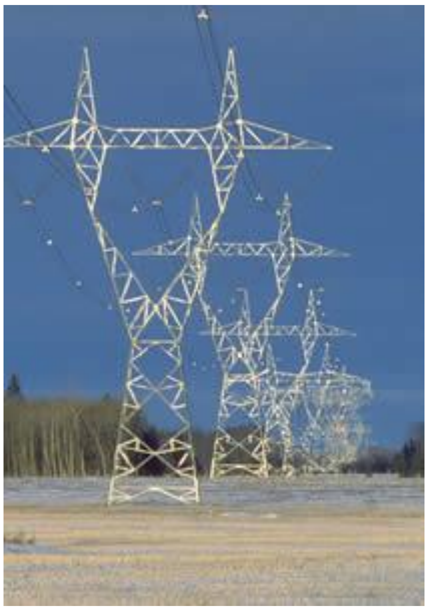
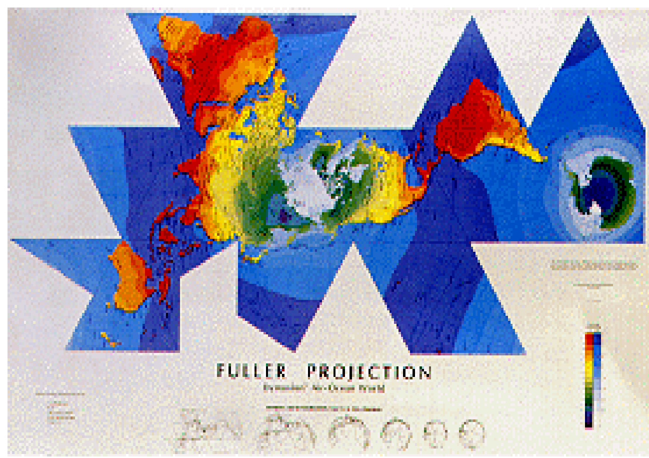
GENI Global Energy Network Institute

Cross-Border Interconnections on Every Continent





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ABSTRACT

A cross-border interconnected grid is one of the main pivots that positively affects the development process between neighboring countries.

International power grid interconnections provide links between the electricity transmission systems of two or more adjoining countries, and, thus, interconnections allow those countries to share power generation resources.

Electricity interconnection projects are important examples of integration that ensures economic, social, and political benefits to the involved countries. The principal objectives of this research are 1) to understand the benefits of a globally interconnected electrical grid and 2) to survey currently existing international cross-border interconnections. As different countries are differently endowed with natural resources, energy trade among countries for centuries has helped to reduce energy prices and increase energy supply in importing countries, while providing an income for exporting countries.

In the first part of this report, we focus on the interconnected grids and their benefits and then explain the different types of links currently existing. In the second part, we look at several proposed or in-constructions projects. We focus on the continent of Africa, describing their special resources and opportunities for development. A spreadsheet cataloguing global interconnections by countries is found in the Appendix.

I. Interconnected grid[1]

1. Technical aspects

a. Historic

Electricity grid interconnections have played a key role in the history of electric power systems. Interconnections among neighboring systems have become increasingly common. The first international interconnections were in Europe in 1906, when Switzerland built transmission links to France and Italy. Today in the North American power system, there are four regional synchronous systems: the Eastern, Western, Texas, and Quebec interconnections. Indeed, the biggest machine in the world is The Eastern Interconnection because of the numerous generators and transmission and distribution lines. At the same time that synchronous AC networks have reached the continental scale, the use of high voltage direct current (HVDC) interconnections is also rapidly expanding as a result of technical progress over the last two decades. HVDC permits the asynchronous interconnection of networks that operate at different frequencies, or are otherwise incompatible, allowing them to exchange power without requiring the tight coordination of a synchronous network. HVDC has other advantages as well, especially for transmitting large amounts of power over very long distances and via underwater cable.

b. Benefits of interconnection grid

• **Improving reliability and pooling reserves:** The amount of reserve capacity can be reduced by sharing reserves within an interconnect network.
• **Reducing investment in generating capacity:** Investment is reduced if they share the generating resources of an interconnected system.
• **Improving load factor and increasing load diversity:** When the power demand is leveled over time, systems operate most economically.
• **Economies of scale in new construction:** Sharing resources in an interconnected system can allow the construction of larger facilities with lower unit costs.
• **Environmental dispatch and new plant siting:** Interconnections can allow generating units with lower environmental impacts to be used more often while units with higher impacts are used less.
• **Coordination of maintenance schedules:** Interconnections permit planned outages of generating and transmission facilities for maintenance to be coordinated so that overall cost and reliability for the interconnected network is optimized.

a. Principal consideration

AC &DC

There are two forms for electric power: alternating current (AC) and direct current (DC). These forms are characterized by the behavior of their waveforms: AC alternates between positive and negative polarity with respect to ground, while DC does not. In the last century, AC systems

[1] Source: www.un.org/esa

have become the standard worldwide. The main reason for this is that it is relatively simple to increase or decrease AC voltage levels by using transformers, while it is difficult to change DC voltages. For AC interconnections especially, a power system interconnection is a kind of marriage in that two systems become one in an important way when they operate in synch. The greatest benefits of interconnection are usually derived from synchronous AC operation, but this can also entail greater reliability risks. In any synchronous network, disturbances in one location are quickly felt in other locations. Once interconnected, a system that used to be isolated from disturbances in a neighboring system is now vulnerable to these new disturbances.

The ultimate objective of an interconnection is to provide power to customers economically, safely, reliably, efficiently, and with minimal environmental impact.

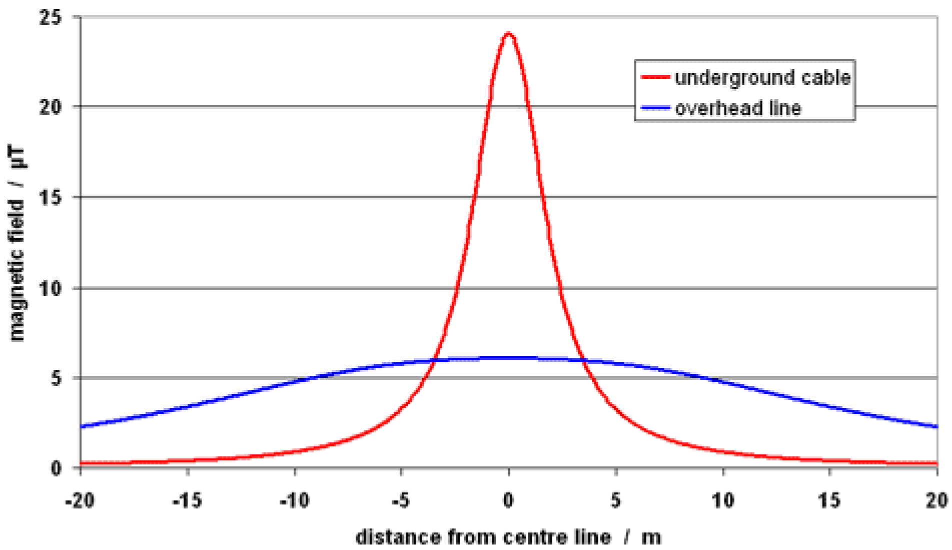
Transmission lines:

They come in two basic varieties: overhead lines and underground (or undersea) cables. Overhead lines are more common and generally less expensive than cables. The main difference for overhead lines is the choice of conductor type and size, which must balance the need to minimize impedance (resistance and the associated losses), minimize cost and minimize the weight that must be carried by support structures.

Underground cables are used where overhead conductors are inappropriate due to environmental or land use considerations, like in high-density urban areas or ecologically sensitive areas. Cables are insulated and are typically routed through underground conduits; they sometimes require cooling systems to dissipate heat. Cables may use copper instead of aluminum, balancing the greater cost of copper against its superior conductivity and lower resistive heating. Undersea cables are usually made of copper and are encased in oil or an oil-soaked medium and a protective wrapping.

Differences in magnetic field and distance from the cable are shown in Figure 1 below. Clearly the magnetic field is strongest for underground cable at the cable. But drops off quickly within 5m from its centerline.

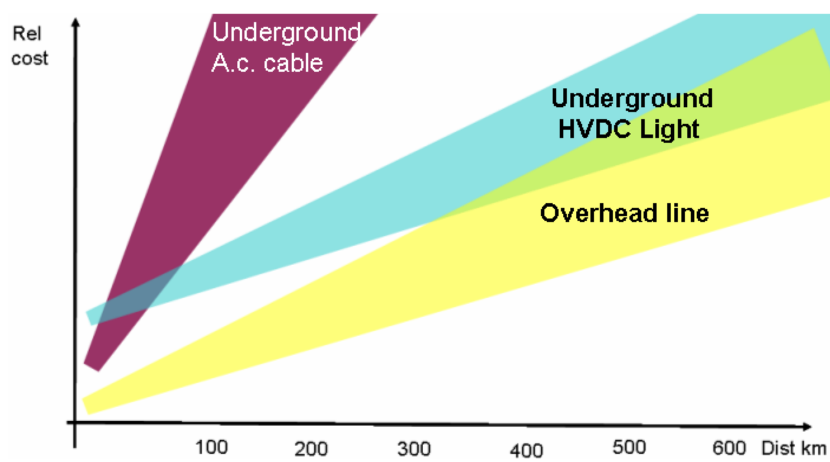
Figure 1: Magnetic field comparison for underground cable and overhead line



Source: http://www.emfs.info/Sources+of+EMFs/Underground/

In the following graph we can see the relative cost of transmission for both underground cable and overhead line. Distance also plays a role in this cost analysis. For distances greater than approximately 500 kms, the use of underground (and submarine) cables for its HVDC Light technology are significantly more than overhead lines—even without accounting for permitting/legal delays.

Figure 2: Relative cost of transmission for both underground cable and overhead line



Source: http://www.solar-nation.org/2009/03/20/keeping-overheads-so-far-down-theyre-underground/

c. Interconnection of power systems with weak grids

In the developing world, many power systems bear the marks of age, poor repair, and insufficient investment. Equipment is often obsolete, and operations that are automated elsewhere may be carried out manually. Systems in poor repair can have serious reliability problems and often fail to comply with safety or environmental standards. As one scholar described the difficulties of interconnection among sparse, poorly maintained systems:

> "The vastness of the area and the low power consumption density in most African countries make the operation of the interconnection difficult from an operational standpoint. Many of the loads are connected to spurs off a grid that has a low level of interconnectivity. In addition, most of the networks have suffered from a lack of maintenance due to a shortage of funds. This has dramatically reduced the reliability of the system and outages frequently occur in many places. The combination of these factors has forced industries to provide their own generating facilities in the form of diesel power. These plants then operate in island mode and will often also provide power to towns and villages in the immediate vicinity of the plant. Some utilities are discouraging this practice, but need to convince these clients to connect to a grid that may not be that reliable in the first place, particularly in areas connected to spurs." (Jan A de Kock, 2004, "Status of International Interconnections and Electricity Deregulation in Africa").

Grid interconnections require a careful calculation of costs, benefits, and risks. Technical planning of a grid interconnection should be coordinated with economic, organizational, legal, and political aspects of a potential interconnection project from the outset of project consideration.

2. Economic and financial impacts

The primary reason for developing an electricity grid interconnection between countries is to reduce the overall combined economic costs of supplying electricity services in the interconnected countries.

Grid interconnections may offer both direct and indirect economic and financial costs and benefit. There are avoided costs:

- Cost for fuels used in electricity generation
- Capital costs of generation facilities
- Operating costs of generating facilities
- Operating costs for any transmission facilities avoided by the interconnection.

The indirect costs and benefits of an interconnection can include:

- Stimulation of the national economy
- Stimulation of local economies through labor employment needed for construction of the interconnection power line and of the power plants that will feed it
- The labor needed to operate the interconnection (and associated power plants) on an ongoing basis.

Other potential indirect economic benefits of an interconnection include the impacts of improved power supplies in fostering development of local industry. Given the need for contracting and/or for market arrangements in the selling of power, the economic and financial costs and benefits of interconnections sometimes interact with political issues between jurisdictions.

3. Legal and political aspects; social benefits

International electricity grid interconnections can be very complex legal undertakings, except perhaps in their very simplest form. International power grid interconnections can offer political benefits to the countries participating in power trading, as well as to individuals and companies within the trading countries. **Grid interconnections have the potential to encourage democratization.** If the process of planning a grid interconnection proceeds in a transparent and inclusive manner, with the (typically) many different constituencies affected by the interconnection project receiving sufficient opportunity to provide input into the planning process, the result may help spur democratization. Another way that grid interconnections may promote democratization is through their effects on power supplies. In addition to providing lighting to learn by, **grid interconnections**, in the way that they **help bring electricity to under-served regions, may enhance political stability by offering opportunities for employment, education, and medical care in areas where there is a lack of these necessities.** Increasing the standard of living of populations, especially rural or suburban populations, through electricity provision helps to **slow migration to urban centers, helps to alleviate poverty and thus mitigates the political difficulties and social tensions involved in providing for the urban poor.**

4. International grid interconnections and Energy security

International grid interconnections may also become political liabilities to one or more of the host countries. One justification often noted for international **electricity grid interconnection** is that they can **improve energy security within the interconnected countries,** depending on how they are configured**.** "Energy Security" has typically meant mostly securing access to oil and other fossil fuels. To take account of these concepts, we can offer a new definition of Energy Security, as follows:

> "A nation-state is energy secure to the degree that fuel and energy services are available to ensure:
> a) survival of the nation
> b) protection of national welfare
> c) minimization of risks associated with supply and use of fuel and energy services."

Potential Impacts of Grid Interconnections on Energy Security

There are five dimensions of energy security**: economic, technological, environmental, social and cultural, and military/security**. International electricity grid interconnections can have impacts in each of the dimensions. The table in the Appendix provides just a few examples of how grid interconnections might provide benefits and incur costs or risks, in each of the dimensions described.

5. Smart Grid

A **smart grid** delivers electricity from suppliers to consumers using two-way digital technology to control appliances at consumers' homes to save energy, reduce cost and increase reliability and transparency. It monetizes the electricity distribution grid with real-time information and net metering services. A smart grid, as part of an electricity power system, can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies.

A smart grid employs communications, innovative products and services together with intelligent monitoring and control technologies to:

- Facilitate connection and operation of generators of all sizes and technologies
- Enable the demand side to play a part in optimizing the operation of the system
- Extend system balancing into distribution and the home
- Provide consumers with greater information and choice of supply
- Significantly reduce the environmental impact of the total electricity supply system
- Deliver required levels of reliability, flexibility, quality and security of supply

Different geographies, different smart grid needs

As we know, every country throughout the world has different energy needs as well as varying types and accessibility of energy resources. For example:

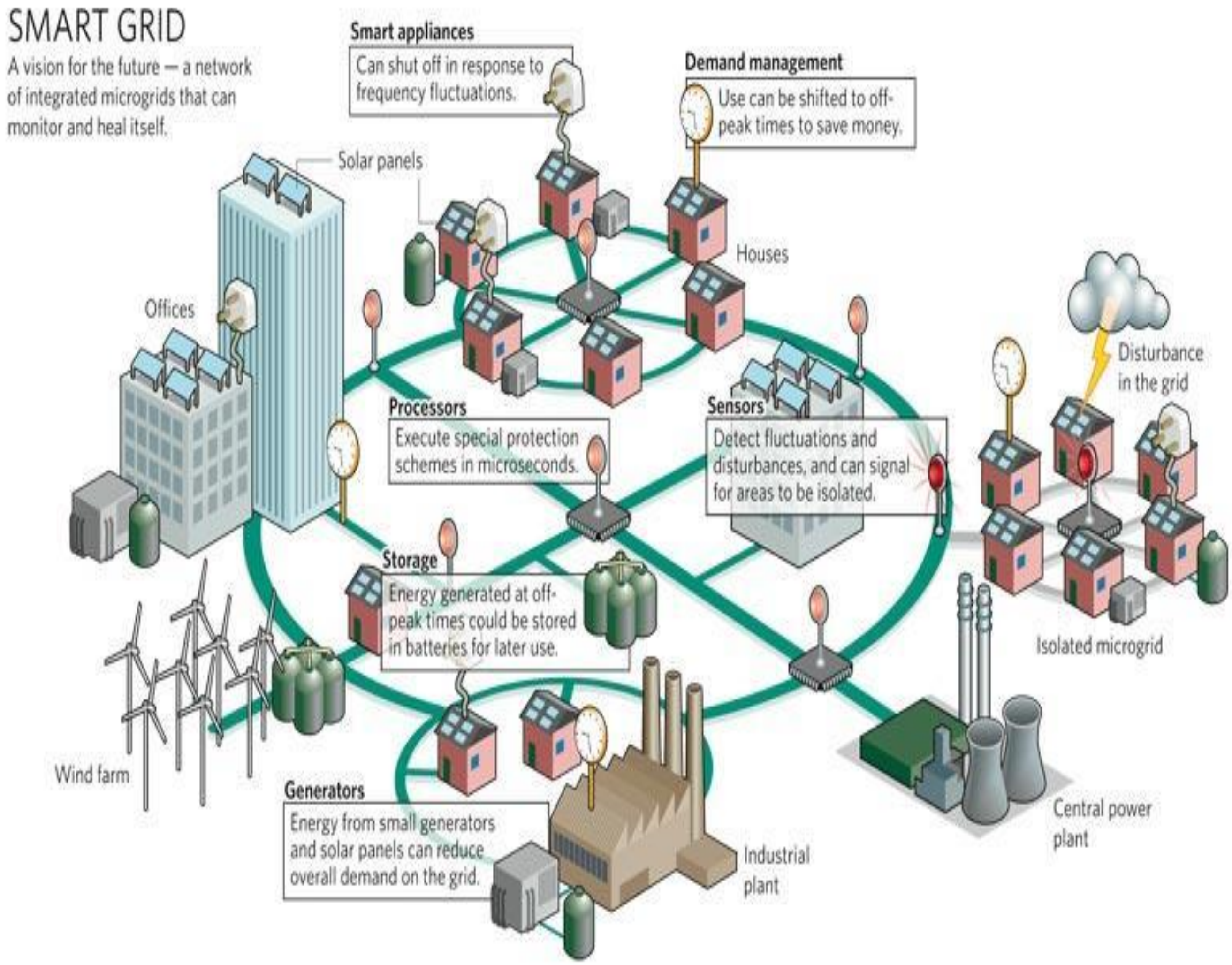
- In Northern Africa, where the huge desert landscape is recognized as an asset for potentially deploying windmills and solar panels, industrial and government leaders are seeking insight into how to ship power across national boundaries and interconnect with other grids.
- The European Union, which has set forth a goal of deploying smart meters to over 80% of power users by 2020, is organizing to better understand the diverse, country-specific smart grid requirements across its membership.

The key drivers of developing the smart grid vary from country to country. **In some developing areas** of the world, the smart grid will bring power to some consumers for the first time. **In other nations**, the motivation is improved reliability and efficiency. Systems of government, public-private relationships and cultural norms also differentiate the markets. But, **interest in making power delivery more efficient, secure and environmentally neutral is shared internationally.**

The new smart grid with also has numerous benefits for IT:

- Reducing waste
- Minimizing the impact of outages
- Integration of renewable energy
- Enabling electric vehicle charging

Figure 3: Smart Grid – a vision for the future



Source: http://www.consumerenergyreport.com/wp-content/uploads/2010/04/smartgrid.jpg

II. Every country's neighbors[2]

In an Excel spreadsheet (created by Alvaro Garcia, an intern at GENI) every country and its neighbors is listed as well as the quantity of export and import of electricity. That Excel sheet is in appendix. The task here is to determine if there is an interconnection between them. This next section covers the different types of links existing today. We will also discover another new technology.

1. Types of Links already existing: HVDC

The first electrical transmission systems built in the1880s were Direct Current (DC). However, because DC could not be readily transformed to higher voltages for long distance transmission, AC systems quickly became the standard. Why do we use HVDC? The first commercial use of

[2] Sources : http://www.electron-economy.org/pages/HVDC-26210.html ; http://climatetoday.org/?p=2333 ; ABB presentation

modern HVDC transmission was in Sweden in 1954. HVDC is used in interconnection projects in three principal applications:

1. Transmitting large amounts of power over very long distances
Unlike long-distance AC transmission, HVDC transmission over long distances has no inherent stability limit. Also, even within AC stability limits, HVDC can overtake AC on cost alone. The relationship between costs of AC and DC transmission lines versus the distance that power must be transmitted is illustrated in this graph:

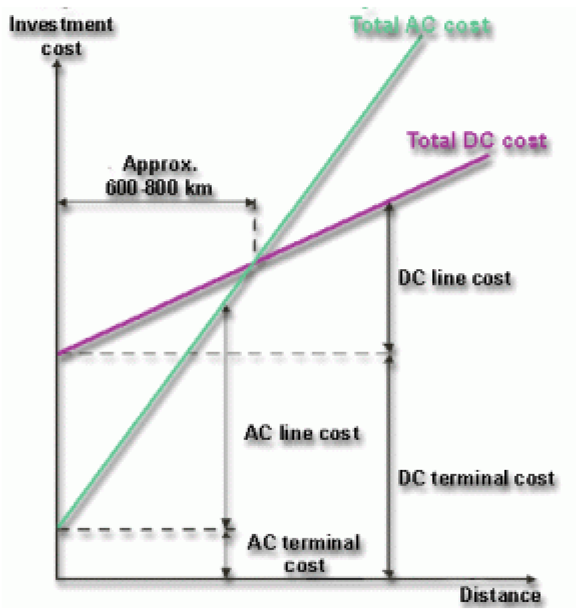


Figure 4: Cost of Investment for AC and DC

Source : http://www.electron-economy.org/pages/HVDC-26210.html

Explanation: an HVDC transmission line costs less than an AC line for the same transmission capacity. However, the terminal stations are more expensive in the HVDC case due to the fact that they must perform the conversion from AC to DC and then back to AC. But above a certain distance, the so-called "break-even-distance," the HVDC alternative will always give the lowest cost. The importance of the break-even-distance concept should not be over-stressed, because other factors exist, such as controllability, which are important in the choice between AC or HVDC.

2. Transmitting power under water
HVDC is preferred for undersea transmission. Undersea cables have a coaxial structure in order to minimize space requirements. The break-even-distance is much shorter for submarine cables (typically about 50 km) than for an overhead line transmission. The distance depends on several factors (both for lines and cables) and an analysis must be made for each individual case.

3. Asynchronous interconnections
HVDC is a viable alternative when synchronous AC connections are difficult or impossible due to different system frequencies to be interconnected. There are two general types of asynchronous interconnection:

- HVDC transmission over long distance, between two converter stations connected at either end to an AC system
- HVDC "back-to-back" interconnection to AC systems on either side, without any intervening transmission. Back-to-back connections have sometimes served as a stepping-stone to a later full synchronous interconnection.

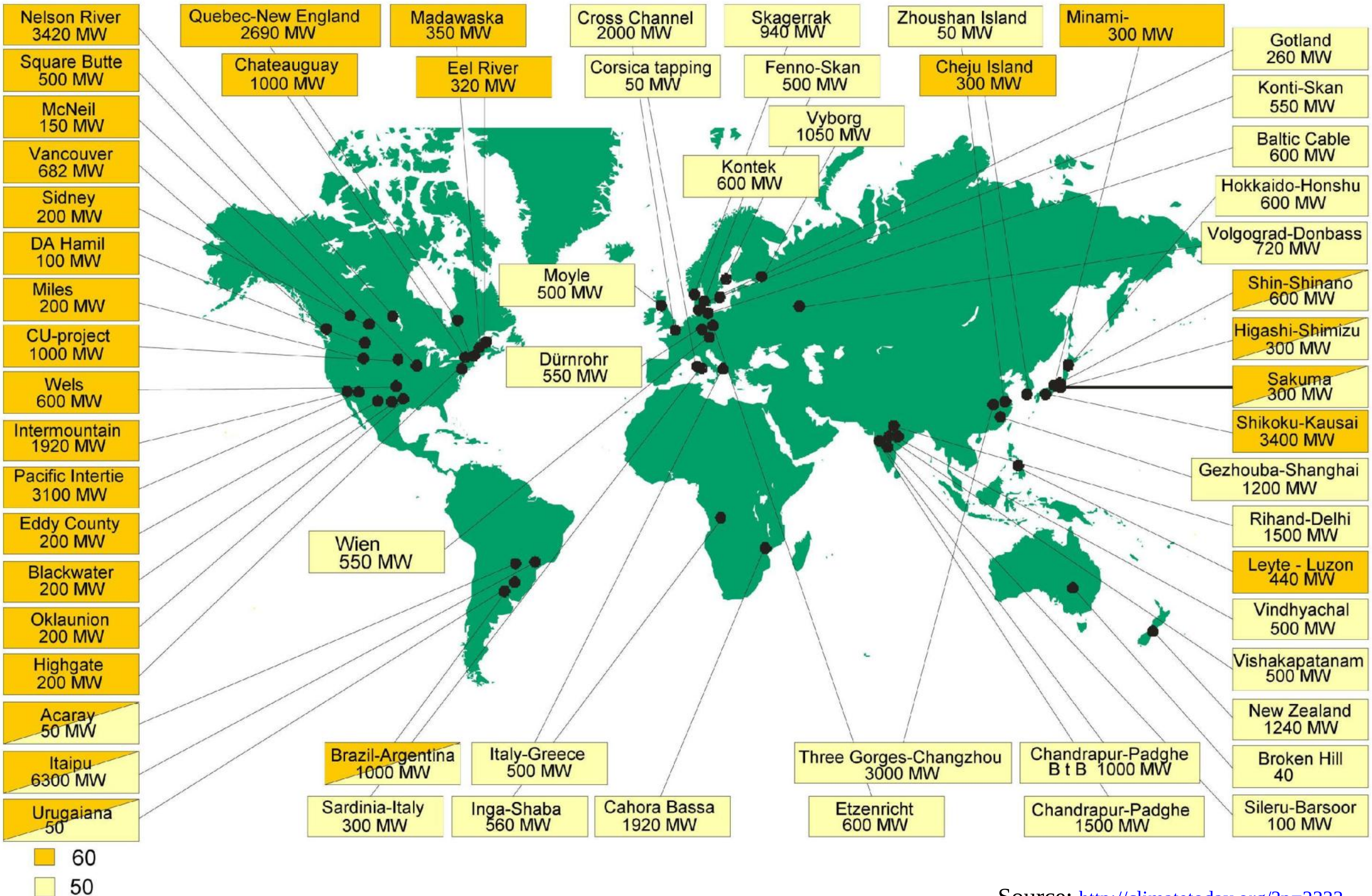
In addition to the three applications listed here, there are other reasons HVDC interconnections are used:

- HVDC carries more power for a given conductor size.
- In situations where existing transmission capacity is constrained, HVDC is an alternative to an AC transmission upgrade.
- HVDC does not increase fault currents in the network it is connected to, so new circuit breakers are not required in the rest of the system.

HVDC projects worldwide

The highest capacity HVDC interconnection in the world at present is a bipolar +/- 600 kV line transmitting 6300 MW of power from the Itaipu dam on the Brazilian-Paraguayan border into Brazil over a distance of 800 km. See map below.

Figure 5: International HVDC Interconnections



Source: http://climatetoday.org/?p=2333

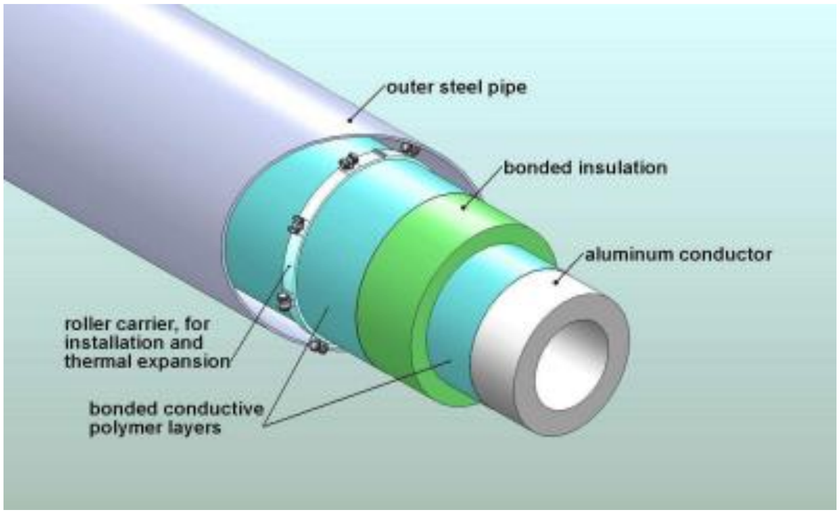
-In Queensland, Australia, HVDC was chosen to interconnect two independent grids (New South Wales to Queensland) to enable electricity trading between the two systems (including change of direction of power flow) and to minimize environmental impact
- In Gotland, Sweden, HVDC was chosen to connect a newly developed wind power site to the main city of Visby, in consideration of the environmental sensitivity of the project area (an archaeological and tourist area) and improve power quality
- In Itaipu, Brazil, HVDC was chosen to supply 50Hz power into a 60 Hz system and to economically transmit a large amount of hydro power (6300 MW) over long distances (800 km)
- In Leyte-Luzon Project in Philippines, HVDC was chosen to enable the supply of bulk geothermal power across an underwater island interconnection and to improve stability to the Manila AC network
- In Rihand-Delhi Project in India, HVDC was chosen to transmit bulk (thermal) power (1500 MW) to Delhi, to ensure minimum losses, reduce right-of-way impact, and insure better stability and control.

2. New type of link: Electric Pipeline Underground cable

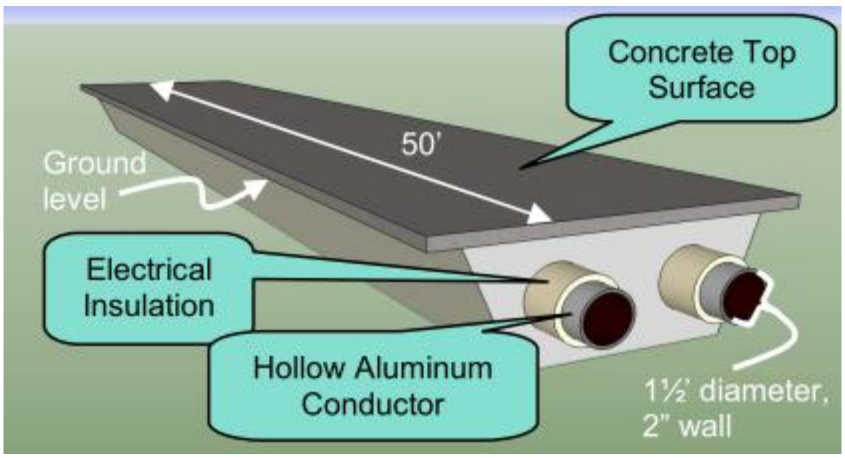
Underground cables have a significantly lower power transfer capacity and cost many times more than overhead power lines, so they are rarely used except in and around cities. Cables can be used to deliver AC or DC power, but AC runs are limited to approximately 50 km (which is short in this context) before capacitive charging currents rise to the point that the cable requires expensive reactive compensators to deliver useful power.

This method of underground cables puts very high capacity non-superconducting high-voltage DC power lines into underground pipelines. Key portions of these technologies **address new high-voltage insulators, high-reliability joints and waste heat removal.**

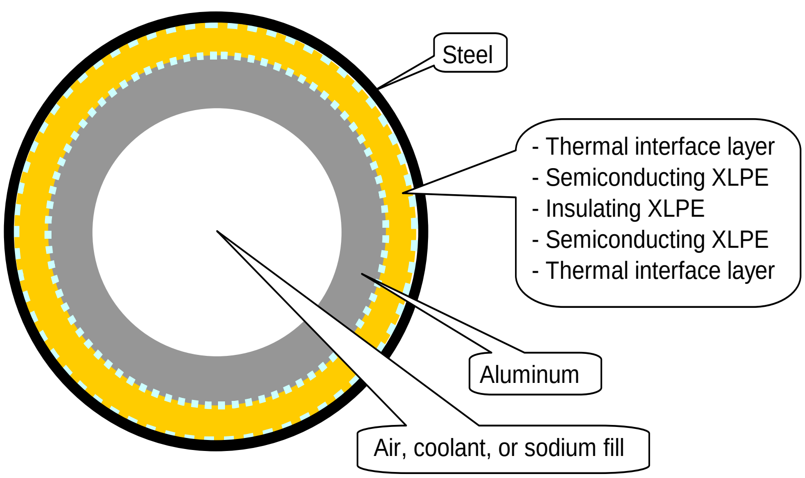
Figure 6: Underground Cable System



- **Fully underground**
  - **Up to 12 GW**



- **Exposed surface**
  - **Up to 24 GW**



- Non-intrusive
- More conductor than is practical for overhead lines
- More efficient due to lower transmission losses
- Greater range (addresses intermittency of wind, solar)

- Much less complex than superconducting lines
- Cheaper than underground cables
- Cost on par with overhead lines

The advantages of superconducting HVDC without the drawbacks

- Scalable to achieve very low loss [1% per 1,000km (1.6 % / 1,000 miles) @ 3-24 GW, passively cooled]
- Scalable to arbitrarily long distances (coast-to-coast)
- Very small Right of Way needs (25', or 7.6 m)
- Unobtrusive, easier to get permitted
- Neighbor-friendly (no noise, no EMF, no corona)
- Minimal maintenance – no refrigeration, pumps, etc.
- Minimal technology risk
- Low cost & complexity

Source: ABB presentation

III. Proposed or projects in construction

1. Bangladesh-India Electrical Grid Interconnection

The regional relations between India and Bangladesh are growing positive. Bangladesh has lifted its opposition to a gas pipeline linking India and Myanmar (Burma) and running through its territory, paving the way for the establishment of a regional gas grid that will feed India's growing energy demand.

Source: http://gurumia.com/category/bangladesh/energy-bangladesh/page/5/

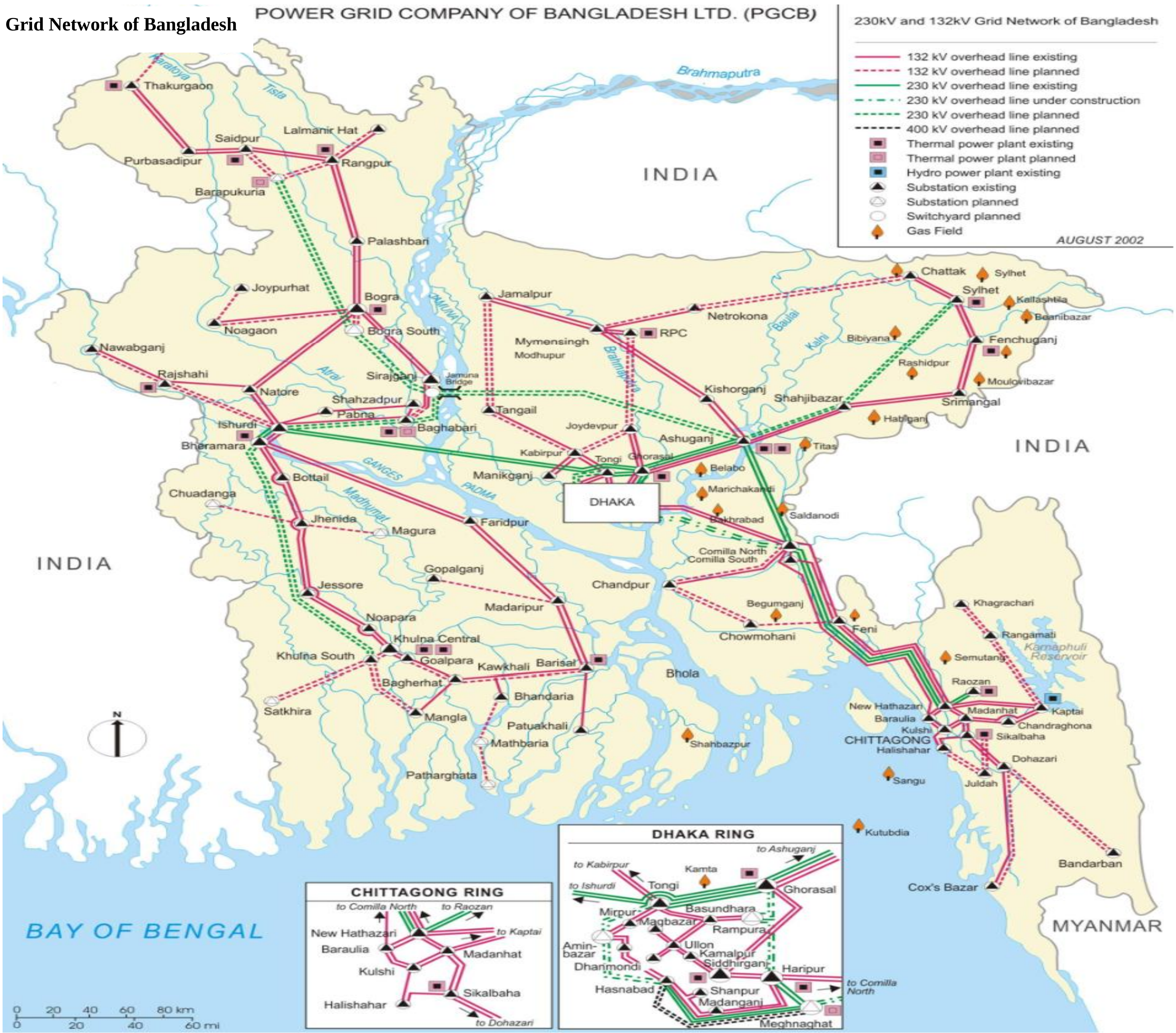
The Bangladesh-India Electrical Grid Interconnection Project (the Project) will establish a cross-border link between the western electrical grid of Bangladesh and the eastern electrical grid of India to facilitate the exchange of electric power between the two countries. In accordance with technical, operational, and economic considerations, the proposed interconnection will include 125 km of 400 kV double circuit transmission line between the electrical substations at Baharampur in India and Bheramara in Bangladesh, a 400 kV switching station at Baharampur (India) and a 500 MW back-to-back high voltage direct current (HVDC) sub-station (400/230 kV) at Bheramara (Bangladesh) and associated infrastructure. The system will facilitate an initial power flow of 500MW into Bangladesh from the Indian grid starting in 2012 to partially address the significant power shortages in Bangladesh, with a provision to enhance the power flow to 1,000 MW. See Bangladesh Power Grid on page 17.

A Joint Technical Team from India and Bangladesh examined multiple options regarding the interconnection of the grid between the two countries before identifying the proposed Project. An asynchronous mode of interconnection between the Indian and Bangladeshi transmission grid was determined to be appropriate to allow each country to retain independent control and operation over its own national grid, ensure complete control of the power transfer between the two countries and to obviate the requirement for additional upstream investment to protect generation assets in either country from cross-border faults and surges.

Impact: Sustained inclusive economic growth in Bangladesh through optimal utilization of power generation capacity in the South Asian region.

Outcome: Successful development and operation of a transmission link between Bangladesh and India. Source: http://gurumia.com/tag/power/

Figure 7: Grid Network of Bangladesh



2. Fenno-Scan HVCD Link

Figure 8: **S6** EXISTING INTERCONNECTIONS BETWEEN THE NORDEL COUNTRIES

Countries Stations	Rated voltage	Transmission capacity as per design rules*		Total length of line	Of which cable
	kV	MW		km	km
Denmark - Norway		**From Denmark**	**To Denmark**		
Tjele-Kristiansand	250/350	1040	1040	240/pol	127/pol
Denmark - Sweden		**From Sweden**	**To Sweden**		
Teglstrupgård - Mörarp 1 and 2	132~	350 [2]	350 [2]	23	10
Hovegård - Söderåsen 1	400~	800 [2]	800 [2]	91	8
Hovegård - Söderåsen 2	400~	800 [2]	800 [2]	91	8
Vester Hassing - Göteborg	250=	290	270	176	88
Vester Hassing - Lindome	285=	380	360	149	87
Hasle (Bornholm) - Borrby	60~	60	60	48	43
Finland - Norway		**From Finland**	**To Finland**		
Ivalo - Varangerbotn	220~	70	70	228	-
Finland - Sweden		**From Sweden**	**To Sweden**		
Ossauskoski - Kalix	220~			93	-
Petajaskoski - Letsi	400~	1300 [3]	700 [4]	230	-
Keminmaa - Svartbyn	400~			134	-
Hellesby (Åland) - Skattbol	70~	35	35	77	56
Raumo - Forsmark	400=	500	500	235	198
Norway - Sweden		**From Sweden**	**To Sweden**		
Sildvik - Tornehamn	132~	50	120	39	-
Ofoten - Ritsem	400~	1350	1350 [5]	58	-
Rössåga - Ajaure	220~	285 [6]	285 [5, 6]	117	-
Linnvasselv, transformer	220/66~	50	50	-	-
Nea - Järpströmmen	275~	450 [6]	450 [6]	100	-
Lutufallet - Höljes	132~	40	20	18	-
Eidskog - Charlottenberg	132~	100	100	13	-
Hasle - Borgvik	400~	1650 [5]	1800 [6, 7]	106	-
Halden - Skogssäter	400~			135	-

Maximum permissible transmission.
Thermal limit. The total transmission capacity is 1,600 MW to Denmark and 1,800 MW to Sweden.
Further 100 MW for power balance deviation.
900 MW can be transmitted during reduced transmission in Finland.
Thermal limit. Stability problems and generation in nearby power plants may lower the limit.
The transmission capacity can in certain situations be lower, owing to bottlenecks in the Norwegian network.
Requires a network protection system during operation (production disconnection).

S7 EXISTING INTERCONNECTIONS BETWEEN THE NORDEL COUNTRIES AND OTHER COUNTRIES

Countries Stations	Rated voltage	Transmission capacity		Total length of line	Of which cable
	kV	MW		km	km
Denmark - Germany		**From Nordel**	**To Nordel**		
Kassø - Audorf	2 x 400~			107	-
Kassø - Flensburg	220~	1400 [1]	1400 [1]	40	-
Ensted - Flensburg	220~			34	-
Bjæverskov - Rostock	400=	600	600	166	166
Finland - Russia		**From Nordel**	**To Nordel**		
Imatra - GES 10	110~	-	100	20	-
Yllikkala - Viborg	±85=	-	1000	-	-
Nellimö - Kaitakoski	110~	60	60	20	-
Norway - Russia		**From Nordel**	**To Nordel**		
Kirkenes - Boris Gleb	154~	50	50	10	-
Sweden - Germany		**From Nordel**	**To Nordel**		
Västra Kärrstorp - Herrenwyk	450=	600 [2]	600 [2]	250	220

Transmission capacity varies between 1,200 and 1,500 MW, depending on operating conditions.
Owing to restrictions in the German network, transmission capacity is currently limited to 450 MW from Nordel and 400 MW to Nordel.

Source: http://web.ing.puc.cl/~power/alumno99/Development%20of%20the%20Nordic%20Electric%20market/Nordel.htm

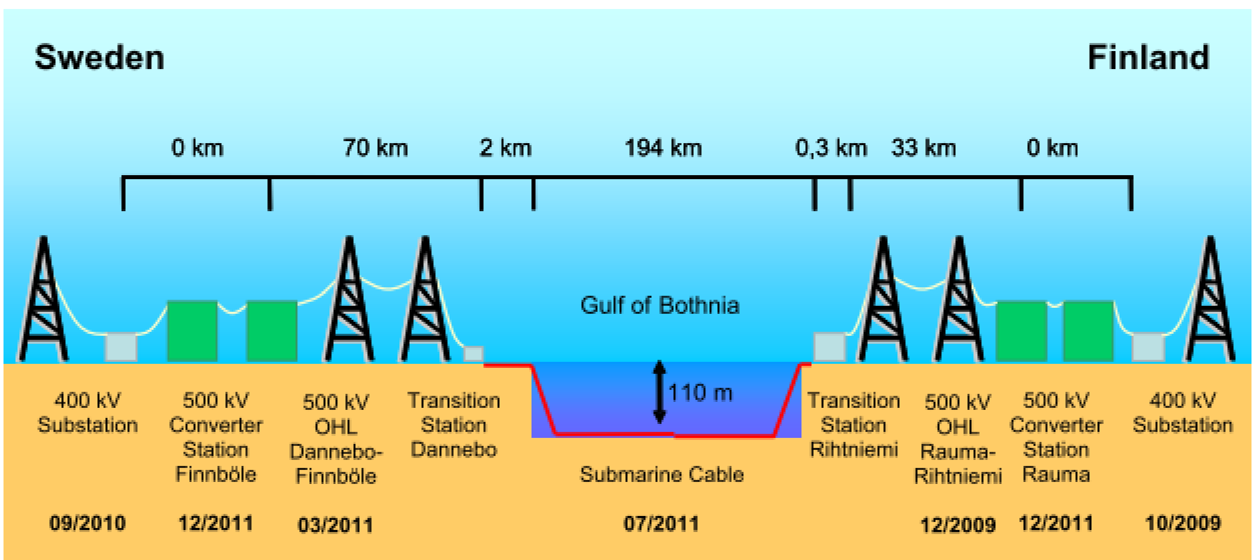
The extension of the Fenno-Skan link is a response to the needs of the electricity market. The submarine cable will increase the electricity transmission capacity between Finland and Sweden by approx. 40 percent and integrate the Nordic electricity market even more closely. The project will reduce temporary differences between Finnish and Swedish electricity prices, which can result if interconnection capacity is insufficient. The interconnection will also reduce losses in the Nordic transmission grids and improve power system security. **Fenno-Skan is one of five prioritized cross-sections recommended by Nordel.**

Features of the Fenno-Skan project:

- Capacity at the receiving end: AC 800 MW
- Voltage: 500 kV (DC)
- Current: 1 670 A
- Overhead line in Finland: 33 km
- Overhead line in Sweden: 70 km
- Submarine cable: 200 km
- To be commissioned by the end of 2011

The European Union has awarded TEN grants for this project.

Figure 9: Fenno-Skan HVDC interconnection cross section



Source: www.svk.se

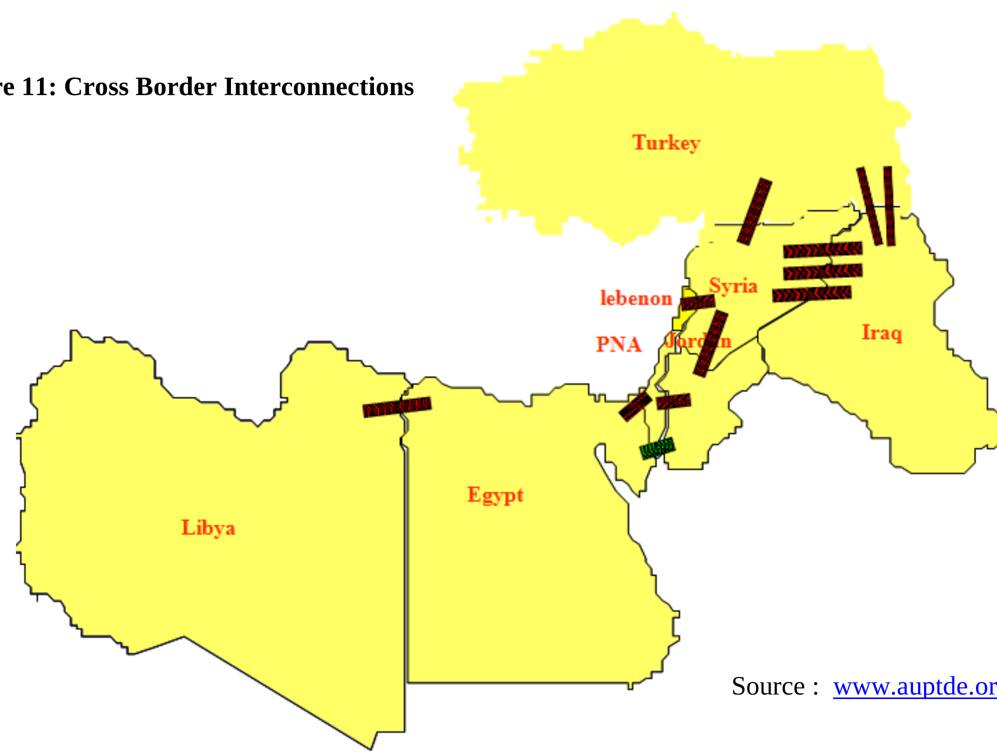
3. Seven Countries Interconnection Project

The Seven Countries Interconnection Project (SCIP) will interconnect the grids of Libya, Egypt, Jordan, Syria, Iraq, Turkey and Lebanon. This project was launched at the beginning of the last decade. **The interconnection will allow for cost reduction, increased reliability, secure operation of networks and economies of scale**, with cost savings from the construction of larger generating units with higher efficiency. The future plan will include enlarging the Seven Countries Power Grid to link it with Europe via Turkey in the north and Morocco in the west.

Figure 10: The Seven Countries Interconnection Project

***The Seven Countries Interconnection Project will connect in stages the grid systems of Libya, Egypt, Jordan, Syria, Jordan, Iraq, Turkey and Lebanon*.**
Source:
http://www.powergenworldwide.com/index/display/articledisplay/288634/articles/middle-east-energy/volume-4/issue-1/features/transmission-grid-network-the-seven-wonders-of-interconnection.html

Figure 11: Cross Border Interconnections



Source : www.auptde.org

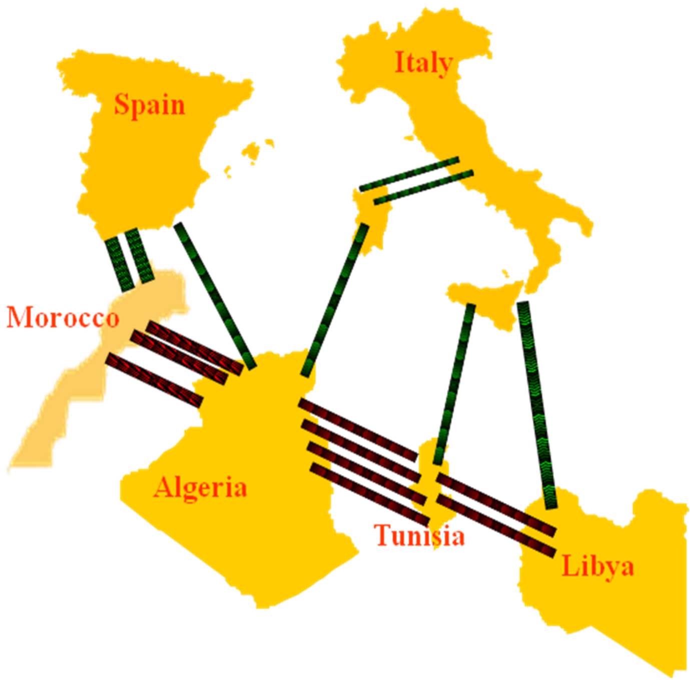
Projects under construction:

- **Syria - Turkey**
- **Syria - Lebanon**
- **Turkey- Iraq**
- **Syria - Iraq**
- **Jordan – Palestine**

Planned projects:

- **Egypt – Palestine**
- **Arab Maghreb – European Interconnection Projects:**

Figure 12: Arab Maghreb – European Interconnection Projects



Source : www.auptde.org

Existing project:

- **Morocco – Spain**

Planned projects :

- **Algeria – Spain**
- **Algeria – Italy**
- **Tunisia – Italy**
- **Egypt, Libya, Tunisia, Algeria and Morocco** (The ELTAM Project)

Completion of all 400 kV interconnection lines is expected by 2012-2015:

- Expected operation of 400 kV Algeria – Morocco line: May 2008
- Expected operation of 400 kV Algeria – Tunisia line: 2011
- 400 kV, interconnection Tunisia – Libya (Bouchama- Sud Sarman): by 2012
- 500 kV, interconnection Libya –Egypt (Tobruk – Marsat Matrouh): by 2015

IV. Case of Africa[3]

1. Energy situation

➢ **Huge fossil energy resources:**

With huge oil and gas reserves in the northern, southern and western regions and coal reserve in the western and southern regions of the continent, Africa could adequately meet its electricity needs solely from fossil fuels. Unfortunately, very little **investment capital**, **from public funds, is used in** the energy sector for electricity generation. Africa **over relies on aid money** for infrastructure.

➢ **Huge renewable energy resources:**

Africa's **renewable energy resources** are as diverse as they are evenly distributed and abundant in quantity:

- Geothermal resources in the Red Sea Valley, the Rift Valley and between Nigeria's Atlantic southeast coast and Cameroon's Atlantic southwest coast remain largely untapped.

- Although **Hydroelectricity** is the biggest source of electricity in a number of countries in Africa, its potential remains largely under utilized. Some of the largest water flows in the world are found in Africa's regions. **Decentralized mini** and **micro hydro power plants** on the Nile, Niger, Senegal, Congo, Orange, Limpopo, Volta and Zambezi rivers could generate enough electricity to meet all of Africa's energy needs.

- Energy from Wind and Ocean current: Africa is surrounded by Indian Ocean on the east coast and Atlantic Ocean on the west coast with huge **wind** and **ocean currents** that, if harnessed for electricity, are sufficient to supply all the electricity needs of Africa.

-Solar resources are by far the single most abundant energy resource in Africa and if harnessed could meet all the electricity needs of Africa. Solar energy is abundant everywhere on the continent. As Africa lacks lacking transmission lines, solar can be utilized to provide off-grid electricity to remote communities far from national grids, as well as utility scale electricity for industries.

2. Electrical power in Africa and the different projects

Overview:

- The development of Africa's electrical power sector is a prerequisite for growth in all industries. A regular, consistent power supply will do much to attract foreign investment and entice international companies to establish operations in Africa. Unfortunately, a combination of corruption, droughts, wars and aging equipment has contributed to an unreliable and underserved electricity supply in many African countries.
- Africa's electricity consumption is expected to grow at a rate of 3.4 % per year over the period between 1999 and 2020. Africa stands to benefit in the future from interconnection projects initiated and implemented by the New Partnership for Africa's Development (NEPAD), an initiative that sees investment in Africa's infrastructure as a high priority. All NEPAD power projects are aimed at boosting electrical power generation, distribution and transmission in Africa.
- Africa is endowed with fossil and renewable energy resources vast enough to cover all its energy needs**,** yet it is estimated that no more than 20 per cent, and in some countries as little as 5

[3] Sources : http://www.desertec-africa.org ; www.gccia.com

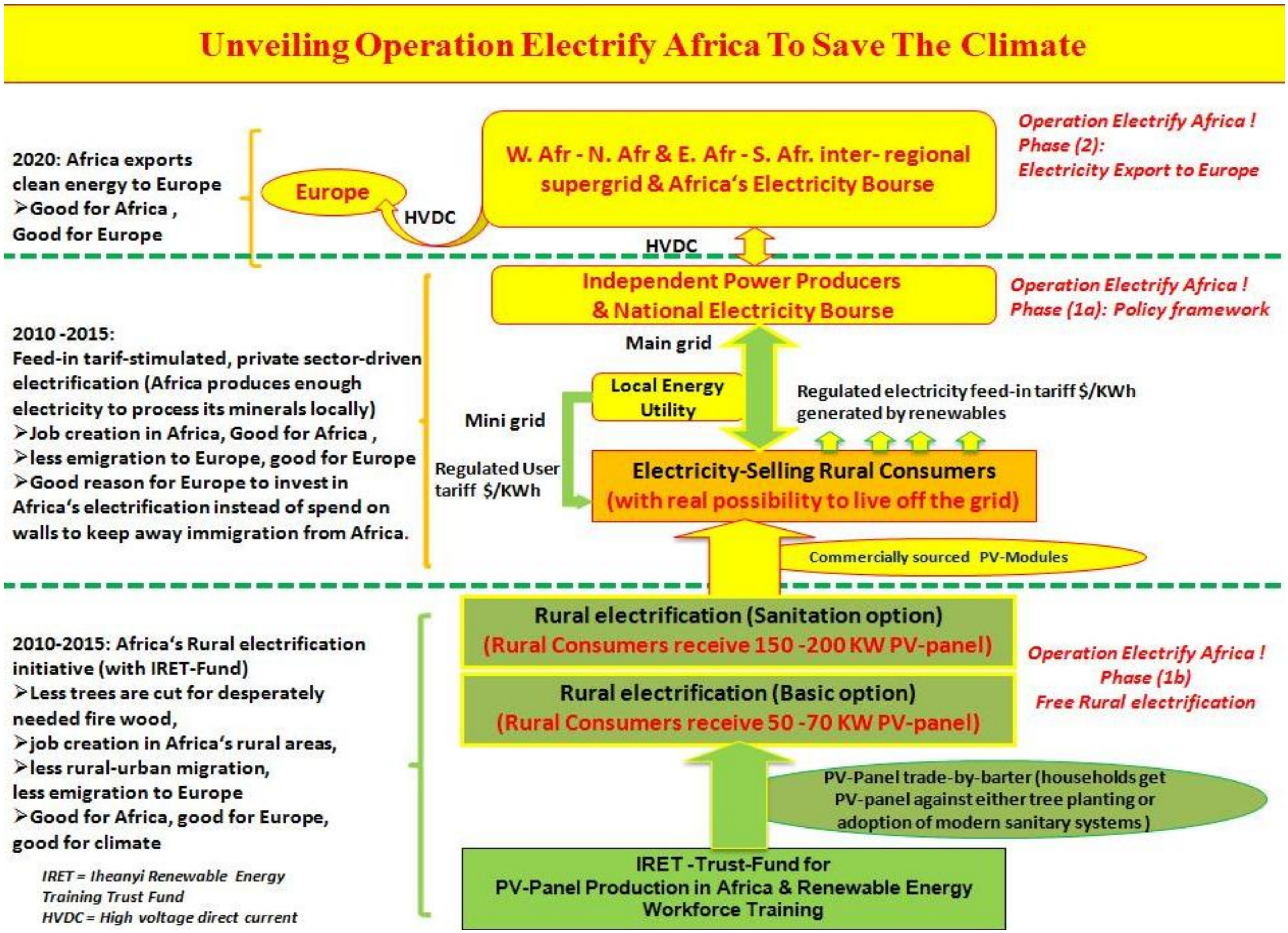
per cent of the population has direct access to electricity. The proportion of people in Africa still without electricity is higher than in any other continent. The rate of urban electrification is lower than in any other continent.

Figure 13: World rate of electrification

World rate of electrification						
	Population (Million)	Population with electricity (Million)	Population without electricity (Million)	Electrification rate (%)	Urban Electrification rate (%)	Rural Electrification rate (%)
Africa	891	337	**554**	**37.8**	**67.9**	**19.0**
Developing Asia	3,418	2,488	930	72.8	86.4	85.1
Latin America	449	404	45	90.0	98.0	65.6
Middle East	186	145	41	78.1	86.7	61.8
Developing countries	4,943	3,374	1,569	68.3	**85.2**	**56.4**
Transition Economies and OECD	1,501	1,501	8	99,5	100.0	98.1
World	6,452	4,875	1,577	75.6	**90.4**	**61.7**

Source: http://www.desertec-africa.org

Figure 14: Operation Electrify Africa Source: http://www.desertec-africa.org

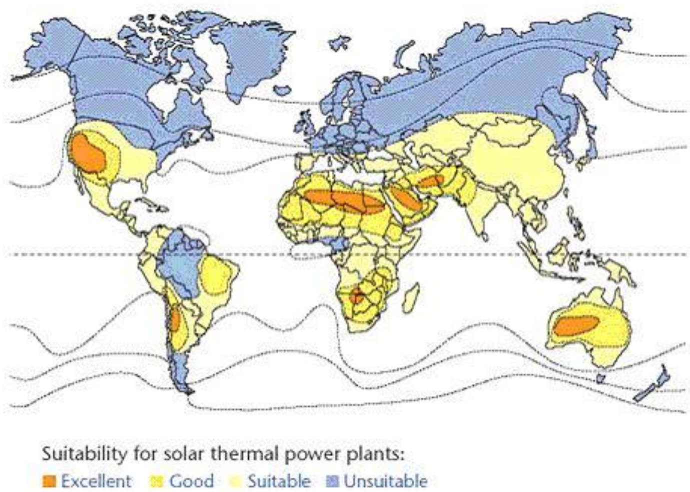


3. Desertec Project

DESERTEC-Africa is an independent organization that has set itself a mission to get the African continent to take advantage of what it has in abundance: **solar energy** on the African deserts to produce what it is in dire need of: **electricity**, by means of Concentrated Solar Power (CSP), as well as harnessing wind energy along its coastal regions.

Africa is the only region in the world with many sites that are considered either excellent (Sahara, Kalahari and Namib deserts) or suitable for solar power installations (arid Sahel steppes and savanna Grassland which stretch from east to West Africa).

Figure 14: Suitability for Solar Thermal Power Plants



Source: http://www.desertec-africa.org

Figures 15: Areas in the world with high solar radiation include Sahara, Kalahari and Namib deserts

Source: http://www.desertec-africa.org

4. The Gulf Cooperation Council Project

The **Cooperation Council for the Arab States of the Gulf**, also known as the **Gulf Cooperation Council** (GCC), is a political and economic organization involving the six Arab states of the Persian Gulf (Kuwait, Bahrain, Qatar, UAE, Oman, and Saudi Arabia) with many economic and social objectives. GCC member states participating in the joint power grid have benefited greatly from the advantages provided since the first day the network came into operation.

Figure 16: The Cooperation Council of the Arab States of the Gulf

THE INTERCONNECTION PROJECT
The GCC Interconnection Grid will be developed in three (3) phases, namely:

Phase I: Interconnection of Kuwait, Saudi Arabia, Bahrain and Qatar. This system is the GCC North Grid.

Phase II: Interconnection of the Independent systems in the UAE as well as Oman. This is the GCC South Grid. GCCIA is not involved in the execution of Phase II.

Phase III: Interconnection of the GCC South Grid with the GCC North Grid. This phase completes the interconnection of the six (6) Gulf States.

Source of this paragraph: www.gccia.com

CONCLUSION:

Cross-border interconnections are very important and offer multiple benefits, including the tapping of abundant renewable energy. The ultimate objective of an interconnection is to provide power to customers economically, safely, reliably, efficiently, and with minimal environmental impact. This report enumerates the many benefits of electrical interconnections. Grid interconnections require a careful calculation of costs, benefits, and risks. Technical planning of a grid interconnection should be coordinated with economic, organizational, legal, and political aspects of a potential interconnection project from the outset of project consideration. As stated by the Russian engineer, Victor Yershevich, Director of Science, Energoset Project :

> "We must see the problem as a whole. We must understand and explain to all other men on our planet that the interconnection between power systems of different countries is one of the important tasks for all humanity."

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http://www.desertec-africa.org

www.gccia.com

Appendix:
Benefits and risks of interconnection

Dimension of Energy Security	Interconnection Benefits	Interconnection Costs/ Risks
Energy Supply	Improved electricity supply	Higher energy imports and increased import dependence
	Diversification of energy supply sources	Dependence on reliability in the interconnected system
	Diversification in fuel imports	Obligation to export resources
	Improved reliability of electricity supply	
Economic	Lower costs of fuel, capital expenditures for importing country (or both partners, in some exchanges)	Additional costs of infrastructure for interconnection
	Earnings from power sales through interconnection (foreign exchange)	Additional costs for generation and other infrastructure in exporting nation
	Indirect economic benefits of less expensive, more reliable electricity (education, jobs, health care, re-spending of cost savings)	Foreign exchange outlays and indebtedness for infrastructure investments
	Cost savings through substitution of electricity for other fuels (lamp oil, batteries)	Exposure to energy price volatility on international markets and/or to terms of "locked-in" contracts
	Economic interdependence	Economic interdependence
Technological	Improvement in power quality	Exposure to risk from poor power quality in interconnected nations
	Exposure to new technologies that can be replicated to improve power system	Exposure to risk from use of new technologies

Dimension of Energy Security	Interconnection Benefits	Interconnection Costs/ Risks
	Reliance on Proven Technologies for generation and transmission	Risk of being obligated to continue use of an older technology as newer, cheaper, more flexible technologies become available (lack of future adaptability)
Environmental	Reduced emissions of air pollutants of local, regional, and/or global significance	Increased emissions of air pollutants of local, regional, and/or global significance Lower = preferred
	Reduced water pollution, solid wastes due to avoided generation, fuel storage, other fuel cycle activities	Increased water pollution, solid wastes due to additional generation, fuel storage, other fuel cycle activities, construction impacts
	Reduced ecosystem and aesthetic impacts through avoided construction of new generation	Increased ecosystem and aesthetic impacts through construction of power lines, new generation plants, construction/ operation of facilities in previously isolated areas
	Reduced exposure to environmental risk through avoidance of need to build new generation with uncertain environmental impacts	Increased exposure to environmental risk through reliance on big projects with uncertain, potentially diverse environmental impacts
Social and Cultural	Increased availability of medical care, education, employment opportunities through extended and/or more reliable and/or less expensive electricity supplies	Risk of social conflict if benefits of interconnection project are not shared appropriately, or if graft or other preference is perceived
	Reduced exposure to risk of social or cultural conflict by bringing cultures together to share power resources	Increased risk of internal social and cultural conflict as isolated populations are brought into contact with construction teams and others associated with the interconnection project
	Improvement of social capacity to participate in complex decision-making	Isolation of populations from traditionally-used resources; "boomtown" impacts

Dimension of Energy Security	Interconnection Benefits	Interconnection Costs/ Risks
Military/Security	Reduced exposure to international military/security risks by increasing political and economic dependence between nations	Increased exposure to international military/security risk by tying economy to inputs from another nation, thus leaving both nations vulnerable to each others' internal conflicts
	Reduced need for internal security due to social benefits of improved electricity supply (reduced unemployment, greater education)	Increased need for spending on energy-related security arrangements, such as on securing power lines