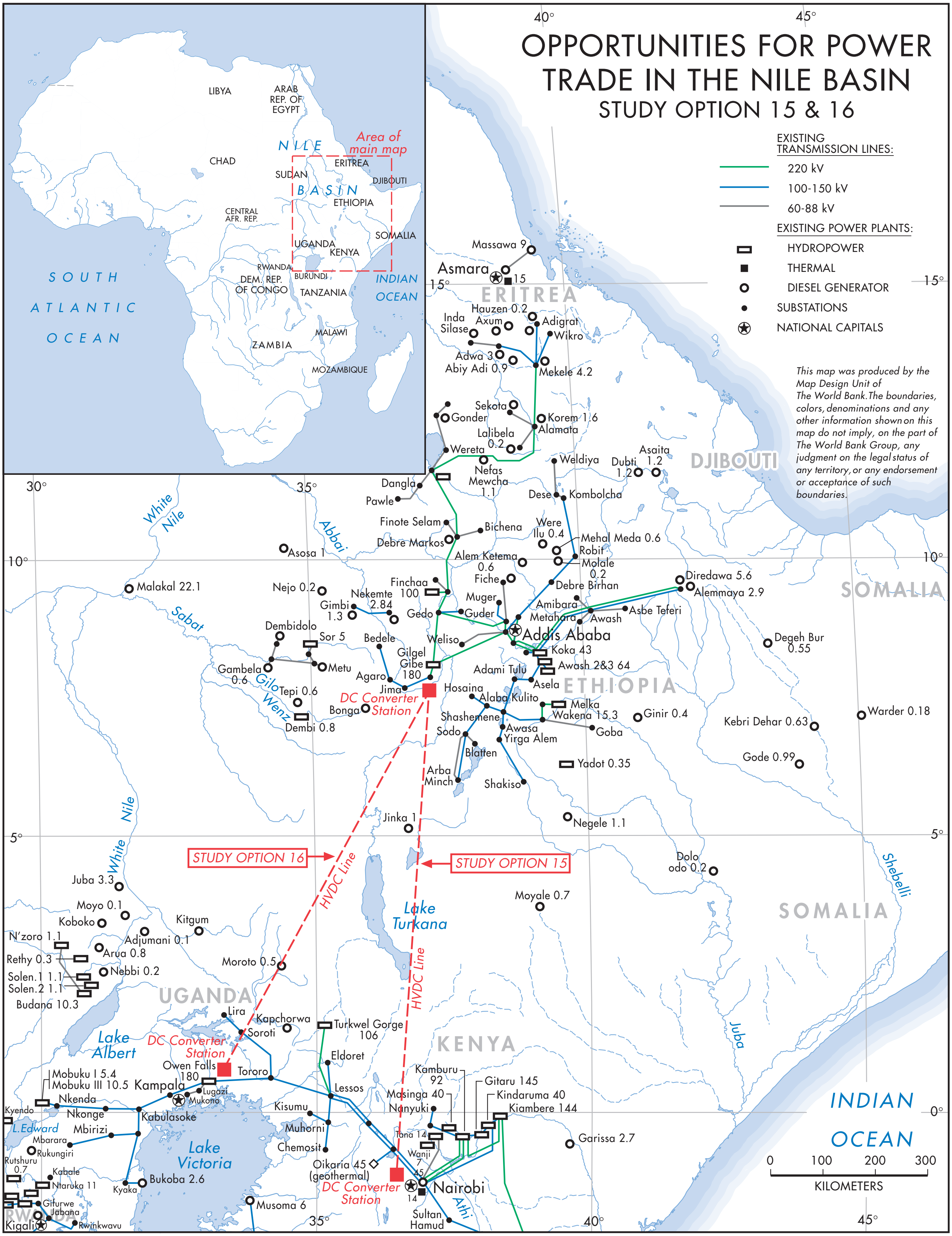

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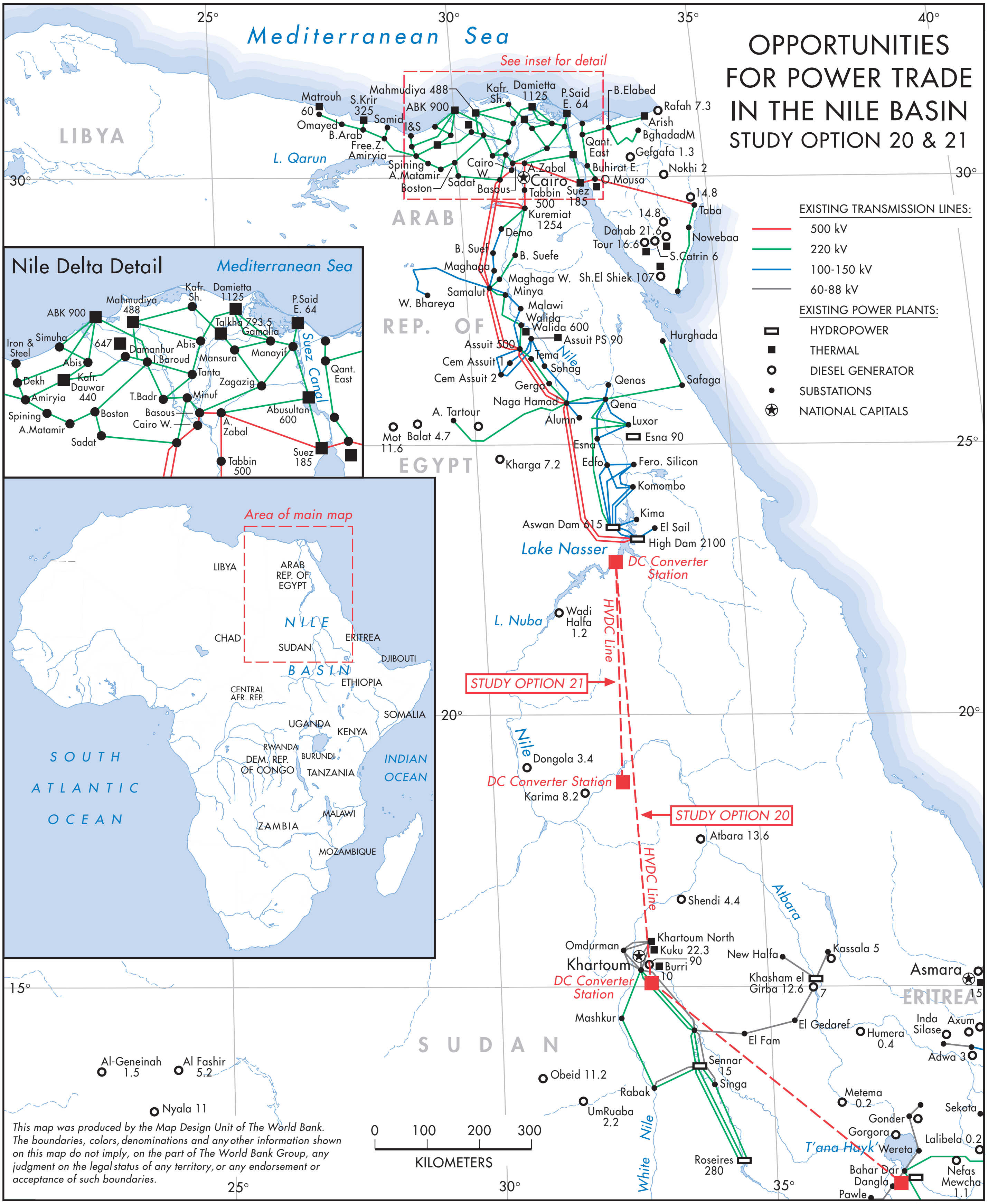
IBRD 32741



JANUARY 2004

4

Framework for Developing Power Trade in the Nile Basin

Summary of Main Findings and Options

4.1 The Nile Basin could be divided into two subregions—the Eastern Nile and the Nile Equatorial Lakes regions. At this time there is no international power trade in the Eastern Nile region comprising Ethiopia, Eritrea, Sudan, and Egypt. It is also important to note that there are no transmission facilities among the countries that could enable such trade.

4.2 In the Nile Equatorial Lakes region, which includes Democratic Republic of Congo-East, Burundi, Rwanda, Tanzania, Uganda, and Kenya, there is some power trade, but its level is rather modest. Hydropower from Uganda is an important element of this trade, which comprises export to Kenya and small amounts of electricity to isolated centers in Tanzania and Rwanda. This trade is characterized as bilateral trade between state-owned utilities.

4.3 There is also power export from Democratic Republic of Congo-East to Rwanda and Burundi, because the three countries have jointly developed two hydropower plants located in the Kivu province of Democratic Republic of Congo. It is understood from the reference documents that this export is based on agreements related to the implementation of the Ruzizi I and Ruzizi II projects.

4.4 Electricity demand in the Nile Basin countries, except Egypt, remains modest, ranging from 108 GWh per year in Burundi to 3,695 GWh per year in Kenya. The per capita consumption of electricity ranges from 18 kWh per year in Burundi to 53 kWh per year in Tanzania. Throughout the region, with the exception of Egypt, only 10 percent or less of the population has access to electricity. The demand in Egypt is about 56,500 GWh or about 15 times the corresponding figure for Kenya, and accounts for about 85 percent of total electricity consumed in the Nile Basin countries.

4.5 Electricity demand forecasts for the years 2005 and 2020 predict a total consumption of about 105,000 GWh and 241,000 GWh, respectively. These figures are about 70 percent and 280 percent higher than demand in 1999—which means considerable amounts of new power generation capacity will be required.

4.6 The energy resource endowment of the region is considerably greater than its foreseeable energy needs. The energy potential for electricity production alone is 1,000 TWh per year or equal to a sustainable generation for the next 40 years of almost 15 times the current level of generation in the area. Excluding Democratic Republic of Congo, which contains the huge energy potential of the Congo River basin, the power generation potential of the Nile Basin countries for about half a century is probably about 550 TWh/year, of which natural gas and hydropower represent approximately even shares of 40 percent each.

4.7 The potential benefits from power trade in the region are substantial based on the cost savings of meeting electricity demand from a combination of national sources and international exchange of power, as compared to meeting demand from domestic sources only. This was analyzed in detail in chapter 2. Several options considered important for future development of power trade were identified for future study in chapter 3 and are listed in table 4.1.

4.8 The findings presented in chapters 2 and 3 also indicate that power trade in the Eastern Nile needs to be evaluated in the context of a broader multipurpose approach to water resources development and management, as summarized below.

Water Resources and Power

4.9 A number of water resource and multipurpose elements can form the basis for the development of new projects or a revision of existing projects to reap benefits from regional power trade. Opportunities in this respect can be derived from some of the facts presented in chapter 2 of the draft data reports. Some examples of generic application of such concepts are summarized below:

Exploitation of the appreciable variation in evaporation throughout the Nile Basin

4.10 The Lower Nile and nearby areas to the north evaporate on average some 2.0 to 1.75 times as much water from open surfaces as the Ethiopian Highlands or the Lake Victoria Basin.[8] The Sudd apparently experiences average evaporation rates of about 0.7–0.8 times those of the Lower Nile and Khartoum rates and approximately 1.3–1.4 times the Lake Victoria rates. Water potentially saved annually in reduced evaporation by theoretically shifting storage reservoirs within the basin can be visualized, in a simplified fashion, per 100 km^2 open surface area as follows:

- From the Khartoum area to the Ethiopian Highlands: 0.15 km^3
- From Wadi Halfa (Lower Nile) to Lake Victoria: 0.12 km^3
- From the Lower Nile to the Sudd: 0.06 $km.^3$

[8] Illustrated by the simplified application of available evaporation rates listed in table 2.4 of draft data report.

Table 4.1: Study Options

No.	*Name*
1	Evaluation of the Ruzizi III Hydropower Project for future supply of the Democratic Republic of Congo-East/ Burundi/Rwanda Grid
2	Evaluation of the Rusumo Falls Hydropower Project for future supply of the Democratic Republic of Congo-East/Burundi/Rwanda Grid
3	Operation of the Democratic Republic of Congo-East/Burundi/Rwanda Grid
4	Power Transmission between Rwegura and Kigoma
5	Interconnecting the Democratic Republic of Congo-East/Burundi/Rwanda Grid and the Tanzania Grid
6	Identification of isolated centers in northern and western Tanzania to be supplied from the Democratic Republic of Congo-East/Burundi/Rwanda Grid or from Uganda
7	Assessment of benefits and ranking of hydropower candidate projects in Tanzania to increase power export
8	Power transmission between Tanzania and Kenya
9	Market-based trade between Uganda and Kenya
10	Assessment of benefits and ranking of hydropower candidate projects in Uganda to increase power export
11	Increased power transmission capacity between Uganda and Kenya
12	Assessment of unit cost of generation for Ethiopian candidate hydropower projects
13	Benefits of multipurpose use of reservoirs in Ethiopia
14	Power transmission between Ethiopia and Sudan
15	Power transmission between Ethiopia and Kenya
16	Power transmission between Ethiopia and Uganda
17	Evaluation of the Merowe Hydropower Project in a regional context
18	Evaluation of hydropower potentials in Southern Sudan in terms of export to the Nile Equatorial Lakes region
19	Evaluation of hydropower potentials in Sudan in terms of export to Egypt
20	Power transmission between Ethiopia and Egypt
21	Power transmission between Sudan and Egypt
22	Basinwide assessment of dispatch, control, and communication capabilities

4.11 The extreme theoretical illustration of these roughly estimated facts is that a reservoir in the Lower Nile with 1,000 km^2 open surface shifted to the Ethiopian Highlands would result in a yearly flow increase to the Lower Nile of about 1.5 km^3 or nearly 2 percent of the annual flow volume into Lake Nasser.

4.12 Another illustration of these estimates is provided by considering Lake Nasser draw-downs to reduce open water surface and thus evaporation losses. Simplified calculations suggest that each 5 percent reduction in surface area from full reservoir level would mean a flow increase downstream of nearly 1.0 km^3 per year or more than 1 percent of the annual flow volume arriving at Lake Nasser.

Exploiting seasonal variations in runoff within power-producing basins of the Nile Basin countries

4.13 This is best illustrated by comparing existing and potential hydropower basins in the three East African countries. The Tanzanian basins of Rufiji and Rumakali experience peak flows during December–May. The Kenyan basins of Tana and Ewaso Ngiro have their main high flow season coincidentally with the main peak of the Tanzanian basins, but an additional short rainy period occurs from October through January. The Victoria Nile in Uganda experiences a nearly constant flow with the lowest mean monthly flow at 80 percent of the highest mean monthly flow.

4.14 These considerable seasonal variations among basins of reasonable proximity open up a potential for power exchange that should benefit all three countries if fully exploited . A quantification of available power for trade during the various seasons and pricing regimes, considering both existing and planned power schemes, should yield interesting results. Such an analysis should internalize the valuation of environmental benefits (for example, avoided pollution and greenhouse gas emissions, biodiversity conservation, socioeconomic effects, regional development) to the degree possible in the given settings.

Taking advantage of multinational and multipurpose potentials of new reservoir schemes in the Ethiopian Highlands

4.15 Thus far these have been studied in a single-country, single-purpose context. Although dams have been assessed as relatively expensive, the terrain features enable deeper reservoirs with relatively low evaporative losses and offer potentials for sediment management. Dam sites need to be located with maximum concern for socioeconomic impact, where watershed management costs can be offset against regional development benefits. Renewed justification for such dam projects should come from downstream benefits that will accrue in a coordinated operation of the dams involved in the system. Benefits will theoretically derive from net reduction in evaporative losses by lowered reservoir levels downstream, when storage is shifted to the upstream highlands; flood control and drought mitigation; downstream low flow augmentation to better meet minimum flow requirements for water supply, irrigation, navigation, fisheries, aquatic ecosystems, and so on; improved sediment management through coordinated release schedules; and potentially improved water availability for irrigation and other benefits downstream. These benefit considerations can only be qualitatively described at this stage. The complex planning problems that may be formulated under such conditions lend themselves to review through systems analysis approaches for comprehensive treatment, but can be simplified by scrutinizing a few parameters at a time.

Win-win opportunities created by considering irrigation abstractions and cropping patterns in a more comprehensive context

4.16 Electrification of pumping schemes, shifts in cropping patterns, and improved water management have a high potential for yielding benefits in terms of fuel economics, agricultural economics, water availability downstream, and external environmental effects brought on by fuel switching and water conservation. Availability of power to electrify pumped irrigation on the White Nile and Jebel Aulia Reservoir could mean efficiency gains in energy and less dependence on high water levels behind the dam. Each 10 percent reduction in reservoir area from the full 1,500 km^2 level would theoretically add approximately 0.4 km^3 of annual downstream water availability or 0.5 percent of the annual flow volume.

Power Sector Reform

4.17 This section addresses the ongoing power sector reform efforts of the Nile Basin countries as a basis for a framework of regional power trade.

4.18 Information on power sector reform available in the source material of the study varied to a large extent. For some countries—such as Kenya, Egypt, and Uganda—the information was quite good. In other cases—such as for Burundi, Ethiopia, Tanzania, Democratic Republic of Congo, Rwanda, and Sudan—good updates have been made using information received directly from the respective countries. Based on the information available, the general impression is that all governments have embarked on power sector reform to improve efficiency in operation and the financial viability of the sector. In a few cases, such as Kenya, Uganda, and Ethiopia, the reform process appears to be well advanced.

4.19 The power sector deregulation models chosen are adapted to specific national circumstances. A common trend is that competition has been introduced or is being introduced in generation: independent power producers enter into license agreements with the government-owned power producer, which is normally the previously state-owned vertically integrated monopoly after unbundling and/or some reorganization.

4.20 National transmission companies with the possibility of open access have in most cases not yet been formed and transmission is taken care of by the government-owned power producer. In distribution, unbundling is at best in a very early stage. Thus, neither vertical and horizontal unbundling is much advanced. Division of responsibility among entities, overall supervision and policymaking, regulation, and operation are defined and implemented to a limited extent. Some of the Nile Basin countries have introduced or are considering the introduction of an independent regulator.

4.21 In general, therefore, deregulation of the power sector in the region is at an early stage. The restructuring efforts that are taking place are, however, moving developments in a direction that is conducive to increased regional power trade. The status of power sector reform in the region is summarized in table 4.2, based on the more detailed presentations made in the draft data reports.

Table 4.2: Status of Power Sector Reform in the Region

Country	*Maturity of the reform process*	*Regulator established*	*Independent power producers permitted*	*Transmission access*	*Market characteristic*
Burundi	The text of the laws ruling the power and drinking water sector is to be studied by Parliament in April 2000. The Government has already expressed its willingness to open the power sector to privatization.	Not yet.	Yes, very soon, after passing the necessary laws.	Not yet	Power is still exclusively sold by REGIDESO and DGHER, Burundi's government-run utility companies. These institutions distribute power right to the consumers' home.
Congo, Dem. Rep.	There is still no institutional reform. Production, transmission, distribution, and sales of energy is handled by the state-owned company, SNEL.				
Egypt	In progress since 1984. Several laws of deregulation introduced.	Under consideration (1997).	Yes (1996).		The power sector still operates much as a vertically integrated state company, but unbundling is in progress both in generation and distribution.

Table 4.2: Status of Power Sector Reform in the Region (continued)

Country	*Maturity of the reform process*	*Regulator Established*	*Independent Power Producers Permitted*	*Transmission Access*	*Market Characteristic*
Eritrea	Only policy statements of will to deregulate				Corporatization and privatization of the Department of Energy being discussed.
Ethiopia	In progress since 1997. Proclamation and regulation have been issued. Directives are under preparation.	Yes, operational since October 1998.	Yes.	Yes, by proclamation.	The State power utility, EELPA, has been corporatized and called EEPCo. Foreign and local private investors are allowed to invest in hydropower generation without capacity limit.
Kenya	The reform process in is now completed. The final step was the transfer of all public sector–owned power generating assets to KenGen and all the transmission and distribution assets to KPLC.	The Electricity Regulatory Board was established through the Electric Power Act 1997 and started operating in 1998.	Operation of independent power producers commenced with two power purchase agreements signed in 1996. Two independent power producer plants started operating in 1997. Two more power purchase agreements have since been signed.	There is no access as yet, although the governing legislation mentions that contracts for the transmission network services are to be approved by the regulator.	Previous monopolies in the public sector have been reorganized into generation, transmission, and distribution companies. Two independent power producer plants have been in operation since 1997, two power purchase agreement were signed in 1998, and another power purchase agreement is currently being negotiated.

Table 4.2: Status of Power Sector Reform in the Region (continued)

Country	*Maturity of the reform process*	*Regulator Established*	*Independent power producers Permitted*	*Transmission Access*	*Market Characteristic*
Rwanda	Preparation of information required to support the tender process for the selection of private sector operators for the sectors. Assistance given during the negotiations and signing of the agreements. The preliminary report is available.				
Sudan	Reform is in process since late 1998. The "Electricity Act" has been prepared for Government approval.	No, awaiting "Electricity Act" approval.	Yes, since 1996.	No.	The power sector still operates as a state corporation with unbundling in distribution, which is in progress. Independent power producers in generation are developing, even before the legal frame is approved.

Table 4.2: Status of Power Sector Reform in the Region (continued)

Country	*Maturity of the reform process*	*Regulator Established*	*Independent power producers Permitted*	*Transmission Access*	*Market Characteristic*
Tanzania	The Government has already made a decision to restructure the power sector to allow for private participation	Legal and regulatory framework is in process.	Yes.	Open access under an independent Transmission Systems Operator is expected.	A move toward more competitive markets in the electricity sector is in its infancy with some competition established in generation.
Uganda	A new Electricity law was enacted in November 1999.	Yes.	Yes.	Yes.	Ring fenced business unit within the transmission company will be responsible for bulk purchase and supply of electric power. In the longer-term, distribution companies and large consumers will contract generation capacity directly with generators. Introduction of limited retail competition will be in the medium term.

Note: Blank cells indicate that information is not available in the source material of this study.

Source: Power experts of the Nile Basin countries

4.22 The governments of the region express their policy on cross-border trade in energy only to a very limited extent. Some of the countries have international cooperation in electricity trade on a bilateral basis, notably Democratic Republic of Congo-East, Burundi, and Rwanda through the Great Lakes Economic Community (CEPGL); Kenya-Uganda; and Egypt-Libya. A few isolated areas in Tanzania and Rwanda are also supplied from Uganda. There is no information on clauses for wheeling of power.

Market Considerations

4.23 As reviewed in chapter 1, there are many considerations involved in establishing a well-functioning regional market in electricity. Such considerations can include coordination and joint efforts in policies; planning, financing, construction, and operation of generation and transmission facilities; power sector reform; and regulation including pricing of transmission, dispatch, and institutional arrangements, all within acceptable environmental parameters.

Policy Concerns

Regional organizations

4.24 Experience from other regions of the world shows that existing power markets have typically been set up under the umbrella of some recognized organization for economic development. This was the case with SADCC, established in 1980 on the basis of consensus decisions.

4.25 SADCC was initially a “loose” organization with the main objective of coordinating its nine member countries’ development efforts, primarily through definition of regional projects and joint efforts to finance them. In this, the Annual Consultative Conferences among officials from the member countries and the international donor community played an instrumental role. As the cooperation matured, SADCC was reorganized into tighter cooperation as a community, giving birth to SADC. Other examples of similar regional organizations are the European Union and Nordic cooperation (Nordisk Råd).

4.26 Such regional organizations can provide the initial forum required to launch the dialogue for regional cooperation. They provide a place where officials, donors, and the industry can meet and get to know each other. Step by step, common understanding and confidence is established that forms a basic condition for regional development.

4.27 Specific national policy initiatives and mandates to promote power trade do not yet exist in the Nile River Basin. These national policy mandates have proven instrumental in fostering cross-border trade in electricity. For example, in the SAPP Inter-Governmental Memorandum of Understanding, the Governments provide the utilities of the region with the mandate to trade power and to form the SAPP organization, as well as agreeing to promote power trade at the national level. The countries of the Mekong river basin are developing a similar policy mandate for their utilities. Such initiatives include the decision to establish a regional energy organization among governments and among power companies, where options for power trade can be analyzed, promoted, and approved or recommended to a specified decisionmaking body. Notably on technical issues, there is a need for the operators—the specialist experts in the power sector—to get together. This is probably key to moving regional power trade ahead, as the technicians are the ones with hands-on experience to assess the viability of power trade options. This is proven by the experience in the electricity subsector (that is, the technical meetings) of SADC and Nordel described in chapter 1. Cooperation at the technical level as well as the policy level, through what could be termed a "power forum," can therefore be expected to be a key instrument in advancing power trade in the Nile Basin region.

Policy on self-sufficiency in electricity supply

4.28 Studies of documents related to the energy sector or power subsector of the Nile Basin countries reveal that they all have self-sufficiency in power supply as a priority. If this were also the case with power trading, the countries would have to balance import with export over a period of time, for example a year. Trading could definitely be advantageous in this context alone, taking power system benefits such as security of supply and reduced reserve margins into consideration. However, if a certain degree of net import or dependency on neighboring countries were to be accepted, the fuller benefit of power trade in the region could be realized.

Harmonization of power sector reforms, particularly concerning power trade

4.29 Laws and regulations have to be adapted to the level of sophistication required for power trade, as discussed in chapter 1. International power trade can begin to operate where regulatory regimes differ; however, the creation of a well-functioning market typically requires consensus on certain key issues. These issues include the extent of deregulation in transmission and consequently transmission network ownership and operation, wheeling arrangements for transit of power, dispatch arrangements, and standardization of equipment, including the compatibility of communications equipment. At this point in time and the development of power trade in the region, no distinct proposal on these issues has emerged. However, the framework for moving forward already presented addresses these issues of harmonization and the possible role of a power forum in this respect.

Technical Concerns

Network development

4.30 Power system development projects identified to strengthen the physical infrastructure for power trade were presented in chapter 3. Some of these projects, which are expected to prove viable when studied, will establish the transmission capacities required to realize existing and near-term potential benefits of power trade in the region. An important technical limitation in these projects is the distances among some of the Nile Basin countries, specifically in the Eastern Nile region.

Planning

4.31 The projects include regional system planning studies by sub-basin to meet the early requirements in developing power trade, and the need to coordinate national planning initiatives by including regional considerations.

4.32 No transmission system analysis has been undertaken for the purpose of this scoping study. Problems with stability and voltage are likely to occur for the proposed projects, and have to be studied in detail at a later stage. The main cause of the problems is the length of the transmission lines and the fact that the existing transmission systems in the region are relatively weak. There are several ways to deal with this obstacle, as indicated below:

4.33 Traditional equipment such as shunt- and series capacitors is often used. Installation of power systems stabilizers on selected generators is also a well-known solution.

4.34 New technology such as flexible AC transmission systems could also be used. Today this equipment is relatively expensive, but it may be useful for satisfying the need for increasing power transmission in the future, even between weak power systems.

Dispatch

4.35 The dispatch and communication arrangements required to facilitate power trade in the region will depend on the extent and viability of alternative options for regional power trade. Currently the limited amount of cross-border transmission minimizes the need for uniform operational arrangements.

4.36 In general, adequate dispatch capabilities are an important factor for power trade. This relates generally both to regional utilities within a national power market and to national utilities in an international market. However, with the present structure of the power industry in the region in mind, this will in most cases be a matter for the national utilities. The activities indicated below could be undertaken and prepared by power utility personnel well in advance of actual trading. The list is quite detailed to reflect the importance of a compatible and reliable network infrastructure for power trade. In some cases, there would be a need for training before or assistance during the implementation of the activities.

Identifying grid capacity

4.37 This could encompass the following:

- Establish single-line diagrams and update the Nile Basin Grid map;
- Collect equipment capability information, including ratings, impedances, governor models, temperature limits, and so on;
- Define equipment connections at and between system nodes and identify limiting equipment ratings; and

- Define binding transfer capability limits for import/export based on transmission capacity.

Defining quality requirements

4.38 Discuss and quantify power system requirements such as the following:

- Acceptable frequency deviation during normal operation;
- Time deviation;
- Frequency bias; and
- Frequency control reserve.

Emergency plans

4.39 This will include discussion and agreement on procedures in case of outages and other unforeseen events.

Maintenance coordination

4.40 This could include the following:

- Preparation and coordination of generation and transmission outage plans; and
- Power system analysis.

4.41 Other matters, more closely related to the daily dispatch and trading itself, are listed next.

Generation and demand forecast

4.42 This may include the following:

- Prepare demand forecasts for the next day depending on weather conditions and the like;
- Work out a generation schedule for all generators in the network; and
- Prepare the generation/demand forecast for the next day and check the balances.

Online power system control matters

4.43 The following should be considered:

- Coordination and approval of outages; and
- Supervision of voltages, currents and power transfer, frequency, and so on.

Institutional Concerns

Existing power trade organizations

4.44 With the exception of the cooperation among Democratic Republic of Congo-East, Burundi, and Rwanda through the CEPGL and SINELAC, there is no interregional organization for power trade among the Nile River Basin countries. The limited amount of bilateral trade in electricity that takes place is handled by state-owned power utilities, notably UEB of Uganda and KPLC of Kenya. Regional energy cooperation also takes place in the East African Community under whose auspices an interconnection study is being undertaken.

Institutional capacity

4.45 The institutional capacity and capabilities available to handle power trade cannot be assessed with a great degree of certainty from the source material of this study. However, indications are that the power companies/utilities of the region as a whole have limited expertise in power trade. The legal frameworks, power trade agreements, market operation, and so on are generally not in place. Most probably there is a need to train personnel in the power subsector of the Nile Basin countries, in order to establish an enabling environment for power trade.

Regional operation protocol

4.46 Such a protocol is required to govern the operation of a regional transmission network (see the list of technical grid requirements above). The protocol would include detailed requirements related to the planning, design, and operation of an interconnected transmission system.

Commercial Concerns

Pricing of transmission services

4.47 Transparent pricing of electricity promotes the development of a power market. (see chapter 1). Transmission services need to be priced separately and without cross-subsidy between generation/distribution and transmission. Because transmission is a “natural” monopoly, this requires restructuring, either by unbundling transmission from generation and distribution or through accounting principles. This has to be coordinated in cross-border power trade and puts demand on the harmonization of national power sector restructuring arrangements dependent on the sophistication in power trade. A regulator will be needed to prevent unreasonable transmission and distribution pricing.

Cost of supply

4.48 The review of existing data on generation and transmission underscores the difficulties in identifying the actual costs of electricity supplies in the region. In practice, such information is not in the public domain. Consequently the actors in the market face a difficulty in identifying the cheapest sources of supply and cannot easily exploit them. A transparent market with information on the cost of electricity supplies to all actors is therefore required to fully realize the potential benefits of trade. The current situation with only limited information on the costs of supply is thus a barrier to the development of regional markets and trade in electricity.

4.49 Supply monopolies, which still prevail in many countries of the region, also contribute to obscuring the costs of supply. Furthermore, market concentration in supply is an obstacle to free competition. Information available in the source material of this study makes it clear that there is a need to further reduce the market dominance of the state-owned, vertically integrated power supply monopolies—which would lead to supply competition in supply and in turn, probably, to more efficient supply at lower cost to the end-users.

Political risk mitigation

4.50 Political risk is carefully considered by private investors. In order to attract private finance for large-scale, cost-efficient power projects in the region, which almost in every case requires a cross-border market in order to become competitive, the political risk should be manageable. Well-functioning regional organizations supported by the host governments could provide some comfort to investors by reducing the political exposure.

Creating markets

4.51 The domestic electricity markets of the Nile Basin countries are small compared to the potential output of the most cost-efficient power generation proposals the region. The lack of a sufficiently large market with purchasing power for electricity is thus a key constraint to cost-efficient development of both hydropower and gas-fired thermal power generation. Power trade could contribute to overcoming this obstacle by pooling the demand in two or more countries for supplies from the least-cost supply alternatives in a regional context. Open access to the transmission network could facilitate such power trade, for instance if large consumers in Kenya could purchase power from the lowest bidder in Uganda and have the power transmitted under transparent and regulated pricing of the transmission services. This idea could be discussed as an example of creating power markets in the power forum, if established.

Investment climate

4.52 Most of the country risks present in large-scale energy projects in the region also apply to possible cross-border projects. Such risks include lack of energy laws and regulations and the capacity to enforce them, currency nonconvertibility, insecure purchasing power of the electricity buyer, potential interference by governments, and breach of contracts or concession agreements. Again, a regional organization could assist where such issues of importance to regional projects can be addressed and solutions to them proposed for action by the host governments.

Environmental Concerns

4.53 Regional power trade in the Nile Basin carries with it potentials and opportunities that have an effect on the environment. Some of these are briefly discussed below.

Project siting

4.54 New hydropower schemes should be located away from environmentally harmful project sites (to avoid, for instance, infringement on national parks and wetlands, resettlement problems, serious biodiversity losses, and so on). Site selection should give due credit to benign sites where environmental impacts can be mitigated such as run-of-river schemes, sites with minimal ecosystem and sociocultural losses, sites that have watershed management integrated with the project, and the like.

4.55 An environmental screening exercise to flag undesirable sites where unmitigable impacts may form clear obstacles to project development would be desirable. Screening parameters should include issues such as avoiding the following:

- Proximity to or encroachment on national parks;
- Wetland impacts;
- Inundation of major biomass (carbon storage) resources;
- Biodiversity reduction;
- Forced resettlement; and
- Other impacts of a more site-specific nature.

Fuel switching

4.56 A host of environmental benefits may be realized by substituting coal/oil/gas-fired thermal generation plants—which emit SO_2 NO_x, particulate matter, and CO_2 and thereby add to local pollution, regional acidification, and global warming threats—with environmentally benign hydropower.

Offsetting land degradation

4.57 The substitution of wood fuel dependency and its potential watershed degradation effects with hydropower-based rural electrification that incorporates watershed management has several environmental effects. Among other things, it reduces local pollution and health problems, limits greenhouse gas emissions, abates land degradation, mitigates flash flooding, and affects downstream sedimentation. Benefits can be substantial in downstream reaches and should be credited to upstream projects if sediment loads are diminished and low-flow augmentation combined with flood peak reduction result.

Multipurpose planning

4.58 New hydropower schemes should be designed to incorporate contemporary concepts of multipurpose planning and environmentally sound design concepts such as the following:

- Seeing relocation from a developmental perspective and making it voluntary, based on affected people's ability to share in benefits;
- Creating hydraulic structures that incorporate water quality and sediment management techniques such as selective withdrawal at high dams, sediment sluicing, minimum releases based on well-researched in-stream flow requirements, releasing simulated natural flow and water quality conditions, and the like; and
- Internalizing upstream watershed management and agroforestry and agricultural community development in hydropower schemes.

4.59 By internalizing the valuation of such environmental factors in the economic analysis of hydropower schemes, their chances of acquiring a feasible status will increase and win-win scenarios may result.

Environmentally sound planning

4.60 The listed environmental premises for power trade in the Nile Basin suggest that efforts should be spent on screening potential hydropower sites for "environmental soundness features" comprising potential opportunity elements such as the following:

- Run-of-river potentials;
- Reservoir schemes that can serve sediment and water quality management roles;
- Schemes in social settings where relocation may be made voluntary; and
- Schemes in areas where regional development and combat against land degradation can be aided.

Framework for Moving Forward

4.61 It would be too ambitious to forecast a specific long-term structure for power trade among the Nile Basin countries. However, some ideas on how to move forward are presented below for review and discussion by representatives of the power sector in the region.

Development of mutually acceptable forms of power trade

4.62 In order to materialize, power trade in the Nile Basin depends on consensus among the participating countries and agreements by governments to embark on and encourage power trade. Tighter economic cooperation, such as common markets or communities, can only be envisaged in the very long-term perspective.

4.63 Once initial consensus has been reached, a next step in clarifying the potential benefits of greater trade of electricity in the region is to assess the results of this desk study and agree on a framework of cooperation. This would involve policy decisions to define how power trade could be promoted under the Nile Basin Initiative, which provides a framework to promote joint economic development among the Nile Basin countries. In this vein, important issues that would likely be presented and further discussed and agreed at a policy level, possibly in an Energy Ministers Meeting (as in the case of SAPP), include the following:

- Regional trade policy that meets priorities in supply reliability;
- Framework of cooperation;
- Institutional forum mechanism to continue dialogue (see the subsection on power forums below);
- Regional projects of mutual interest to develop power trade;
- Project promotion and financing; and
- Data availability, collation, and presentation.

Incremental evolution of power trade

4.64 Models of power trade differ from region to region when international exchange of power takes place. In all cases, it has taken a long time to develop the power trade, and the development has gone through phases from a single-buyer market through third-party access and open access to competitive markets. In general, solutions applied have historic reasons as well as reflecting natural conditions and advances in technology, including recent computer and communication innovations that facilitate operation of competitive power markets (for instance, spot, term, and financial power trade markets).

4.65 For the Nile Basin countries, the challenge is to establish a framework of power trade that is adapted to their specific situation and future developments as they can be envisaged from the presentation in chapter 2. In this, experience from other regions can be utilized, and adapted to fit regional circumstances.

4.66 An evolution of international electricity markets also can be envisaged for the region, where power trade matures with the overall economic development and the ongoing restructuring of the electricity sectors.

Subregions

4.67 The pace and character of developments could possibly differ in the two subregions of the Nile River Basin, as defined in chapter 3. In the Eastern Nile region power trade could, for instance, start out with bilateral trading between national utilities. Gradually, it could mature with the unbundling of utilities and more decentralized trading patterns, depending on the development of the power sectors in the countries concerned.

4.68 The specific trading regimes that are conducive to the Nile Equatorial Lakes region will start from the bilateral trade under the one-to-one seller/buyer regime that takes place among state power utilities. As power sector reforms materialize in the subregion, the power trade regime could possibly mature quite quickly into a loose pool with close cooperation among independent state-owned transmission system operators. Coordination in dispatch, technical standards, and regulation of transmission prices would then have to be included. Eventually, a competitive market in subregional power trade might materialize.

4.69 The Direct Current links identified could possibly be developed in the private sector under Special Purpose Companies, a solution that could prove feasible when the time comes to implement the projects in the distant future.

4.70 In the longer-term perspective, these subregional markets might be merged into a regional interconnected market of all the Nile Basin countries.

Power forums

4.71 As already mentioned, the region would benefit from a regional mechanism, referred to here as a power forum, which could address all aspects of power trade, including institutional, legal, technical, economic, financial, and environmental issues of relevance. The institutional arrangements for a forum would need to be developed based on the objectives and functions desired by the Nile Basin countries. The forum could range from an informal technical organization to a more structured organization with technical and policy levels; one possibility is outlined below.

4.72 A power forum could serve as a body for cooperation among system operators—in other words, the technical personnel from the region's power companies. The forum could include representatives from state-owned utilities, independent power producers, transmission and distribution companies, and large consumers. Experience in power trade in the region could be included through representatives of CEPGL and SINELAC.

4.73 The power forum could act as the secretariat for meetings of the Energy Ministers. To this end, it could present recommendations for decision by the Energy Ministers and arrange their meetings.

4.74 The types of issues that could be addressed by the power forum could include, but are not limited to, the following:

- Preparing projects to be promoted through the International Consortium for Cooperation on the Nile (ICCON) for financing and implementation;
- Regional energy policy;
- Power system regulation and reform in the context of regional markets;
- Power system planning;
- Human resource development requirements;
- Environmental opportunities and constraints; and

- Relationships with other institutions (national and regional institutions and the donor community).

4.75 The power forum would be designed to benefit all participating countries in the Nile Basin. The idea would be to draw on both local and international expertise to tailor solutions to the specific conditions in each country. The development of a framework to facilitate regional power trade would form an integral part of this effort. Based on a review of the power trade potential and the status of power sector reform in the Nile Basin countries, the Consultant believes that there is a need to exchange views on the alternative models of power sector reform to see how the national initiatives are, or could be designed to be, conducive to promoting international power trade in the region. If the Nile Basin countries are interested in pursing increased levels of power trade, the types of issues of regional concern that could be addressed and coordinated regarding power sector reform include the following:

- Compatibility of existing deregulation efforts with regional power trade requirements;
- Network standards;
- Dispatch and communication arrangements;
- Regulation, notably pricing of transmission services;
- Agreements for international trade;
- Dispute resolution arrangements; and
- Wheeling arrangements.

4.76 Other issues that could be addressed by a power forum relate primarily to (a) the planning and operation of power systems and (b) the financing/implementation of projects such as the following:

Power system planning and operation

- Load forecasts and generation/transmission planning (least-cost regional expansion);
- Generation and transmission projects for system expansion (investment programs); and
- Requirements for a secure interconnected system operation and control.

Project financing/implementation

- Exchange of experience in project promotion (financing; contracts; contacts with investors, banks, contractors, suppliers, and so on); and
- Conferences/meetings with investors, donors, and others to promote and secure financing of regional projects.

4.77 Subregional power forum meetings might prove more efficient than regional ones as some of the questions to be addressed would be of particular interest to a few of the countries with power trade and not to the others. However, in discussions on models and modes of power sector reform, a common interest in harmonization exists and all member countries stand to benefit from and contribute to successful power trade in the region.

4.78 In human resource development, a power forum could explore ways of using the existing national institutions for regional training.

4.79 A power forum could also contract regional power system studies as agreed, for instance those given priority from the study options defined in chapter 3 and discussed as 'Next Steps' below. For this purpose, the organization would need to have a budget provided by host governments and foreign contributors, private and public sources, or possibly the companies that are participants in the forum.

Evaluation and prioritization of power trade development options

4.80 A review of the study options identified in this study would clarify whether the proposed regional initiatives meet the national priorities and whether there are additional options that should be considered. This type of evaluation and prioritization would need to be made by the Nile Basin country governments themselves.

Next Steps

- Developing policy consensus
- Developing a strategy framework for moving forward
- Establishing a power forum
- Conducting further studies
- Reviewing study options for the purpose of promoting power trade

Conclusion

4.81 This final scoping study shows that based on the hydropower resources of the Nile, significant opportunities for competitive electricity generation exist in combination with international power trade.

4.82 To exploit this potential, a specific challenge for the Nile Basin countries is establishing a framework of power trade that is adapted to the specific characteristics of the region.

4.83 An incremental evolution of power trade in the Nile Basin can be envisaged in which power trade matures with the overall economic development and the ongoing restructuring of the electricity sectors in the region. The speed and sophistication of development in electricity exchange may vary by subregion.

4.84 A number of policy issues need to be addressed in order to advance power trade in the region. Such issues include the policy on regional trade, framework of cooperation, establishment of a mechanism to continue regional dialogue through a power forum, regional electricity projects, and the availability of national data for regional planning and implementation of projects.

4.85 Cooperation in power trade in the Nile Basin will need to be based on regionwide consensus. Once this has been reached, a next step in clarifying the potential benefits increasing regional electricity trade is assessing the results of this desk study. The four main proposals to start the consensus-building process are as follows:

- Establish a policy consensus to promote power trade in the Nile Basin region;
- Establish a power forum;
- Advance the scoping study; and
- Identify, at a preliminary level, priority projects to be considered within the NBI's two subsidiary action programs (for the Eastern Nile and the Nile Equatorial Lakes regions).

Appendix 1

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Multinational	Energy Statistics 1995–1996: Electricity production, TWh.	1997
Multinational	Energy Statistics 1995–1996: Electricity production from fossil fuels, TWh.	1997
Multinational	Energy Statistics 1995–1996: Electricity Consumption by end use, GWh.	1997
Multinational	Energy Statistics and Balances of Non-OECD countries.	1997
Multinational	Power Sector Reform and Efficiency Imptovement in Sub-Saharan Africa.	1995
Multinational	ESMAP Annual Report 1998.	1999
Multinational	International River Basin Organizations in Sub-Saharan Africa.	1994
Multinational	Agreement Uganda/Rwanda (Newspaper Article).	1999
Multinational	A Decision Support System for the Nile River. Georgia Technical University.	1999
Multinational	Future Coal Prospects, Country and Regional Assessments. Wocol World Coal Study.	n.d.
Multinational	Water and Agriculture in the Nile Basin. Background Paper Prepared by FAO.	1999
Multinational	Development of Regional Electric Power Network; UNDP/World Bank.	1994
Multinational	Impact of Power Sector Reforms on International Electricity Trade; UNDP/ESMAP.	1996

Appendix 2

Energy Potential and Balance of the Nile Basin Countries

Table A2.1: Energy Resources (in physical units)

	Burundi	*Congo, Dem. Rep.*	*Egypt*	*Eritrea*	*Ethiopia*	*Kenya*	*Rwanda*	*Sudan*	*Tanzania*	*Uganda*	*Total*
					Commercial						
Hydropower (MW)	300	100,000	2,810		30,000	1,400	115	5,100	4,700	2,000	146,425
Oil (106 TOE)		37	522					65	0	0	624
Natural gas (109 Sm3)		51	1,135		114		51	80	45	0	1,475
Coal (106 Tons)		50	27		15				350		442
Geothermal (MW)					700	1,050	340			450	2,540
					Traditional						
Woodfuel (106 m3)	13	25,000					74	12	1,800	1,190	28,090
Crop residue (106 m3)	0						49		15	230	295

Notes: Oil, natural gas, and coal—data in the source material on reserves are limited and often sparsely specified. When available, recoverable reserves have been used. Methane (including coal bed), oil shale, and tar sands are not included

Sources: National energy experts or Ref.6.13

Table A2.2: Commercial Energy Potential (GWh/yr)

	Burundi	*Congo, Dem. Rep.*	*Egypt*	*Eritrea*	*Ethiopia*	*Kenya*	*Rwanda*	*Sudan*	*Tanzania*	*Uganda*	*Total*
Hydropower	1,314	438,000	18,462	0	131,400	6,132	504	22,338	20,586	8,760	647,495
Oil a)	0	4,082	58,373	0	0	0	0	7,269	0	0	69,723
Natural gas b)	0	8,176	181,568	0	18,160	0	8,096	12,800	7,264	0	236,064
Coal c)	0	3,700	1,998	0	1,110	n.a.	0	0	25,900	0	32,708
Geothermal d)	0	0	0	0	4,599	6,899	2,234	0	0	2,957	16,688
Total											1,002,678

Notes: a) 40 years depletion period and thermal plant efficiency of 35%, that is, conventional oil steam power plant.
b) 40 years depletion period and thermal plant efficiency of 58%, that is, modern combined cycle power plant.
c) 40 years depletion period and thermal plant efficiency of 33%, that is, coal steam power plant.
d) 75 percent load factor assumed.

Table A2.3: Developed Commercial Electricity Generation

	Burundi	*Congo, Dem. Rep.*	*Egypt*	*Eritrea*	*Ethiopia*	*Kenya*	*Rwanda*	*Sudan*	*Tanzania*	*Uganda*	*Total*
Hydropower	120	0	10810		1145	3295	0	1074	1748	805	18,997
Petroleum products	8	0	21352		103	355	0	989	0	0	22,807
Natural gas	0	0	25399		0	0	0	0	0	0	25,399
Coal	0	0	0		0	0	0	0	0	0	0
Geothermal	0	0	0		68	390	0	0	0	0	458
Total thermal	8	0	46,751		171	745	0	989	0	0	48,664

Source: Country reports (hydropower); Energy balances of ICCON Member States (hydrocarbons and geothermal).

Table A2.4: Utilization of Potential (Generation as Share of Potential [%])

	Burundi	*Congo, Dem. Rep.*	*Egypt*	*Eritrea*	*Ethiopia*	*Kenya*	*Rwanda*	*Sudan*	*Tanzania*	*Uganda*	*Total*
Hydropower	9	0	59		1	54	0	5	8	9	3
Petroleum products		0	37					14			33
Natural gas		0	14		0		0	0	0		11
Coal		0	0		0				0		0
Geothermal					1	6	0			0	3

Appendix 3

Nile Basin Countries' Generation Expansion Plans

Table A3.1: Burundi Future Generation Expansion

Year	*Project name/type*	*Installed capacity (MW)*	*Average energy prod. (GWh)*	*Firm energy prod. (GWh)*	*Total system energy (GWh)*		*Total system capacity (MW)*	
					Required	*Surplus*	*Required*	*Surplus*
2000		49	193.2	145.9	143.8	49.33	27	22
2001	3rd unit Ruzizi II	53.43	219.2	171.9	160.7	58.5	30.6	22.6
2002	-	53.43	219.2	171.9	170.1	49.1	32.4	21.03
2003	Doubling of Nyemanga	54.83	231.4	184.1	172.7	58.7	33	21.83
2004		54.83	231.4	184.1	178.8	52.6	34	20.83
2005		54.83	231.4	184.1	185.2	46.2	35.3	19.53
2006		54.83	231.4	184.1	189.2	42.2	36	18.83
2007		54.83	231.4	184.1	196	35.4	37.3	17.53
2008	Mpanda	65.2	261.4	214.1	203.2	58.2	38.6	26.6
2009		65.2	261.4	214.1	210.9	50.5	40.1	25.1
2010		65.2	261	213.7	221.7	39.7	42.2	23
2011	Kabu 16	82.2	363.4	265.9	233	130	44.3	37.9
2012		82.2	363.4	265.9	245.5	117.9	46.7	35.5
2013		82.2	363.4	265.9	258.7	119.7	49.2	33
2014		82.2	363.4	265.9	272.8	90.6	52	30.2
2015		82.2	363.4	265.9	287.8	75.6	54.8	27.4
2016		82.2	363.4	265.9	304	59.4	57.8	24.4
2017		82.2	363.4	265.9	321	42.4	61	21.2
2018	Mule 34	94.7	435.4	299.9	340	95.4	64.7	30
2019		94.7	435.4	299.9	360	75.4	68.5	26.2
2020		94.7	435.4	299.9	381.6	53.8	72.6	22.1

Table A3.2: Burundi Future Generation Expansion (High Scenario)

Year	*Project Name/Type*	*Installed Capacity (MW)*	*Average Energy Prod. (GWh)*	*Firm Energy Prod. (GWh)*	*Total System Energy (GWh)*		*Total System Capacity (MW)*	
					Required	*Surplus*	*Required*	*Surplus*
2000		49.00	193.2	145.9	143.8	49.33	27.0	22.00
2001	3rd unit Ruzizi II	53.43	219.2	171.9	160.7	58.50	30.6	22.60
2002		53.43	219.2	171.9	170.1	49.10	32.4	21.03
2003	Doubling of	54.83	231.4	184.1	172.7	58.70	33.0	21.83
2004	Siguvyaye	144.80	717.4	670.0	404.8	312.00	77.0	67.80
2005		144.80	717.4	670.0	409.3	308.00	78.0	66.80
2010		144.80	717.4	670.0	439.0	278.00	83.5	61.30
2015		144.80	717.4	670.0	510.0	207.00	97.0	47.80

Table A3.3: Democratic Republic of Congo-East Generation Projects Envisaged for the SNEL Development Plan

Hydro	*Thermal*
Province Orientale	
Rehabilitation of Tshopo (18.8 MW)	Rehabilitation of Tshopo (12 MW)
Rehabilitation of Budana (13.5 MW)	Rehabilitation of Buta (0.52 MW)
Bengamisa (15 MW)	Bondo, Basoko, and Bafwasende
Nepoko (10 MW)	
North Kivu	
Mungomba (40 MW)	None
Semiliki (28 MW)	
South-Kivu	
Rehabilitation of Ruzizi I (40MW)	None
Ruzizi III (82 MW)	
Maniema	
Kamimbi (7.5 MW)	Kindu: installation of a 1,350 kVA unit (temporary solution)
	Kasongo: installation of 1,000 kVA unit
	Kimbombo: installation of a 350 kVA unit
	Kabambare: installation of a 250 kVA unit
	Lubutu: installation of a 250 kVA unit

Table A3.4: Egypt Demand Forecasts

Demand—Category or Area No.	*2000/ 01*	*2001/ 02*	*2002/ 03*	*2003/ 04*	*2004/ 05*	*2005/ 06*	*2006/ 07*
Demand Total GWh Domestic	66,152	70,979	75,940	81,046	86,322	91,764	97,462
Peak	12,470	13,322	14,156	15,040	15,897	16,786	17,670
Export (GWh)							
Losses (GWh)	13,001	13,488	13,965	14,446	14,852	15,239	15,593
Required generation (GWh)	78,652	83,909	89,407	95,257	100,964	106,904	112,993

Table A3.5: Egypt Required Capacities before 2004

Plant Name	*Capacity (MW)*	*Type of Technology*	*Commission Year*
Sidi Krir (1,2)	650	Steam	2000
Ayoun Mousa	650	Steam	2000
Zafarana	120	Wind	2001
Sidi Krir (3,4)	650	Steam	2002
Suez Gulf	650	Steam	2003
Port Said East	650	Steam	2003
Total	3,370		

Table A3.6: Egypt Required Capacities, 2004–06

Plant name	*Capacity (MW)*	*Type of technology*	*Commission Year*
Zafarana (5)	30	Wind	2004
Cairo North (1)	500	Combined cycle	2004
El Kurimat	150	Solar/Gas	2004
Nobaria (1)	500	Combined cycle	2005
Cairo North (2)	500	Combined cycle	2005
Zafarana (6)	200	Wind	2005
Nobaria (2)	500	Combined cycle	2006
Nag Hamadi	64	Hydro	2006
Total	2,444		

Table A3.7: Egypt Required Capacities, 2007–10

Plant Name	*Capacity (MW)*	*Type of Technology*	*Commission Year*
Cairo West (7,8)	650	Steam	2007
Zafarana	100	Wind	2007
Borg El Arab (1)	300	Solar/Gas	2007
Safaga	500	Combined cycle/water desalination	2007
El Kuriemat (3)	650	Steam	2008
Sharm El Shiekh	500	Combined cycle/water desalination	2008
Ayoun Mousa (3,4)	650	Steam	2009
Borg El Arab (2)	300	Solar/Gas	2009
Toshky (1)	325	Steam	2009
Toshky (2)	325	Steam	2010
Dabbaa	600	Nuclear/Water desalination	2010
El Walidia (3)	325	Steam	2010
Attaka (1)	1,400	Pump storage	2010
TOTAL	6,625		

Table A3.8: Ethiopia Future Generation Expansion

Year	*Project name and type*	***Installed capacity (MW)***	***Average energy prod. (GWh)***	***Firm energy prod. GWh)***	***Total system energy** (GWh)*			***Total system capacity (MW)***		
					Avail-able	***Required***	***Surplus***	***Avail-able***	***Required***	***Surplus***
2000	Existing ICS	385	1,822	1,706	1,706	1,684	22	385	330.7	54.3
2001	Tis Abay II	73		331	2,037	1,885	152	458	330.3	127.7
2002	Fincaa 4th Unit	34		137	2,174	2,014	160	492	395.7	96.3
2003	Gilgel Gibe	184		642	2,816	2,157	659	676	453.6	222.4
2004					2,816	2,309	507	676	453.6	222.4
2005					2,816	2,464	352	676	484.0	192.0
2006	Tekeze Stg. I	225		735.75	3,551.75	2,616	935.75	901	514.0	387.0
2007					3,551.75	2,771	780.75	901	544.4	356.6
2008					3,551.75	2,929	622.75	901	575.4	325.6
2009					3,551.75	3,090	461.75	901	607.0	294.0
2010					3,551.75	3,253	298.75	901	639.0	262.0
2011	Gojeb Stg. I	100		242.70	3,794.45	3,420	374.45	1,001	672.0	329.0
2012					3,794.45	3,597	197.45	1,001	706.6	294.4
2013	Tekeze Stg. II	75		245.25	4,039.7	3,780	259.7	1,076	742.7	333.3
2014	Gojeb Stg. II	50		121.3	4,161	3,972	189	1,126	780.2	345.8
2015	Halele			382	4,543	4,171	372	1,126	819.3	306.7
2016					4,543	4,377	166	1,126	859.9	266.1
2017	Aleltu East Stg. I			780	5,323	4,594	729	1,126	902.4	223.6
2018					5,323	4,821	502	1,126	947.1	178.9
2019					5,323	5,061	262	1,126	994.2	131.8
2020	Geothermal			275.5	5,598.5	5,313	285.5	1,126	1,043.7	82.3

Table A3.9: Kenya Future Generation Expansion (Interconnected System)

Fiscal year	*Project name and type*	*Installed capacity (MW)*	*Average energy prod. (GWh)*	*Firm energy prod. (GWh)*	*Total system energy (GWh)*		*Total system capacity (MW)*	
					Required	*Surplus*	*Required*	*Surplus*
2000	Gitaru 3 (hydro) Kipevu I (diesel)	80 75			5,021		1,032	167
2001	Olkaria III (geothermal) Kipevu II (diesel) Fast Track	8 75 110			5,312		1,224	312
2002	Kipevu Steam Olkaria II (geothermal)	-45.5 64			5,627		1,408	445
2003	Olkaria III (geothermal) Sondu (hydro) Nairobi GT	56 60 -13.5			5,965		1,455	436
2004					6,344		1,445	371
2005	Diesel	40			6,742		1,495	342
2006	Geothermal	64					1,559	333
2007	Geothermal	64					1,623	319
2008	Diesel Ewaso Ng'iro I (hydro)	20 90					1,733	347
2009	Ewaso Ng'iro II (hydro)	90	550	330			1,8231	349
2010	Olkaria I Diesel	-45 80			9,124		1,858	292
2011	Geothermal Diesel	64 20					1,942	278
2012	Diesel	120					1,062	293
2013	Geothermal Diesel	64 40					2,165	289
2014	Diesel	120					2,286	292
2015	Geothermal Diesel	64 60				12,286	2,309	293
2016	Diesel	150					2,559	313
2017	Geothermal Diesel	64 80					2,704	320

Table A3.10: Rwanda Future Generation Expansion

Year	*Project name/type*	*Installed capacity (MW)*	*Average energy prod. (GWh)*	*Firm* energy prod. (GWh)*	*Total system energy (GWh)*		*Total system capacity (MW)*	
					Required	*Surplus*	*Required*	*Surplus*
2001	* Ruzizi II	14.7	55	126,278	185.6	-59,322	41	-11
2003	Methane Power Station	16.0	**112**		208.5	+29,778	57	-11
2005	Nyabarongo	27.5	144	270,278	234.31	+147,968	67	+6.5

Table A3.11: Sudan Generation Expansion, NEC Development Plan, 1999–2005 Option 1: Combined Cycle and Steam

Years	*Load forecast MW GWh*	*Retirement (start of year)*	*Additions (start of year)*	*Sys. inst. cap. MW*	*LOLP (days per year)*	*Annual ENS %*	*Load Shed GWh*
1999	636			588.40	192.786	13.228	261.1
2000	682		26 MW Kh. Refinery	614.40	204.984	13.901	305.5
2001	732		2 x 30 MW GT	674.40	186.3	11.296	270.8
2002	786		2 x 80 MW GT	834.40	88.098	3.477	71.9
2003	844	2 x 30 MW GT	3 x 30 MW CC 1 x 60 MW Steam	924.40	69.019	2.033	47.7
2004	908	2 x 80 MW GT	3 x 80 MW CC 1 x 90 MW Steam	1,094.40	1.288	0.028	3.8
2005	976	Burri Diesel (3 x 8 MW)	1 x 90 MW Steam	1,160.40	4.822	0.124	4.9
2006	1,051			1,160.40	10.195	0.246	10
2007	1,132		4 x 65 MW (Merowe Hydro)	1,420.40	0.031	0.001	0.4
2008	1,219			1,420.40	0.94	0.002	1.1
2009	1,315		3 x 65 MW (Merowe Hydro)	1,615.40	0.008	0	0.3
2010	1,418			1,615.40	0.035	0	0.3
2011	1,531		3 x 125 MW 7 x60 (Upgrading of first seven units) Merowe Hydro	2,410.40	0.818	0.015	2
2012	1,653			2,410.40	2.308	0.054	9.5
2013	1,786	Burri Diesel (2 x 8 MW) Kh.N.G.T. (2 x 18 MW)		2,358.40	3.622	0.09	35.5

Table A3.12: Tanzania Future Generation Expansion

Year	*Project name/type*	*Installed capacity (MW)*	*Average energy prod. (GWh)*	*Firm energy prod. (GWh)*	*Total system energy (GWh)*		*Total system capacity (GWh)*	
					Required	*Surplus*	*Required*	*Surplus*
2000	Lower Kihansi	180	922	808	3042.4	792.1	524.8	234.5
2001	UGT 5	40						282.9
	IPTL	100	8.2	-	3498.3	1717.6	616.4	
2002	CT 120	120	696	-	3982.5	1465.4	712.8	226.5
2003	CT 60	60	348	-	4291.2	1504.7	764.2	235.1
2004	Zambia import	200	1051.2	-	4583.8	2372.1	813.2	386.1
2005	CC	200	1160.0	-	4850.7	3265.2	858.1	541.2
2006					5128.5	2987.4	904.9	294.4
2007					5419.4	2696.5	953.5	245.8
2008					5722.7	2393.2	1004.1	195.2
2009	GT	60	348.0		6043.1	2420.8	1100.0	159.3
2010	Ruhudji	358	2000.0	1662	6375.5	4164.8	1162.0	455.3
2011					6756.1	3784.2	1219.0	398.3
2012					7127.7	3412.6	1280.0	337.3
2013					7519.7	3020.6	1344.0	273.3
2014	Rumakali	222	1320	1242	7933.3	3894.6	1411.0	428.3
2015					8235.7	3592.2	1490.0	349.3
2016					8647.5	3180.4	1564.0	275.3
1017					9075.9	2748.0	1642.0	197.3
2018	CC	180	1044		9533.9	3338.0	1724.0	295.3
2019					10,010.5	2861.4	1811.0	208.3
2020	GT	60	348		10,511.1	2708.8	1908.0	171.3

Table A3.13: Uganda Future Generation Expansion

Year	*Project name/type*	*Installed capacity (MW)*	*Average energy prod. (GWh)*	*Firm energy prod. (GWh)*	*Total system energy (GWh)*		*Total system capacity (MW)*	
					Required	*Surplus*	*Required*	*Surplus*
2000	Owen Falls Extension M11&12	80			2379		390	-115
2001	Owen Falls Extension M13-15	120	(for 11-15) = 750		2580	-330	425	-30
2002					2736	-486	450	-55|
2003					2885	-635	470	-75
2004	Bujagali H.P	250	1,600		3073	787	505	140
2005	Karuma H.P.	200	1,200		3191	1859	525	320
2006								
2007								
2008	Kalagala H.P.	270	1,650					
2009								
2010					4414	2286	730	345
2015					5467	1233	900	175
2020					7049	-349	1153	-78