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The Potential of Regional Power Sector Integration

**Gulf Cooperation Council
Countries | Transmission &
Trading Case Study**

Submitted to ESMAP by:
Economic Consulting Associates

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Abbreviations and acronyms

AC	Alternating Current
EIA	US Energy Information Administration
GCC	Gulf Cooperation Council
GCCI	Gulf Cooperation Council Interconnection
GCCIA	Gulf Cooperation Council Interconnection Authority
GIS	Gas Insulated Substation
GWh	Gigawatthour
Hz	Hertz
HVDC	High-Voltage Direct Current
IPP	Independent Power Producer
ICC	Interconnection Control Center
IWPP	Independent Water and Power Producer
MW	Megawatt
kV	Kilovolt
OPEC	Organization of Petroleum Exporting Countries
PETA	Power Exchange and Trading Agreement
TSO	Transmission System Operator
UCTE	Union for the Co-ordination of Transmission of Electricity
WTO	World Trade Organization

Preface

This case study is part of an Energy Sector Management Assistance Program (ESMAP) project on Regional Power System Integration (RPSI). The objective of the project is to facilitate and accelerate RPSI projects in developing countries around the world. The project will draw on international experience and theoretical analysis in this area to provide a framework to assess:

- o the economic, financial and environmental benefits that can accrue to regional power trading;
- o the institutional and regulatory arrangements needed to sustain and optimize regional projects; and
- o the ways in which obstacles to integration have been successfully overcome.

The final output of the project will be an umbrella report, *Regional Power Sector Integration – Lessons from Global Case Studies and a Literature Review*. This review will summarize the 12 case studies and literature review undertaken and analyze common themes on barriers to RPSI and solutions to overcome them.

Economic Consulting Associates was contracted to execute the project. In doing so, we are working closely with ESMAP and World Bank staff, as well as government officials, utility, power pool, and regional economic community personnel, and others directly involved in implementing regional power schemes.

This and other 11 Case Studies are prepared as clear, factual presentations of the selected projects. The intent is to provide a direct, easily digestible description of each of the selected projects without imposing an analytic framework or making judgments about the degree of success. Such analysis will be undertaken at the global level, considering the entirety of experiences from the Case Studies, in the aforementioned umbrella report.

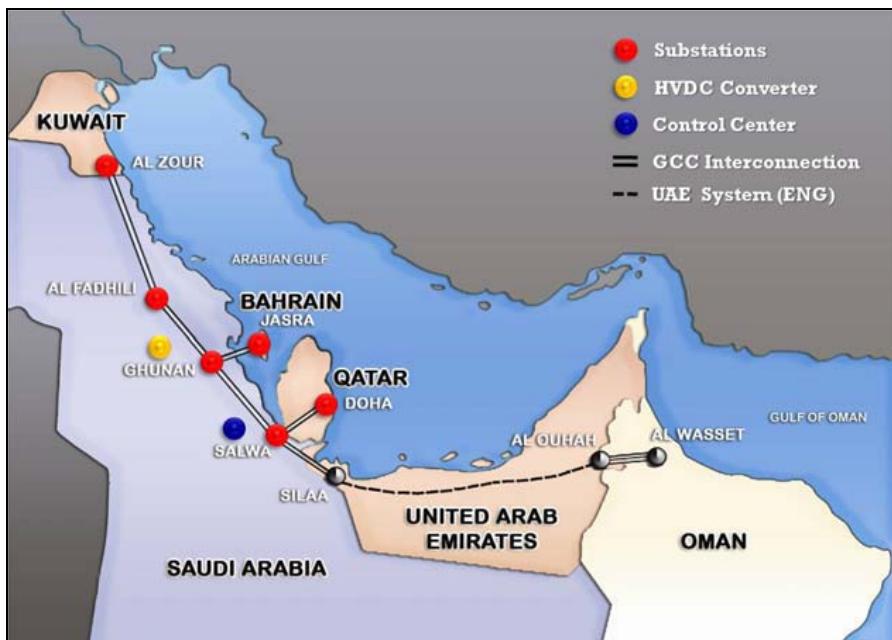
All 12 Case Studies follow a uniform structure to facilitate ease of comparison and reference from one Study to the next. Some sections are longer than others, depending on the specifics of the Study. Additionally, there is some cross-referencing within each Study.

1 Executive summary

The Gulf Cooperation Council (GCC) electricity interconnection scheme was originally conceived in 1981 but took off in earnest in 2001 when the GCC Interconnection Authority (GCCIA) was established and, subsequently in 2004, when the national governments of the six member states – Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates (UAE) and Oman – agreed to finance the interconnections and a control center. The physical infrastructure (see Figure 1) is being implemented in three phases, the last of which – to connect the northern countries (Kuwait, Saudi Arabia, Bahrain and Qatar) with the southern states (UAE and Oman) – is expected to be completed in 2010.

The physical infrastructure consists of an AC interconnection of the 50 Hz systems of Kuwait, Bahrain, Qatar, UAE and Oman with a back-to-back HVDC interconnection to the 60 Hz Saudi Arabian system.

Figure 1 GCC Geographical Route of the Interconnection



Source: Al Asaad, *GCC: The backbone of power reform*

In parallel with the interconnection of the GCC electricity networks, the GCC countries have taken steps toward greater integration of the gas networks. The GCC gas pipeline project currently exports from Qatar to UAE and Oman, and consideration has been given to export gas to Bahrain and Kuwait.

Other than Bahrain, the countries participating in the GCC electricity interconnection project are well endowed with oil and/or natural gas resources. Saudi Arabia, Kuwait and the UAE have substantial oil reserves with associated natural gas. Qatar holds the third-largest gas reserves in the world and is the world's top exporter of natural gas as LNG. The GCC electricity trading scheme is unusual in that four of the GCC countries endowed with major

hydrocarbon resources are members of OPEC,¹ and while their exports of oil are capped by OPEC quotas, their domestic consumption is not. This results in a low opportunity cost for domestic oil use, and, despite the high export value of the petroleum products, the economic incentive for oil-rich countries to import electricity or use natural gas in power generation is significantly diminished. Because the international market for natural gas is much more regionalized and fragmented, OPEC-style policies to cap exports have not been adopted. Despite this, the cost of exporting gas outside the region (as LNG) is high, the opportunity cost of using gas domestically or regionally for power generation is relatively low, and there is therefore significant use of natural gas for power generation among GCC countries either using domestic gas or gas imported from Qatar (as is the case in the UAE and Oman).

Qatar is a major exporter of natural gas within the region to UAE and Oman. Kuwait and Bahrain were also hoping to import gas from Qatar. But concerns that exports of LNG have been overcontracted have led the Qatar government to place a moratorium on further gas export contracts both regionally and internationally. Because of this moratorium, and despite of the abundance of oil and gas in the region and the low opportunity costs of petroleum products and natural gas, three GCC countries are, or are now considering, building coal-fired power plants. The moratorium disrupted gas-fired power generation investment plans in Bahrain, UAE and Oman that were based on imported gas and, given the long periods necessary to make investments to allow alternative regional sources of natural gas or petroleum products to supply power plants, Dubai, Abu Dhabi and Ajman Emirate and Oman have paradoxically been forced to look for alternative energy sources (coal) from outside the region to supply future power plants.

Instead of being a tool to foster greater economic efficiency through regional dispatch of plants, the GCC electricity scheme was envisaged primarily to allow participating countries to share reserve capacity to minimize overall investment in peaking plant. The feasibility studies justified the interconnection scheme on the basis of savings in reserve generating capacity. The trading arrangements, which are still under development, are based primarily around the interconnectors functioning for the sharing of reserve power generation capacity and with a secondary function to allow active trade in electricity.² However, the balance of the capacity of the interconnector after allowing for its primary functions is not sufficient to allow major exchanges of electrical energy in base load.

The legal framework for trade is centered on the proposed Power Exchange Trading Agreement (PETA) which will be signed by participating entities – primarily the transmission entities in member countries. This agreement relates chiefly to the obligations of participating entities, including an obligation to maintain a minimum (standing) reserve margin of capacity relative to system peak demand and operating reserves, and arrangements by which members may use reserves from other countries to satisfy those obligations. Any surplus interconnector capacity available once these primary roles are satisfied may be used to trade energy. Any such trades will be bilateral contracts between

¹ Oman and Bahrain are relatively small oil producers and are not OPEC members.

² “Active trade” here refers to substantive exports or imports of electricity and can be considered similar to the export or import of primary energy (e.g., natural gas or, in other contexts, coal). Active trade is distinguished from the other uses to which an interconnector may be put, including reserve sharing (i.e., use of the interconnector to provide mutual support in the event of unplanned plant outages) or trading that minimizes short-term fuel and variable costs by optimally dispatching the plants on the combined system to exploit differences in the costs of the plants that are operating “at the margin” in each hour.

the trading parties, and the only role of the GCCIA in relation to these trades will be to ensure that sufficient interconnection capacity is available before authorizing the trade and to provide information to trading parties on the trades that actually took place. It has also been proposed that the GCCIA will auction interconnector capacity rights.

The GCCIA is governed by a board of directors nominated by member countries, and the rules and regulations governing the Authority and members are issued either by the board or by a General Assembly comprising the board and members of planning committees and operating committees (also nominated by member countries). The GCCIA and the interconnection control center are located in Saudi Arabia.

The trading arrangements have not yet been finalized and, at the time this case study was prepared, the physical infrastructure, other than the northern grid, had yet to be completed, so that no information was available on actual operation of the scheme and whether the trade realized in practice will go substantially beyond the sharing of reserve capacity to allow trade in electrical energy.

2 Context

2.1 Economic and political context

The GCC electricity interconnection project involves six countries of the Middle East (see Annex A1 for economic statistics on the countries) of which three are very well endowed with oil and gas, one is well endowed with gas, one has moderate oil and gas resources, and only one has relatively poor endowments of hydrocarbons. The project was originally conceived in 1981 as a means to help develop closer economic and political ties among the six countries. The closer ties were to have included not only electricity but also transport and telecommunications.

With increasing world market prices for oil, oil products and natural gas, the wealth of the six countries has grown, and increasing wealth has been associated with population growth and increasing demand for electricity. As a result, large investments are required in electricity generating capacity. In response to the challenge of meeting the growing demand for electricity, a number of the countries have begun to liberalize their electricity markets. They have invited private participation by having independent power (and water) plants sell their output to a single buyer or to a utility:

- o Saudi Arabia has formed the Electricity and Co-Generation Regulatory Authority.³ IPPs are planned, and privatization is under discussion.
- o The Qatar General Electricity & Water Corporation (Kahramaa) was created in 2000 as a single buyer of electricity and water from IPPs under 25-year contracts.⁴
- o Abu Dhabi (one of the emirates of the UAE) has created the Abu Dhabi Water and Electricity Authority as the single buyer and has established the Abu Dhabi Regulation & Supervision Bureau as the regulator. Dubai Electricity and Water Authority and the Sharjah Electricity and Water Authority have discussed developing power plants using the IPP model but lag behind Abu Dhabi.
- o Oman has introduced the Oman Power and Water Procurement Company as the single buyer.

Despite the abundance of hydrocarbon resources in the GCC countries, three of the GCC states have now begun to develop coal-fired power plants, or are considering doing so (see Section 2.2). But at the time the interconnection project was re-activated in 2001, active electricity trade was not envisaged as a primary goal of the scheme.⁵ Instead the

³ The Saudi Electricity Regulatory Authority was established in 2001, and its name changed in 2004.

⁴ www.kahramaa.com.qa

⁵ "Active trade" here refers to substantive exports or imports of electricity and can be considered similar to the export or import of primary energy (e.g., natural gas or, in other contexts, coal). Active trade is distinguished from the other uses to which an interconnector may be used, including reserve sharing (i.e., use of the interconnector to provide mutual support in the event of unplanned plant outages) or trading that minimizes

interconnector was seen as a means to reduce capacity reserve requirements and reduce investment in peaking capacity.

In parallel with the interconnection of the GCC electricity networks, the GCC countries have taken steps toward greater integration of the gas networks. The GCC gas pipeline project will export natural gas from Qatar to the UAE, Bahrain, and Kuwait. This project includes the following planned components:

- o Dolphin Gas pipeline exports natural gas from the Qatar Northern field to UAE and Oman. It became operational in 2007 when gas began to flow to Abu Dhabi; exports to Oman began in November 2008.
- o Qatar-Bahrain pipeline to export natural gas from Qatar to Bahrain.⁶
- o Extension of the Qatar-Bahrain pipeline to Kuwait.

2.2 Supply options

The energy resources and the existing power generating capacity in the GCC states are described in the sections that follow. It is important to note that the demand for potable water is a factor affecting the location of power plants and the possibilities for trade. All GCC countries face water shortages, and all rely on desalination to differing degrees to provide potable water. In this region, one of the most efficient methods to produce potable water is through desalination using the waste heat from electricity generation. The demand for water is therefore an important driver affecting the optimum location of power plants in the GCC countries.

2.2.1 Resources

Four of the six GCC countries have abundant oil and/or gas resources, and one has moderate reserves, as summarized in Table 1. The countries are home to the world's largest concentration of hydrocarbon resources in the form of crude oil and natural gas. Saudi Arabia has the world's largest oil reserves and is the world's largest producer of oil. The UAE is an important oil producer with the fifth-largest proven oil reserves in the world and is the world's eighth-largest producer. Qatar and Oman are also major world producers of oil and natural gas, and Qatar has the third-largest gas reserves in the world. Among the GCC countries, only Bahrain is endowed with relatively small reserves of gas and oil by the standards of its neighbors.

short-term fuel and variable costs by optimally dispatching the plants on the combined system to exploit differences in the costs of the plants that are operating "at the margin" in each hour.

⁶ The future of the planned Qatar-Bahrain and Qatar-Bahrain-Kuwait pipelines is uncertain due to the temporary moratorium imposed by Qatar on the expansion of gas extraction from its North field. Saudi Arabia has also raised objections to laying the pipeline in its territorial waters in the Gulf.

Table 1 Energy Resources of GCC Countries

Country	Energy Resources
Kuwait	<p>Kuwait is ranked fourth in terms of world oil reserves and is the tenth-largest producer of oil in the world. It is ranked 20th in world natural gas reserves, with proven reserves estimated at around 1.8 trillion cubic meters at the end of 2006. The majority of Kuwait's natural gas reserves are associated.</p> <p>Consumption and production of natural gas was around 12.6 BCM in 2007. Kuwait hopes to significantly increase its use of natural gas, both domestic and imported, especially for use in electricity generation, desalination, and petrochemicals. Prior to the 1990/1991 Gulf War, Kuwait imported significant volumes of natural gas from Iraq, and it plans to restart these imports.</p>
Kingdom of Saudi Arabia	<p>Saudi Arabia has the world's largest oil reserves and is the world's largest producer of oil. It also has the world's fourth-largest gas reserves.⁷ Nearly 60% of proven gas reserves are associated gas at the giant onshore Ghawar field and the offshore Safaniya and Zuluf fields.</p> <p>Gas production nearly doubled over the period 1997 to 2007 from 45.3 BCM to 75.9 BCM, but despite the abundance of gas, production has failed to meet the demand for gas in the power sector. The Kingdom flared around 3.4 BCM in 2007.⁸</p>
Bahrain	<p>Bahrain has proven natural gas reserves of less than 0.1 trillion cubic meters, much of it associated gas from the Awali oil field, and is ranked at a relatively modest 53rd position in terms of gas reserves. With gas production of 11.5 BCM in 2007, it is 39th in the world in terms of production. Imports of gas via pipeline from Iran are under consideration.</p> <p>Bahrain is a relatively small producer of oil.</p>
Qatar	<p>Qatar's proven natural gas reserves were 2.6 trillion cubic meters in 2007, about 15% of the total world reserves and the third-largest in the world behind Russia and Iran. Among the GCC members, Qatar holds the highest reserves, followed by Saudi Arabia, then the UAE. Most of Qatar's natural gas is located in the massive offshore North Field which, uniquely among GCC countries, is almost all non-associated.⁹ Gas production levels stood at 59.7 BCM in 2007. In 2005, Qatar exported 27.6 BCM of LNG, or 14.5% of all globally traded LNG. By 2006, Qatar surpassed Indonesia to become the largest exporter of LNG in the world. Gas consumption, excluding gas for re-injection and flaring, was 20.5 BCM in 2007. Gas was the dominant fuel in 2007, accounting for 81.7% of primary energy demand. The government is, however, concerned that it may not be able to provide gas to fulfil its LNG commitments, and it has placed a temporary moratorium on further contracts to export gas as LNG or via pipelines.</p> <p>Qatar is also among the top oil producers in the world, ranked 13th in the world in terms of oil reserves and 20th in terms of production.</p>

⁷ 7.07 trillion cubic meters in 2006 according to the *BP Statistical Review of World Energy*, June 2008.

⁸ Source: GGFR website.

⁹ EIA country information

Country	Energy Resources
UAE	<p>UAE ranks fifth in terms of world oil reserves and eighth in terms of world oil production.</p> <p>Proven gas reserves are around 6.1 trillion cubic meters. Production of gas for the market (i.e., not flared or re-injected) has increased steadily in recent years, more than doubling from 20 BCM in 1990 to 49.2 BCM in 2007. Gas consumption was around 43.2 BCM in 2007. UAE is an exporter of gas as LNG (7-8 BCM per year) but simultaneously imports up to 17 BCM per year via the Dolphin pipeline from Qatar. In 2007, 0.9 BCM of gas was flared.¹⁰</p>
The Sultanate of Oman	<p>Proven gas reserves in Oman are around 0.7 trillion cubic meters. Consumption of natural gas is approximately 12 BCM, while production is around 30 BCM. Oman exports around 13 BCM of gas as LNG annually and was, until recently, an exporter to UAE, but it is now an importer of gas from Qatar via the Dolphin pipeline, which supplies the country with 2 BCM per year. Oman is among the 20 countries with the largest amounts of gas flared according to GGFR – 1.9 BCM was flared in 2007.</p> <p>Oman is also a relatively important producer of oil and is 24th in terms of production of 35.5 million tonnes in 2007.</p>

Despite the huge endowment of oil and gas reserves, among the GCC countries, energy deficits have emerged. Kuwait, UAE and Bahrain have plans to import natural gas from Iran, Iraq or from neighboring Qatar. Qatar is concerned that it may not be able to fulfil contractual commitments to supply LNG, and it placed a temporary ban on further export projects, including exports to GCC countries. The moratorium on gas exports by Qatar disrupted gas-fired power generation investment plans in Bahrain, UAE and Oman that were based on imported gas and, given the long periods necessary to make investments to allow alternative regional sources of natural gas or petroleum products to supply power plants, power utilities in the region have paradoxically been forced to look for alternative energy sources from outside the region. As a consequence, Dubai, Abu Dhabi and Ajman Emirates and Oman have plans or are considering coal-fired power plants using imported coal.¹¹ Ajman Emirate was reported to have signed a 20-year Build-Own Operate Transfer contract for a 1,000 MW Ajman coal-fired power plant.¹²

2.2.2 Existing generating capacity and supply

The power generating capacity and peak demands of the GCC countries are summarized in Table 2.

¹⁰ http://www.ngdc.noaa.gov/daymsp/interest/gas_flares.html

¹¹ Oman Power and Water Procurement Co., 7-Year Statement (2009-2015). Abu Dhabi Water and Electricity Company (ADWEC), Statement of Future Capacity Requirements, 2008-2030. Dubai's search for alternative fuels is also documented in the ADWEC statement.

¹² Ajman is the smallest of the emirates by area. The signing of the contract was reported by the WAM News Agency (the official news agency of the UAE) to have taken place in July 2008.

Table 2 Power Generating Capacity in the GCC Countries

State	Peak Demand	Generating Capacity
Kuwait	9,710 MW (2008)	Five plants provide electricity and, in some cases, water to the country: Doha East, Doha West, al-Subiya, Shuaiba South, and al-Zour South. The total electrical generation capacity is about 10,300 MW. The majority are fuelled with heavy fuel oil (89%) with some gas-fired plant (9%), but future generation is planned to be gas-fired if gas is available.
Saudi Arabia	34,708 MW (2008) ¹³	Electricity generating capacity reached 37,154 MW in 2007 with a total of 72 power plants—all thermal. In 2007 natural gas supplied 52% of power generation, followed by heavy fuel oil 19%, diesel 18%, and crude oil 11%.
Bahrain	2,136 MW (2007) ¹⁴	Bahrain gets its power from two combined water and power production complexes and two smaller electricity-only plants. In 2007 Bahrain had an estimated generating capacity of 2,767 MW.
Qatar	3,230 MW (2006)	Almost 100% of Qatar's power generation is based on open-cycle gas turbines fuelled with natural gas. Some of Qatar's power plants are integrated with water desalination units. The Qatar Electricity and Water Corporation had a total installed capacity of 2,113 MW and desalination capacity of 0.4 MCM/day in 2007. The balance of demand is met by self-generation by large electricity users.
UAE	13,294 MW (2007) ¹⁵	The total electricity generating capacity in the UAE was around 17,369 MW in 2007. The emirates of Abu Dhabi, Dubai and Sharjah account for 90% of the country's installed capacity. Of the total capacity, 11,526 MW was from gas turbines and 5,829 MW from steam turbines with the balance provided by diesel plants.
Oman	3,031 MW (2008) ¹⁶	The main interconnected system has seven main power plants with around 3,319 MW of capacity, mostly gas fired (92%).

Kuwait's power production¹⁷ is dominated by heavy fuel oil (63%) and crude oil (26%), with the balance provided by gas oil (1%) and natural gas (9.3%).

Saudi Arabia is divided into four operating areas—Eastern, Central, Western and Southern—as shown in Figure 2.

¹³ Saudi Electricity Company Annual Report, 2008.

¹⁴ Bahrain Ministry of Electricity and Water website: www.mew.gov.bh

¹⁵ www.moenr.gov.ae

¹⁶ The main interconnected system only. Source: 7 Year Statement (2009-2015)

¹⁷ "Restructuring Kuwait Electric Power System: Mandatory or Optional?" *Proceedings of World Academy of Science, Engineering and Technology*, Vol. 35 (November). Data for 2005.

Figure 2 Electricity Map - Saudi Arabia



Source: Saudi Electricity Company, Annual Report 2007 www.se.com.sa

Saudi Arabia's Eastern region is interconnected with the GCCI, and the Eastern region is in turn interconnected with the Central region. All of the kingdom's power generation is thermal and burns natural gas, heavy fuel oil, crude oil and diesel oil. In 2007 natural gas supplied 52% of power generation, followed by heavy fuel oil at 19%, diesel at 18% and crude oil at 11%. In the Eastern region, natural gas is the dominant fuel for power plants.

Almost all of Qatar's power generation is based on open-cycle gas turbines, and almost all power plants are fuelled with natural gas.

The power sector in the UAE is organized in different ways in each of the seven emirates. There are four power authorities in the UAE:

- o Abu Dhabi Water and Electricity Authority;
- o Dubai Electricity and Water Authority;
- o Sharjah Electricity and Water Authority; and
- o Federal Electricity and Water Authority (FEWA), which is responsible for the other four northern emirates of Ajman, Umm Al Qaiwain, Fujairah and Ras Al Khaimah.

Generation in the Main Interconnected System (MIS) of Oman is largely gas-fired, but there are plans to introduce coal-fired power plants by 2015. The electricity supply industry in Oman is divided into three main isolated systems and a number of small isolated networks:

- o The main interconnected system (MIS) covers about 90% of the total electricity supplied in the sultanate, or approximately 500,000 customers. This network will be connected to the GCC inter-connected system.

-
- o The Salalah system covers Salalah and surrounding areas in the Dhofar region in the south of Oman, serving around 50,000 customers.
 - o Petroleum Development Oman, the main oil company in Oman, has its own dedicated system of 618 MW.

2.3 Demand

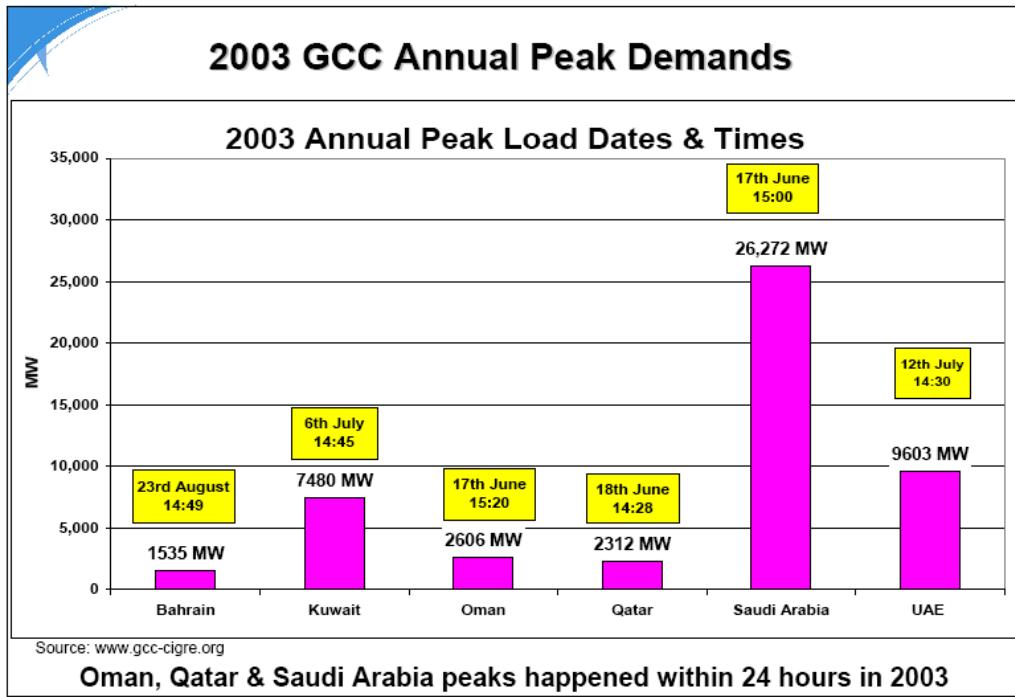
The current aggregate peak demand in the six GCC countries was shown in Table 2 to be approximately 65 GW, of which nearly half is accounted for by Saudi Arabia.

Most of the GCC countries have been developing energy-intensive industries (such as petrochemicals, steel, aluminium and cement), and some, particularly the UAE, have developed other economic sectors such as tourism and business services. The birth rate in the region is also high at 7% per year (one of the highest in the world). The combinations of high population growth, development of electricity-intensive economic activity, and low electricity prices have led to a fast-growing demand for electricity. The electricity sector in the region has been encountering exponential growth, which has reached almost 10% annually in many of the member states, thus requiring approximately US\$100 billion worth of investments in the electricity sector in the next 15 years.¹⁸

The GCC countries generally have similar load patterns, with peak demand occurring in the daytime during the summer months driven primarily by high temperatures and air conditioning load. As shown in Figure 3, the peak demands of three of the GCC countries – Oman, Qatar and Saudi Arabia – peaked around a single day in 2003. But despite the relatively close geographical proximity of the GCC countries, there was some diversity of peak demands, with the peaks of other countries occurring from June through to August. Though diversity of demands does exist, the absence of major differences in timing of peak demands implies that the opportunities to exploit the interconnector are more limited than they would be in other regions.

¹⁸ Hassan K. Al-Asaad (2008) *GCC: The Backbone of Power Sector Reform*. Power Engineering International.

Figure 3 GCC Annual Peak Demands



Source: Miller, Akhtar, and Fakhar (2005).

2.4 Energy tariffs

Domestic energy prices in the GCC countries tend to be low by international standards for both economic and sociopolitical reasons.¹⁹ Electricity is free to Qatari nationals. In Saudi Arabia prices are only approximately US¢ 1.3/kWh for residential customers up to 2,000 kWh per month, and for industrial customers the tariff is only US¢ 3.2/kWh. Bahrain, which has relatively modest hydrocarbon resources, charges residential customers using less than 2,000 kWh per month only US¢ 0.8/kWh. Prices are therefore typically well below international benchmarks.

While it will always be difficult to assess the true economic costs of fuels in the energy resource-rich GCC countries and it will therefore be difficult to estimate corresponding cost-reflective electricity tariffs, we note that artificially low (i.e., subsidized) prices would undermine incentives for producers in one country to export electricity via bilateral contracts to consumers in another. While the current institutional arrangements do not allow bilateral contracts between producers in one country and eligible consumers in another, we note that domestic pricing policies could be a barrier to active electricity trade in the future should suitable trading arrangements be established and should economic cost differences be sufficiently high to justify active electricity trade (see below).

¹⁹ Sources: Saudi Arabia: Ministry of Water and Electricity, www.mowe.gov.sa; Bahrain Electricity and Water Authority, www.mew.gov.bh/en/

Four of the six GCC countries are members of OPEC and as such exports of crude oil are capped by the quotas agreed upon with OPEC and are designed to optimize the international price of oil and maximize net revenues from exports of oil. This applies particularly to Saudi Arabia which, by itself, has the ability to affect international crude oil prices. Most countries that are small in relation to international energy markets are price takers, and the economic value of energy consumed or energy produced is the international market price. In such countries, the consumption of oil in the domestic market has an economic cost measured either as the cost of importing that oil or the opportunity cost of not exporting the oil. However, the oil-exporting GCC countries, collectively with other OPEC members, are not price takers, and oil that is not consumed in the domestic market cannot automatically be exported. This applies particularly to Saudi Arabia, which accounts for half of the electricity demand in the GCC countries. A barrel of oil that is not consumed domestically may therefore be left in the ground and exported at some date in the distant future. The economic value of oil and of oil products that are used in the domestic market in GCC countries may therefore be low, and policies that price oil-related energy products at low levels may therefore be economically justified.

This economic justification for typical GCC energy pricing policies does not, however, extend to all GCC countries,²⁰ nor does it extend to the sale of energy products to energy-intensive export industries within a country. The export of energy-intensive products such as fertilizer or aluminum has the same impact of depressing international energy prices as the export of the primary energy itself.

This has important implications for electricity trade among GCC countries. Since the economic value of oil is low and the cost of production is low, there is a strong economic argument in favor of using oil products for power generation to supply the domestic market. But this applies equally to all GCC countries, so there will be fewer opportunities for energy trade among GCC countries except among those, such as Bahrain, UAE or Oman, that are expected to import energy from outside the region.

Given that there is no international market for natural gas, the economic justification for selling gas to the domestic market at prices below international netback prices is much weaker. Nevertheless, most of the GCC countries do sell natural gas at very low prices. Saudi Arabia has, for some time, sold natural gas at only US\$0.75/mmbtu, which is well below the opportunity cost of export to Saudi's neighbors, some of which are contemplating imported coal.

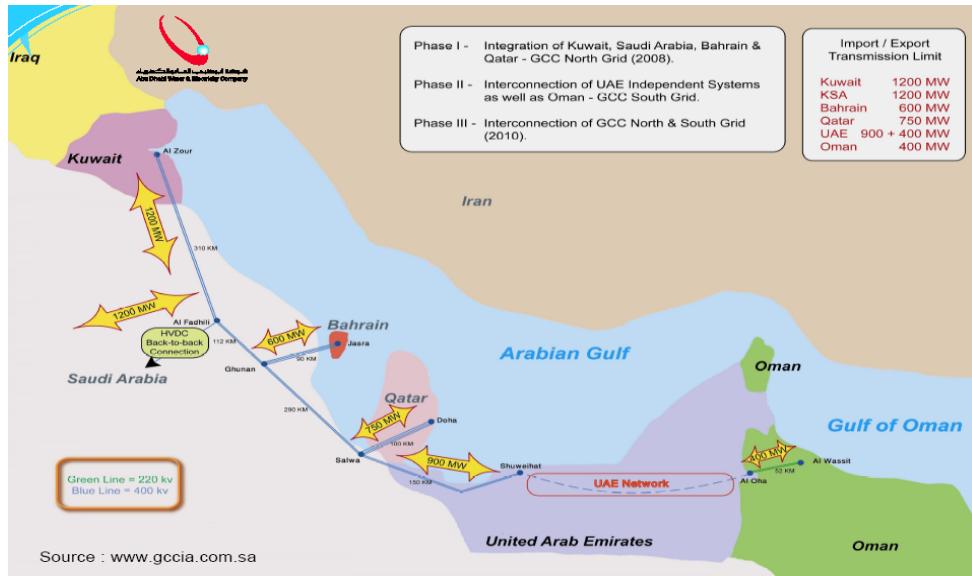
²⁰ Bahrain in particular.

3 History of the scheme

3.1 Overview—including timeline/chronology

The GCC regional power grid shown in Figure 4 will allow electricity exchange among the six member states—Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates (UAE) and the Sultanate of Oman.

Figure 4 GCC Electricity Interconnection



Source: www.gccia.com.sa

3.1.1 History

The GCC Interconnection (GCCI) project was formally inaugurated as long ago as 1981 with a signed agreement between GCC countries to interconnect their networks, and at that time various committees were formed with representatives from the relevant ministries of electricity and water of each state to study the prospects of linking their independent power systems. The project stalled for over two decades, with intermittent activities including feasibility studies and updates of feasibility studies in 1986 and 1992 and the resumption of committees and low-profile meetings. The project took off in earnest with a royal decree issued in 2001 to formally establish the GCC Interconnection Authority (GCCIA), located in Damman, Saudi Arabia, to be managed by a board of directors represented by members from the six states.

A new feasibility study was undertaken by GCCIA in 2003 and a recommendation was made to the GCC leaders to move ahead with the project. In May 2004 the GCC countries agreed to finance the project, and the GCCIA then moved ahead with the tenders and construction contracts. Table 3 summarizes some of the key milestones of the GCCI project.

Table 3 Chronology of Regional Power Integration for GCC

Year	Event
1981	GCC Interconnection Authority founded
1986	Initial feasibility study
1992	Second feasibility study
2001	Royal decree issued (in Saudi Arabia) to create the GCC Interconnection Authority
2003	Further update of feasibility study
2004	GCC electricity and water ministers agree to finance the project
2005	Requests for tenders issued in February and major contracts awarded in November
2006	The UAE–Oman interconnection was completed (part of Phase II). Abu Dhabi was connected to Dubai in late 2006 (part of the Emirates National Grid and part of Phase II of the GCCIA)
2007	Sharjah was linked to Dubai and Abu Dhabi in mid-2007 (part of Phase II)
2009	Phase I commissioned
2010	Expected completion of the Phase III of the project

Source: Various, see Reference list in Annex A4.

3.1.2 Timeline

The GCC interconnection project is divided into three phases as shown in Figure 5.

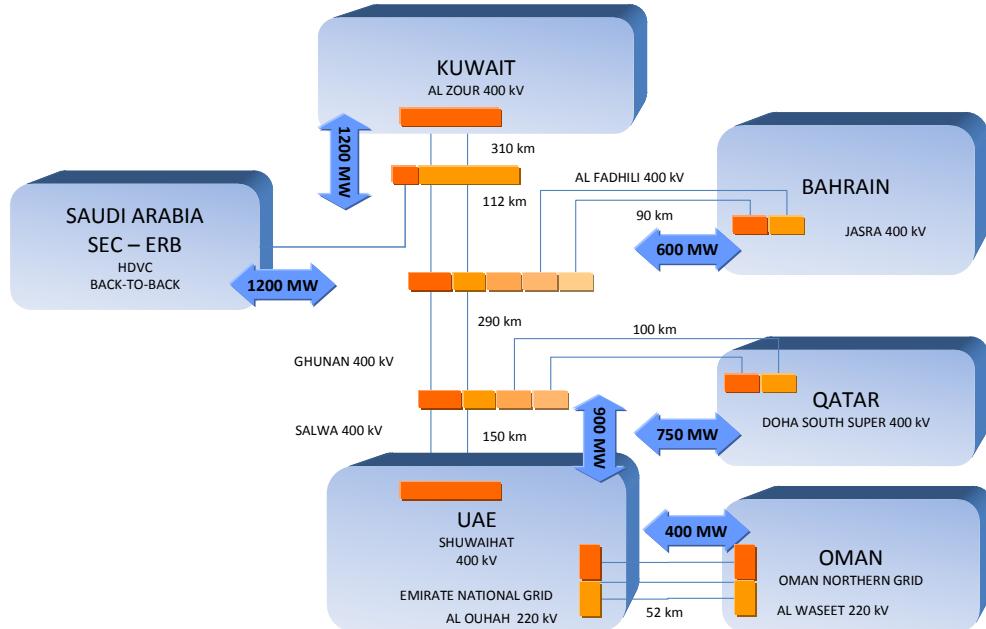
In **Phase I**, the power grids of the northern states of Kuwait, Saudi Arabia, Bahrain and Qatar are being interconnected to form the GCC North Grid. The grid was scheduled to become fully operational in the first quarter of 2009.

In March 2009 commission testing began on the operation of Al-Fadhili substation in Saudi Arabia and the 300 km transmission line from there to Al-Zour in Kuwait. Commission testing also began on the Al-Jassra substation in Bahrain.

Phase II of the project integrates the isolated networks of the seven emirates of the UAE to form the Emirates National Grid (ENG). Four major contact points were established under the four power authorities in the UAE: Abu Dhabi Water and Electricity Authority (ADWEA), Dubai Electricity and Water Authority (DEWA), Sharjah Electricity and Water Authority (SEWA) and the Federal Electricity and Water Authority (FEWA), which is responsible for the other four northern emirates of Ajman, Umm Al Qaiwain, Fujairah and Ras Al Khaimah. Phase II also includes the creation of Oman's integrated northern grid. This combined system is the GCC South Grid.

Abu Dhabi, Sharjah and Dubai had been interconnected by mid-2007. The remaining four emirates are in the process of being interconnected.

Figure 5 Electricity Interconnection Projects, Phases I, II and III



Source: GCCIA

In **Phase III**, the GCC North Grid will be interconnected with the South Grid, linking Oman and UAE with the other four GCC countries. This is expected to be complete in 2010–2011.

3.2 Project concept, objectives and development

The long-term comprehensive development strategy goal of the GCCI at the outset in 1981 envisaged greater economic integration of the GCC countries and covered much more than electricity: “The complete interlinking of the infrastructure network among the GCC States, especially in the fields of electricity, transportation, communication and information.”²¹

In relation to electricity, the GCC countries viewed the interconnection primarily as a mechanism to share generating reserves in emergency situations, to increase the reliability and security of the power supply, and to reduce the investment requirements in reserve capacity. The feasibility studies (see Section 3.3) did not justify the scheme on the basis of trade in energy.²² As the design of the scheme was being finalized and construction begun, presentations made by the GCC Interconnection Authority all mentioned the other benefits of trade, including the opportunity to engage in regional and extra-regional energy trade.

²¹ This vision of the broader GCCI, originating in 1981, is repeated in various presentations made by representatives of the GCCIA.

²² Subsequently, the ambitions may have grown but the original project was justified on the basis of the use of the interconnector to share reserve capacity and reduce the need for each country to maintain separate reserve capacity.

3.3 Feasibility studies

Three feasibility studies have been undertaken since the GCCI project was first launched in 1981:

- o In 1986, a team from Kuwait Institute of Scientific Research and the King Fahad University of Petroleum and Minerals prepared a technical and economic feasibility study.
- o Following lack of progress on the implementation of the project, another study was undertaken in 1992 by a consortium of local and international consultants to update the results of the 1986 study to reflect growth in demand and capacity among GCC members. The study concluded that the project was technically, financially and economically feasible.
- o In 2003 the GCCIA, which had been created two years earlier, once again decided to update the feasibility study. This study again showed the project to be viable.

The studies showed a benefit-to-cost ratio of 1.77, but this reflected only savings on investments in generating capacity from the sharing of operating reserves (i.e., not energy trade or other benefits).²³ The net present value over a 25-year period was estimated at US\$2.5 billion for Phase I (see Reference 9).

3.4 Assets built and planned

Phase I includes a 400 kV overhead transmission line from Kuwait through Saudi Arabia to Qatar with a 400 kV submarine cable link to Bahrain. It also includes a 380 kV, 60 Hz back-to-back HVDC transmission line to connect this 50 Hz grid with the 60 Hz Saudi Arabian system (see Annex A2)²⁴:

- o A double-circuit 400 kV, 50 Hz line from Al Zour (Kuwait) to Ghunan (Saudi Arabia) with an intermediate connection at Fadhili (Saudi Arabia) and associated substations.
- o A back-to-back HVDC interconnection to the Saudi Arabian 380 kV, 60 Hz, system at Fadhili.
- o A double circuit 400 kV comprising overhead lines and submarine link from Ghunan (Saudi Arabia) to Al Jasra (Bahrain) and associated substations.
- o A double circuit 400 kV line from Ghunan to Salwa (Saudi Arabia) and associated substations.

²³ Reference 3.

²⁴ Adnan Al-Mohaisen, Reference 2.

- o A double circuit 400 kV line from Salwa (Saudi Arabia) to Doha South (Qatar) and associated substations.
- o A control center located at Ghunan (Saudi Arabia). This links to each member country's national control center via fiber optic cable.

Phase II of the project comprised the internal integration of isolated networks of the various emirates of the UAE into a national grid and a 220 kV line between Al-Waseet in Oman and Al-Ain in the UAE to form the GCC South Grid. The 220 kV UAE -to-Oman interconnection was completed in 2006. The integration of the UAE networks did not come under the GCCI project.

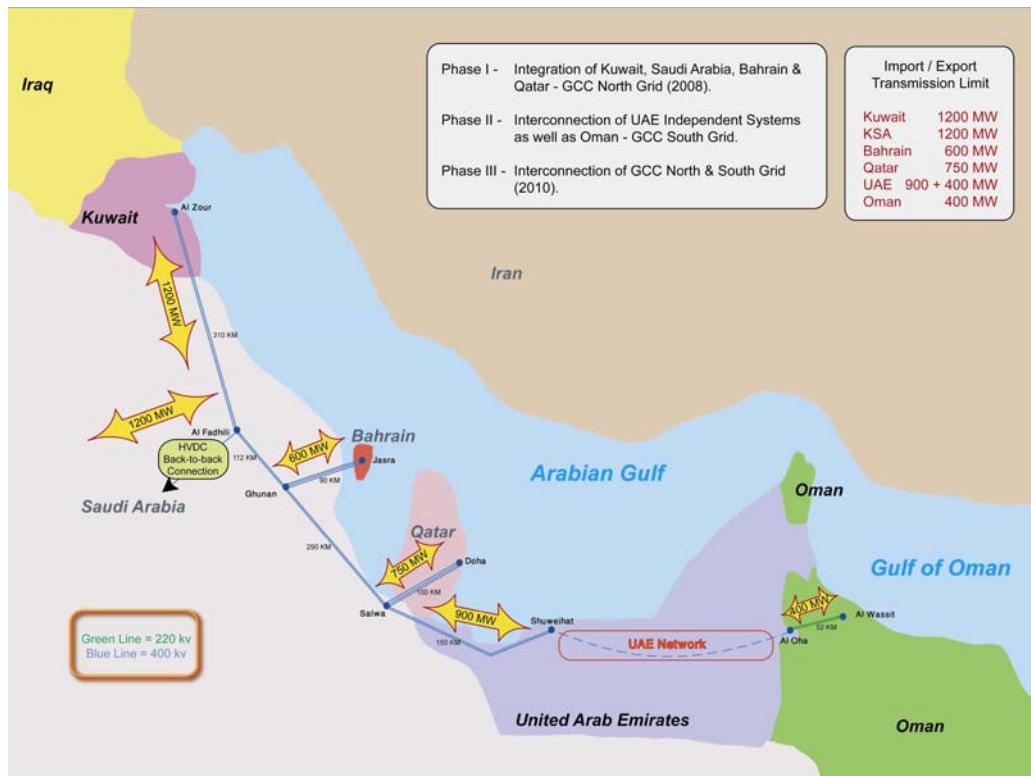
Phase III will interconnect the northern and southern GCC systems. This is to be completed in 2010 and will include:

- o A double circuit 400 kV line from Salwa (Saudi Arabia) to Ghuwaifat (UAE) and associated substations.
- o A double and a single circuit 220 kV line from Al Ouhah (UAE) to Al Wasset (Oman) and associated substations.

3.5 Interconnections and electricity trade

When completed, the GCCI electricity grid will allow for the possibility of exchanges between countries as shown in Figure 6 and Table 4. Kuwait and Saudi Arabia will each be able to export or import up to 1,200 MW from the grid. Bahrain, Qatar and UAE will be able to trade 600 MW, 750 MW and 900 MW, respectively. Oman has the lowest interconnector capacity at 400 MW.

The GCC control center is located in Ghunan in Saudi Arabia.

Figure 6 Capacity of the Interconnectors

Table 4 Size of Interconnectors to Each Country

Country	Capacity (MW)
Kuwait	1,200
Saudi Arabia	1,200
Bahrain	600
Qatar	750
UAE	900
Oman	400

Source: Al-Mohaisen et al. (2002).

3.6 Environmental issues

We understand that changes to greenhouse gas (GHG) emissions resulting from the interconnection project have not been estimated by the GCC countries, and CDM financing has not been proposed.

Hydrocarbons are used almost exclusively for power generation in the GCC countries. GHG and other emission reductions are likely to arise, if at all, by using those hydrocarbons in more efficient plants (i.e., displacing less efficient generation in one state by more efficient generation in another) or by greater utilization of fuels with lower carbon content per kWh.

To the extent that the GCCI electricity project leads to an increased use of natural gas and a reduction in flaring of associated gas, then the project should unequivocally lead to a reduction in GHG emissions.

Additionally, if the GCCI electricity project leads to an increase in regional utilization of gas, then the impact depends on whether this displaces oil-fired (or, possibly coal-fired) generation in the region and/or whether it leads to reduced LNG exports and displaces gas-fired generation in countries that would otherwise have imported LNG. The possible impacts under various baseline scenarios are shown in Annex A3 and range from a 44% reduction in GHG emissions to a 46% increase in emissions per GWh from the affected power plants. If, without the interconnector project, the gas would otherwise have been re-injected, then GHG emissions will be reduced,²⁵ but the scale of the GHG emission reduction depends on how the mix of production from different power technologies changes as a result of increased trade. For example, if gas-fired generation in CCGT plants displaces oil-fired generation from open-cycle gas turbines, then a 44% reduction (per GWh) would be achieved. But if gas-fired generation in open-cycle plants displaces oil-fired generation from open-cycle plants the reduction is only 24%.

If regional utilization of natural gas reduces the region's exports of gas—for example, if Qatar develops gas-fired generation and exports its gas as electricity to its neighbors rather than exporting it as LNG to the world—then the impact on world GHG emissions is more complex. If the reduced export of LNG leads to a reduction in the world supply of natural gas outside the GCC region and if this, in turn, leads to increased use of coal outside the region then, despite a reduction in emissions in the GCC countries, there would be a net increase in overall emissions worldwide (of around 46% per GWh of electricity produced by the displaced plant).

In any event, any change in the regional emission profile of GHGs will be small since active electricity trade is not foreseen.

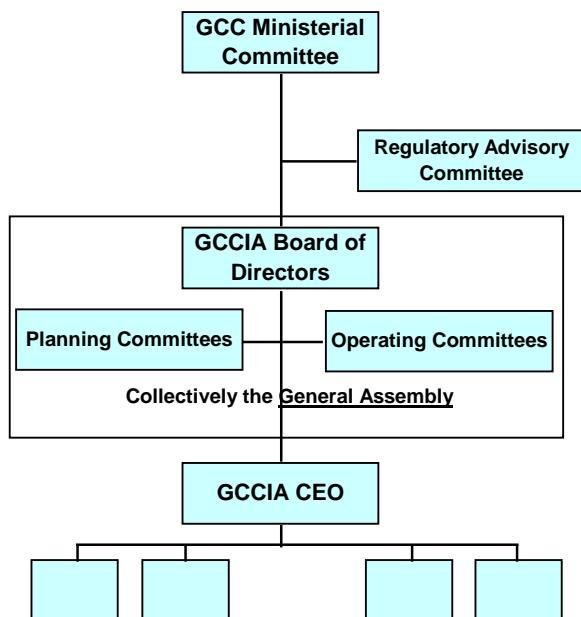
²⁵ Because a power plant using natural gas produces less GHG emissions than a similar plant burning petroleum products.

4 Institutional arrangements

4.1 Institutional structure and governance of the scheme

The institutional structure and governance arrangements for the implementation and operation of the GCCI electricity scheme are shown in Figure 7.

Figure 7 Institutional and Governance Framework



Source: ECA diagram based on information from Al-Asaad and Ebrahim (2008) and other references.

The GCC Ministerial Committee comprises ministers of electricity and water from each of the member countries. This committee, with inputs from the Regulatory Advisory Committee, guides the GCCIA board of directors on its policies and procedures. The board itself is nominated by the six member countries.

The GCCIA board together with the planning committees and the operating committees (also nominated by GCC member states) form a General Assembly, which makes decisions on codes and agreements governing trade among member utilities and governing the activities of the GCCIA itself.

GCCIA is physically located in Al Khobar, Saudi Arabia, and was set up in 2003. The dispatch center is located at Ghunan, also in Saudi Arabia, and is under the control of GCCIA.

GCCIA is a joint stock company owned by the electricity ministries in the six GCC states. Although it is based in Saudi Arabia and was created by a royal decree,²⁶ it is governed by

²⁶ Its Articles of Association and by-laws were approved by royal decree in 2001.

its board which, in turn, is under the control of the ministers from the six GCC member countries. Financing for the approved interconnection scheme was obtained from national governments (see Section 5.2), and GCCIA's administration costs, set-up and annual, are funded on the same shared basis.

Initially GCCIA will also play the role of transmission system operator (TSO). In that capacity it will be responsible for system planning and operations as well as engineering and maintenance. It is not yet clear how GCCIA's ongoing costs will be financed.²⁷

The GCCIA was responsible for the feasibility studies, tendering of the contractors, and supervision of the construction of the physical infrastructure. The construction work has been executed on an engineering, procurement and construction (EPC) basis and an "owner's engineer" was appointed by GCCIA for this purpose.²⁸ EPC contracts were tendered and awarded on the basis of international competitive bidding.

GCCIA, together with the operating committees, has also been responsible for coordinating the development of the contractual and trading arrangements governing the operation of the scheme.

It is anticipated that a System and Market operator will take over from GCCIA within 10 years after start-up.

4.2 Role of national governments and regional institutions

The GCCI electricity project was first conceived in 1981 and, though it is difficult to establish precisely the motivations for the project at that time, it appears to have been driven by an interest by the countries in forming closer economic ties. Subsequently, the ministers of electricity and water and national electricity utilities through the Regulatory Advisory Committee and the planning committees guided the design of the scheme, and these set the limits on aspirations, envisaging the scheme primarily for exchanges to share reserve capacity.

The Gulf countries have, for many years, seen rapid demand growth, but there were no specific shortages of generating capacity or of primary energy resources that led to sustained periods of serious load shedding, and that drove the development of the GCCI scheme. It was prompted, in part, by the wish to reduce the reserve margin and delay some investment in generating capacity. It is also possible that the opportunity to export energy indirectly as electricity may have been an underlying motive for support by some of the GCC countries.

²⁷ Pricing arrangements for use of the interconnector are still under discussion – see Section 5.3.

²⁸ SNC Lavalin.

4.3 Regulatory agencies

We understand that national regulatory agencies do not have responsibilities with respect to the GCCIA or of electricity trade except to the extent that the regulators are themselves ministries of electricity and water.

The GCCIA board will initially act as the regulator in relation to the scheme until the Regulatory Advisory Committee is established. The committee will be responsible for monitoring compliance by the participating parties with its regulatory principles and performance standards.²⁹ The committee will act as the regional regulator until a regulator is formally established by the member states.

4.4 Role of outside agencies

The cost of the interconnection investment and financing arrangements are described in Section 5. Financing was arranged differently by each country but included borrowing from international banks. We are not aware of the involvement of risk mitigation agencies or regional political or multilateral organizations.

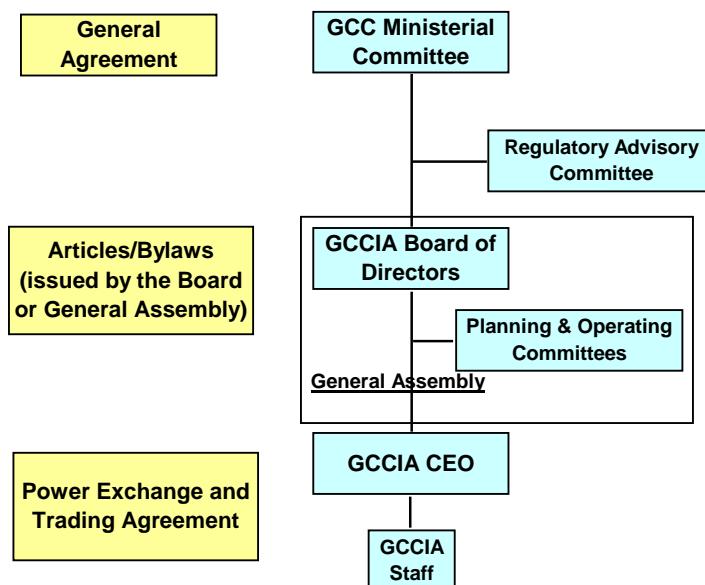
²⁹ Al-Asaad and Ebrahim (2008)

5 Contractual, financial and pricing arrangements

5.1 Contracts

The legal and contractual framework governing the operation of the scheme is still under development, but the proposed arrangements are described in the paragraphs that follow and summarized in Figure 8 (alongside the institutional framework, described in Section 4).

Figure 8 Legal and Contractual Framework



Source: ECA diagram based on information from Al-Asaad and Ebrahim (2008) and other references.

The General Agreement (GA) will be signed between ministers in each of the states and will govern the high-level relationships among the member states in relation to the scheme.

The GCCIA board and the General Assembly will issue rules and regulations governing the activities of the GCCIA itself and the participating utilities from the GCC states.

The Power Exchange and Trading Agreement (PETA) is a key document that governs access to and use of the interconnector and trading rights and obligations among the participants. The agreement will be signed by the participating entities, which may differ depending on the power sector framework in each member state, but they will include either the TSO or, where there is both a TSO and a market operator, both.

Subsidiary to PETA will be the Interconnector Transmission Code, which will govern minimum transmission standards (including ancillary services), and a Metering Code. PETA covers:

- o Obligations to maintain a minimum generating capacity
- o Allocation of interconnector transmission capacity

-
- o Energy trade
 - o Ancillary services
 - o Allocation and pricing of interconnector rights
 - o Treatment of unscheduled transfers of energy

The components of PETA will be described further based on descriptions from various sources but particularly Reference 9.

5.1.1 Installed capacity obligation

One component of PETA is the imposition of an installed capacity obligation on each member state, which requires that nominated entities in each member state maintain a minimum level of capacity expressed as a percentage above its system peak demand. This is similar to the obligations imposed by UCTE. A nominated entity may fulfil this obligation by nominating capacity in another member state subject to the interconnector transfer capacity constraint. When generation capacity in one state is used to meet the obligation of another, the contracted capacity does not necessarily need to be in the form of a contract to export the capacity, but the capacity must be capable of being delivered through the interconnector when needed, and capacity allocated to meet the obligation in another state cannot be counted toward the installed capacity obligation in the both states.

GCCIA will be tasked with keeping records of installed capacity in each state, and compliance with the obligation will be monitored using an approach to be developed by a planning committee. Penalties may apply to the nominated entities that fail to meet the obligation.

5.1.2 Allocation of interconnector capacity

The primary purpose of the interconnector will be to share reserve capacity, and the GCCIA will determine the share of the capacity on each interconnector link that should be allocated for this purpose. All member states will be assigned basic transmission rights primarily for sharing reserve capacity, but any surpluses may be allocated to trade in capacity, energy and ancillary services. The net capacity available for this purpose will vary by time of day, day of the week and week of the year, and the rights to use the spare net capacity may be contracted for different durations (day ahead, week ahead or year ahead).

PETA defines two types of rights for the net capacity (available after allocating basic transmission rights):

- o installed capacity interconnector rights, and
- o interconnector rights for operations.

“Installed capacity interconnector rights” relate to the installed capacity obligation described previously, where the capacity obligation is partially met from capacity located in another state. The interconnector rights for this purpose are granted for a period of a year ahead and the two parties involved must be able to demonstrate that they have been assigned rights to

the transmission capacity. Installed capacity interconnector rights cannot be used at the same time for trading energy.

“Interconnector rights for operations” for the purpose of trading energy may be assigned on a residual basis after rights have been allocated to satisfy the intended primary purpose of the interconnector – sharing of reserve capacity. The rights for operation are non-firm; basic rights and installed capacity interconnector rights take priority in the event of a constraint on available capacity in real time.

5.1.3 Trading energy

GCCIA will act as a facilitator rather than a market operator. It is expected that parties will trade on the basis of bilateral contracts and make their own arrangements for settlement. But parties must inform GCCIA of the details of the origin, destination, start time and finish time, and quantity of the intended trade, and the parties must ensure that they have the appropriate level of interconnector rights for operations. GCCIA in turn subsequently confirms to the parties that the trade took place or if the actual trade differed from that notified in advance, it notifies them of the actual exchange. The Authority has the right to refuse trade if it judges the trade to be infeasible.

Details of balancing arrangements, if any, have not yet been revealed.

5.1.4 Ancillary services

Ancillary services are expected to be traded only minimally. It appears that trade in ancillary services is expected to focus on operating reserve which, like the installed capacity obligation, can be supplied through the interconnector if capacity is available. Operating reserve requirements will be mandated by GCCIA through the Interconnector Transmission Code, and compliance, whether from in-country reserve or from reserve supplied by a neighboring country, will be monitored by GCCIA. Interconnector capacity for the purpose of importing operating reserve must be booked as interconnector rights for operations.

5.1.5 Pricing of interconnection capacity

GCCIA has proposed that net interconnector capacity should be auctioned by the Authority for different timescales. Installed capacity interconnector rights would be auctioned for annual contracts. Interconnector rights for operations would be auctioned for annual, monthly or daily contracts. Secondary trading of rights would also be permitted.

5.1.6 Unscheduled transfers of energy

As the interconnector is designed primarily to provide reserve capacity, small unscheduled transfers will inevitably occur when a power plant or supply to a large consumer unexpectedly trips. This type of unscheduled transfer is expected to be repaid by a like-for-like (scheduled) reverse electricity flow within a few days of the unscheduled transfer. If the unscheduled support was provided in, for example, peak hours, then the repayment should be in similar peak hours. PETA will also allow for the possibility of payment for sustained unscheduled transfers through publication of tariffs by member states.

5.2 Ownership and finance

The capital cost of the three phases of the project is estimated at US\$1.1 billion, US\$300 million and US\$137 million, respectively.³⁰

It was agreed among the GCC countries that costs would be shared in proportion to the net present value of estimated reserve capacity savings as outlined in Table 5. Each country was responsible for sourcing their share of the capital required, which could be from combinations of debt or equity as decided by each member state.

Table 5 Sharing of Capital Costs

Country	Phase I	Phase I & III
Kuwait	33.8%	26.7%
Saudi Arabia	40.0%	31.6%
Bahrain	11.4%	9.0%
Qatar	14.8%	11.7%
UAE	-	15.4%
Oman	-	5.6%
Total	100.0%	100.0%

Source: Al-Asaad and Ebrahim (undated). Ownership of each country's share of the investment is assumed to lie with either the ministry of electricity, the national utility or, in the case of unbundled electricity sectors, the national transmission company.

5.3 Pricing arrangements

As described in Section 5.1, trading of energy through the interconnector will be based on bilateral agreements between two parties, and neither GCCIA nor the Regional Advisory Committee acting as regional regulator will play a role in setting prices for energy trades. It has been proposed that GCCIA will auction interconnection capacity rights, but details of this arrangement are not yet available.

Electricity is transmitted through the interconnector, but even though most of the interconnector is located in Saudi Arabia and electricity will be transported physically through the kingdom to other GCC countries, the interconnector operates at 50 Hz and is independent of the kingdom's electrical network. Electricity could also be wheeled through the interconnector on the territory of UAE between Oman and other member states, but the rights to the interconnector do not rest with UAE, and we understand that wheeling

³⁰ Al-Asaad and Ebrahim (undated)

charges, other than the charges implied by capacity auctions, would not be paid to Saudi Arabia and UAE.

6 Future plans

Immediate plans for the future are the completion of the physical infrastructure (Phase III – to connect the northern and southern systems) and finalization of the general agreement and the trading arrangements (the Power Exchange and Trading Agreement). The implementation of this trading arrangement, which focuses primarily on shared generating reserve capacity, will test the ability of the scheme to cope effectively with its secondary role – energy trade.

In the longer term there are plans to create a regional regulatory body and to add a regional market operator function to the existing functions of GCCIA. The latter is anticipated within 10 years. There are also plans to interconnect the region's interconnected grid with other neighboring grids.

Annexes

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A1 Leading indicators for the GCC countries

Table 6 Indicators for GCC Countries

	Kuwait	Saudi Arabia	Bahrain	Qatar	UAE	Oman
Population (millions)	2.6	23.7	0.7	0.8	4.2	2.5
Surface area (km ²)	17,820	2,000,000	710	11,000	83,600	309,500
GDP (US\$ Billions)	102	356	16	53	163	36
GNI per capita (PPP)	52,510	22,370	n/a	n/a	n/a	21,650
GDP growth % per year	6	3	n/a	n/a	n/a	7
Inflation (GDP deflator annual %)	18	9	n/a	n/a	12	8
Exports (% of GDP) ^a	65	63	99	58	91	63
Electrification Rate (%) [*]	100	97	99	71	92	96
Electricity Consumption per capita (kWh) [*]	15,423	6,902	11,932	19,840	12,000	5,079
Life expectancy at birth (years)	78**	73**	76	75	79	76
Mortality rate under 5 years (per 1,000)	11	25	10	15	8	12**

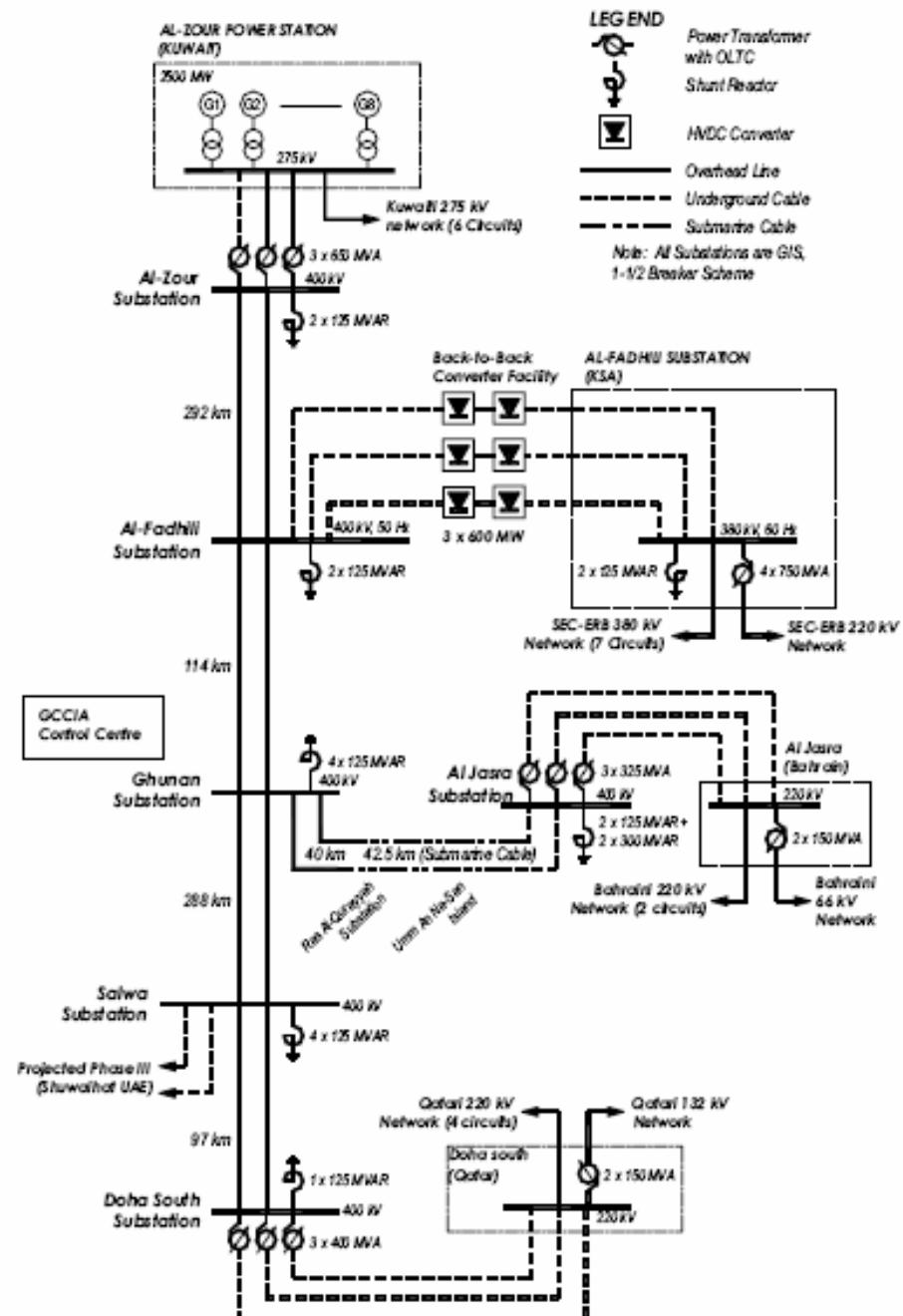
Source: All data from *World Development Indicators (World Bank)*, 2006 except:

* UNDP Human Development Report, 2007/2008

** Denotes 2007 EIA data

A2 Schematic diagram of the GCCI – Phase I

Figure 9 GCC Electricity Interconnection Phase I Diagram



Source: Al-Mohaisen et al. (2007).

A3 GHG emission calculations

Table 7 Greenhouse Gas Emissions

Baseline (without GCC interconnection)				Scenarios for Impact of Interconnector on Fuel/Technology in GCC and Rest of the World		Overall Impact on GHG Emissions
Scenario for Use of Gas	GCC Power Technology	Baseline Fuel for Power in GCC	Baseline in Rest of the World	Technology Using Gas in GCC	Replacement Fuel/Technology in Rest of the World	
Re-injection	CCGT	HFO, crude oil or distillate	n/a	CCGT	n/a	- 24%
Re-injection	GT	HFO, crude oil or distillate	n/a	GT	n/a	- 24%
Re-injection	GT	HFO, crude oil or distillate	n/a	CCGT	n/a	-44%
Re-injection	Steam	HFO	n/a	CCGT	n/a	-44%
Export as LNG	CCGT	HFO, crude oil or distillate	LNG-CCGT	CCGT	coal/steam	+46%
Export as LNG	GT	HFO, crude oil or distillate	LNG-CCGT	GT	coal/steam	+34%

Baseline (without GCC interconnection)				Scenarios for Impact of Interconnector on Fuel/Technology in GCC and Rest of the World		Overall Impact on GHG Emissions
Scenario for Use of Gas	GCC Power Technology	Baseline Fuel for Power in GCC	Baseline in Rest of the World	Technology Using Gas in GCC	Replacement Fuel/Technology in Rest of the World	
Export as LNG	GT	HFO, crude oil or distillate	LNG-CCGT	CCGT	coal/steam	+21%
Export as LNG	Steam	HFO	LNG-CCGT	CCGT	coal/steam	+21%

Source: ECA calculations based on IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, UNFCCC; and IEA, Projected Costs for Generating Electricity, 2005, OECD

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