REPORT Approved FINAL B4008314

Client **Arab Fund for Economic and Social Development (AFESD)**

Subject Feasibility Study of the Electrical Interconnection and Energy Trade Between Arab Countries
Executive Summary

Order Agreement between AFESD and CESI –Ref. Ref T/05-04-00/359 date 1.02.2012

Notes

N. of pages 25 **N. of pages annexed**

Issue date 12 March 2014

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Capitale sociale € 8.550.000 interamente versato
C.F. e numero iscrizione Reg. Imprese di Milano 00793580150
P.I. IT00793580150
N. R.E.A. 429222

REVISION HISTORY

Revision Number	Date	Protocol	List of modified paragraphs
00	05/02/2014	B4002505	Pre-Final
01	12/03/2014	B4008314	Final

Consultancy Services Related to the Feasibility Study of the Electrical Interconnection and Energy Trade between the Arab Countries

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EXECUTIVE SUMMARY

The main objectives and scope of this study include establishing a strategy and master plan to develop the trade of energy among Arab countries, and determine the trade-offs between export of electricity and/or natural gas. The objective was to address the adequacy of the planned generation system and interconnected network to deliver the economic amount of electricity and gas trade necessary to fulfil the objectives of the pan-Arab electricity trading market.

To this purpose, the best options for new electricity and gas interconnections were identified on the basis of the electricity markets in the Arab countries, the investigation of practical scenarios for its development, supported by techno-economic feasibility analysis of those scenarios. The study investigated, evaluated and ranked all possible alternative scenarios to expand, expedite and reinforce the interconnections among Arab countries. It clearly identified each economically feasible electrical and natural gas project and estimated its cost. The horizon year of the analysis is 2030 and the study period is 2012-2030.

The beneficiaries of the study are the members of the League of Arab States, the Electrical and Natural Gas Authorities of the Arab Countries as well as policy makers, producers and consumers, in the energy markets of the Arab Countries. Some Arab Countries, such as Syria and Lebanon did not participate during the study development, but their power and NG sectors were part of the analysis. The Pan Arab interconnected model of generation and interconnection expansion includes both countries up to horizon year 2030.

DATA COLLECTION FOR ELECTRIC POWER, DEMAND AND GENERATION SUPPLY OPTIONS AND FORMULATION OF PLANNING CRITERIA

The study was based on an extensive data collection phase for electricity, natural gas national generation and transmission development plans. Different activities were performed for data consolidation including validation of provided data, site visits, and interactions with the focal points and using reasonable assumptions for missing information.

Starting from the data base containing the up-to-date information of actual and expansion plans of the generation system, electrical energy consumption profiles, the existing, under-construction and any planned electrical interconnection projects, the current infrastructure for NG and information on NG reserves in the region, four main study directions were pursued: demand forecast, transmission network analysis, NG infrastructures characterization and power generation system planning. The databases prepared at the end of data collection represented the basis for the execution of the subsequent activities.

Electric Power System Sector

The collected information regarding the operation and planning of the transmission network and generation system was based on the data gathered by planning questionnaires filled out by the Arab countries. The Consultant performed a review of the existing national demand forecast available in the Arab countries, the adopted forecast methodologies, key assumptions and overall results. The aim of the electricity demand forecast was to determine the amounts of electricity demand in terms of energy

consumption and peak demand, starting from year 2012 up to year 2030, as a key driver in planning the generation capacity investment and the estimation of economic electricity exchanges.

The electricity demand forecast study provided the system peak power projections (MW) and the electric energy projections (GWh) for each Arab Country. Under the baseline scenario, the Pan Arab non-coincident peak power is expected to grow from 179,660 MW in 2012, to 446,481 MW in 2030, with a compound annual growth rate (CAGR) of 5.12% during the 2012-2030 period. The gross electric energy demand is expected to increase from 956,132 GWh in 2012, up to 2,458,519 GWh in 2030, a compound annual growth rate CAGR of 5.39%.

The Consultant also developed a planning memorandum, where the agreed and common to all countries generation and transmission planning criteria are stated. The planning criteria of generation system were based on least cost generation and interconnection expansion under NG supply constraints.

The national generation master plans of each Arab country, partially provided for the planning period (2012-2030), were revised and cross-checked for each country. Furthermore, the adequacy of the expected capacity development plans was assessed over the planning period in order to validate the input data of the least cost generation and interconnection expansion study.

Preliminary investigations were carried out to review the existing, under construction and potential electric interconnections with the final objective of determining their adequacy to support the amount of electricity trade up to horizon year 2030. The purpose of this screening analysis was to avoid the iterations between the least-cost generation planning and the examination of the various electrical and NG interconnection candidates, in order to achieve the best electric energy and NG trade scenario for all Arab countries. Before conducting the screening analysis, which addresses the economic feasibility of all identified new electrical interconnections, an assessment of the potential use of existing interconnections for economic electricity exchanges was performed, adopting a simplified approach based on the calculation of the average levelized cost of electricity production of each system. The simulation results were used to evaluate the opportunity to exchange power and electrical energy between interconnected countries. The selection was based on judgments regarding the expected benefits of interconnection candidates related to reliability improvements, economics and operation benefits.

After discussions with the country focal point representative about the feasibility of the interconnection candidates, the list shown in Table 1 was agreed upon. The table lists the set of new interconnections composing the Pan Arab interconnected system, the feasibility of which is examined more in-depth in the subsequent analyses.

Table 1 List of the New Interconnection Links Included in the Model

	Additional Interconnections/reinforcements	Commissioning year
1	Libya (Tobruk) - Egypt (Saloum) 500/400kV BtB + AC OHL 500 kV	2017
2	Tunisia (Bouchemma) - Libya (Rowis) AC OHL 400kV	2020
3	Saudi Arabia (Qurayyat) – Jordan (Qatranah) BtB + AC double circuit OHL 400 kV	2020
4	Saudi Arabia (Kudmi) – Yemen (Bani Hoshish) BtB + AC double circuit OHL 400 kV	2025
5	Iraq (Faw) - Kuwait (Subiya) AC double circuit OHL 400 kV	2020
6	Second circuit of Egypt (Taba) - Jordan (Aqaba) AC link 400 kV	2020
7	Second circuit of Jordan (Amman North) - Syria (Dir Ali) AC OHL 400 kV	2020

Natural Gas Sector

The interconnections in terms of both gas and electricity depend on the availability of adequate gas resources to be consumed in power plants or exported for consumption in other countries.

The first part of the study was focused on determining the availability of gas and, to this purpose questionnaires were drafted, approved, and sent out to each participating country. To complement the questionnaires visits were made in some of the key countries in the analysis, namely Kingdom of Saudi Arabia and Qatar. Finally, whenever information in questionnaires was missing or not submitted, evaluation was made by the Consultant relying on experience and publicly available and renowned data sources.

The collection of data was focused on establishing an overview of the potential country reserves and to make credible gas balances for each country taking production, export, import, and consumption into account. The reserve data was found to be hard to obtain from producing countries, instead the data obtained for the study showed very few differences indicating that all data at the end of the day in all likelihood originated from one or few sources. Gas balance data were compiled from questionnaires and public sources and showed that, many if not most non-producing countries would experience gas deficits in the years to come. This would force electricity generation to use other potentially more polluting and expensive fuels. If import could be made available this situation could be alleviated. However, the study found that interconnections were restricted by a number of key factors, such as local gas supply/demand and government policies on gas export. In particular the government positions to export in the form of the moratorium on gas export in Qatar and the "no connection policy" in Saudi Arabia restricted the potential set of opportunities for interconnections as the two countries are the largest reserve holders in the Arab countries. Keeping the two countries' reservations implied that the set of potential interconnections decrease and remain limited to gas interconnections connecting Libya and Iraq with their neighbors. In these two countries production is expected to surpass demand in only a few years leaving room for export of gas to the neighboring Arab States.

The second part of the gas data analysis aimed for determine credible gas prices in each individual Arab country for use in the simulation of the integrated electricity model. Estimation of the gas prices relied on international gas prices in Japan, EU, and the US with the relevant transportation costs in the transport chain to these markets deducted. This approach gives an estimate of the alternative value/price of gas in the region.

Prices were found to follow the availability, thus high availability implied low prices and vice versa, with the exception of prices in the North African countries, where countries are linked by pipelines to the European markets.

The current infrastructure was used as a basis for both the gas balance and the price calculations. A survey initiated at the beginning of the gas study revealed that the level of gas interconnections between the countries is very limited. Only two interconnections existed, the Arab Gas Pipeline, connecting Egypt, Jordan, Syria, Lebanon, and the Dolphin Pipeline connecting Qatar, the UAE, and Oman. Based on the restrictions in gas interconnections and availability, the Consultant selected the following interconnections for further analysis. The reduced list of interconnection projects includes the following:

- Algeria-Libya
- Libya-Tunisia
- Libya-Egypt
- Egypt-Sudan
- Iraq-Jordan
- Iraq-Kuwait
- Qatar-Egypt (only relevant when Moratorium in Qatar is lifted)
- Qatar-Bahrain-Kuwait (only relevant when Moratorium in Qatar is lifted)
- Morocco LNG
- Bahrain LNG

The above links were tested one by one along with the proposed electricity interconnections and the projects giving the highest regional benefits were: Libya-Egypt, Iraq-Kuwait, and Bahrain LNG.

These links underwent a closer review in order to arrive at a preferred list of projects consisting of five projects. In order to do this, a multi criteria model was utilized comparing the projects against each other on four different categories: demand/supply, market development, maturity, and security of supply.

The screening analysis of feasibility of the candidate of NG interconnection pipelines identified the NG projects to be included in the regional priority plan of Pan-Arab Pipelines. The analysis resulted in the recommendation of the following projects

- Libya-Tunisia
- Libya-Egypt
- Iraq-Kuwait
- Morocco LNG
- Bahrain LNG

In the case of the Libya-Egypt pipeline the largest identified barrier at the moment is the lack of incentives to produce gas. Gas is believed to be in abundance in Libya, and in order to exploit these resources it is recommended to introduce a feed-in price for gas export to Egypt.

In the case of a pipeline Iraq-Kuwait to enable export from Iraqi fields to Kuwait would most likely require some treatment.

PAN-ARAB ELECTRIC POWER AND NG INTERCONNECTION SCENARIOS

The Pan Arab Electrical and NG interconnected model was prepared considering existing and future generation units and electrical and NG interconnections. The model includes 1,450 thermal power plants of different technologies; 74 hydro power plants, 180 RES power plants of different technologies, 39 electrical interconnections and 5 NG cross-border infrastructures. The simulations were carried out with OPTGEN software package for the definition of the least cost planning as the sum of investment plus expected value of operation costs of the Pan Arab interconnected power system.

The Consultant elaborated five main scenarios and two additional scenarios as sensitivity cases. The outcome of the analysis allowed the identification of a target scenario named the “Preferred Scenario”, which represents the NG-constrained least cost investment schedule - sum of investment plus expected value of operation costs - for the construction of new generation capacity and of Electrical and NG interconnections. Two sensitivity scenarios were simulated, namely:

- **Alternative NG scenario** based on the assumption of growth in the NG supply to Arab countries by implementation of the Pan Arab Pipeline (PAP) in addition to an optimist assumption that Qatar lifts the Moratorium;
- **Alternative ICr scenario** based on a different strategic development of the Generation Expansion Plan in Saudi Arabia making nuclear power and renewable energy an integral part of a national sustainable energy mix.

The **Business As Usual (BAU) Scenario** was formulated as a self-sufficient national approach to electricity power supply based on a strategy of using primarily national resources and maintaining the current levels of NG consumption for power generation, i.e. no extra expansion on NG feed stocks and electric regional interconnections. BAU scenario represented NG constrained least cost generation investment plans based on the national expansion plans to meet national loads only. BAU

scenario considered the base case load forecast assuming that no electricity exchanges occur between the interconnected countries. The results of BAU scenario were used to establish a base point against which the investment needs of all Arab countries were, and were compared combined in order to maximize the use of their gas resources.

The **Electrical Interconnection Scenario (IC Scenario)** consists of NG constrained least cost generation investment plans considering the economic usage of the existing and already decided electric interconnections with emphasis on regional electricity trade and electricity import/export without expanding or reinforcing the existing regional NG supply infrastructures.

The **reinforced Electrical Interconnection Scenario (ICr Scenario)** consists of NG constrained least cost generation and electric interconnection investment planning considering the economic usage of the existing, additional reinforcements, and new electrical interconnections with emphasis on regional electricity trade and electricity import/export without expanding or reinforcing the existing regional NG supply infrastructures.

The technical and economic evaluation of candidates allowed the selection the most profitable new electrical interconnections given in Table 1, as part of the Pan Arab interconnected system for further analysis.

The economic evaluation of the Tunisia – Libya interconnection line demonstrated that the project was highly viable with an Economic IRR of 322%.

The economic evaluation of the Libya – Egypt electrical interconnection link demonstrated that the project was highly viable with an Economic IRR of 91%.

The economic evaluation of the Saudi Arabia – Jordan electrical interconnection link demonstrated that the project was viable with an Economic IRR of 40%.

The economic evaluation of the Iraq – Kuwait electrical interconnection line demonstrated that the project was very viable with an Economic IRR of 1,201%.

The economic evaluation of the second circuit Egypt – Jordan interconnection link demonstrated that the project was very viable with an Economic IRR of 184%. The extension of the second circuit from Jordan to Syria was justified due to reliability improvements and extension of the electricity market in the region.

The **Natural Gas Interconnection Scenario (NG scenario)** consists of NG constrained least cost generation and NG cross-border infrastructures (pipelines and/or LNG) investment planning, with emphasis on best options of power generation inside a country using the additional NG resources and existing electric interconnections.

The optimum search for the "**Preferred Scenario**" was a combination of the simulation results of Pan Arab Electrical and NG interconnected model and techno-economic feasibility analysis of a set of near-optimum scenarios (ICr + pipelines and/or LNG).

The "Preferred Scenario" considered the benefits originating from economic electricity exchanges and viable economic NG transport projects. In order to arrive at the optimal solution of NG and electricity scenario, the NG projects were introduced one by one into the electricity scenario finding the best match. This meant that 11 different simulations were run with various combinations of gas interconnections. The interconnection combination yielding the highest benefit to the Arab countries was found to be:

- "Integrated electricity" scenario (ICr) and the following NG projects:
- NG cross-border Libya-Egypt pipeline in 2018.
- NG cross-border Iraq-Kuwait pipeline in 2017.
- LNG Terminal in Bahrain in 2018

These projects were investigated further with a focus on potential trade model, financing, and implementation.

The Economic evaluation of the Libya – Egypt Project is demonstrated to be highly feasible with an Economic IRR of 106%. The NG Project has an inter-regional impact on Arab power sector.

The Economic evaluation of the Iraq-Kuwait Project demonstrated that the NG Project has a regional impact and is highly feasible with an Economic IRR of 226%.

The Economic evaluation of the LNG Terminal Project in Bahrain demonstrated that it is feasible with an Economic IRR of 49.5%. The NG Project is an important project not only for the country but also for the entire GCC region.

The comparison of capital cost and operation costs for power generation projects such as future thermal, hydro and renewable energy projects and including the interconnection projects was carried out for all scenarios.

Table 2 shows the Present Value (PV) of capital investment costs for development of the generation systems and electrical and NG interconnections during the 2012 -2030 period of all scenarios. The investment cost are given for each country, region and for all Arab countries.

Table 2 Investment Cost of all Scenarios during the 2012 -2030 period

Present Value of TOTAL CAPEX 2012-2030					
Country	**BAU Scenario**	**IC Scenario**	**ICr Scenario**	**NG Scenario**	**ICr&NG Scenario**
	MUSD	MUSD	MUSD	MUSD	MUSD
Morocco	13,723	15,221	15,157	15,098	15,008
Algeria	21,664	21,224	21,224	21,224	21,224
Tunisia	4,713	4,719	4,748	4,716	4,748
Libya	12,929	12,741	12,812	12,809	13,512
Egypt	47,828	43,070	43,510	41,935	42,187
Sudan	7,861	7,860	7,841	7,747	7,778
Total North Africa Region and Sudan	**108,719**	**104,834**	**105,293**	**103,528**	**104,457**
Jordan	11,409	11,550	11,488	11,131	11,250
Syria	10,727	10,467	10,896	10,255	10,869
Lebanon	1,945	1,884	1,653	1,884	1,653
Iraq	22,205	22,942	22,672	22,591	22,767
Total JSLI countries	**46,286**	**46,844**	**46,710**	**45,863**	**46,541**
Saudi Arabia	70,215	69,023	68,894	68,921	68,620
Kuwait	18,665	18,239	17,981	17,615	16,933
Bahrain	2,700	2,858	2,802	3,258	3,161
Qatar	2,522	2,783	2,987	2,620	3,142
UAE-Abu Dhabi	18,873	18,843	18,739	18,376	19,118
Oman	6,026	5,764	5,768	4,859	5,755
Yemen	2,020	2,075	2,070	2,058	2,075
Total GCC countries and Yemen	**121,021**	**119,585**	**119,241**	**117,708**	**118,804**
TOTAL Arab Countries	**276,026**	**271,262**	**271,244**	**267,099**	**269,802**

The comparison of the total PV of capital expenditure of all scenarios is illustrated in Figure 1. The NG scenario is the scenario with the lowest CAPEX, followed by ICr&NG scenario where additional investments for new electric interconnections are considered.

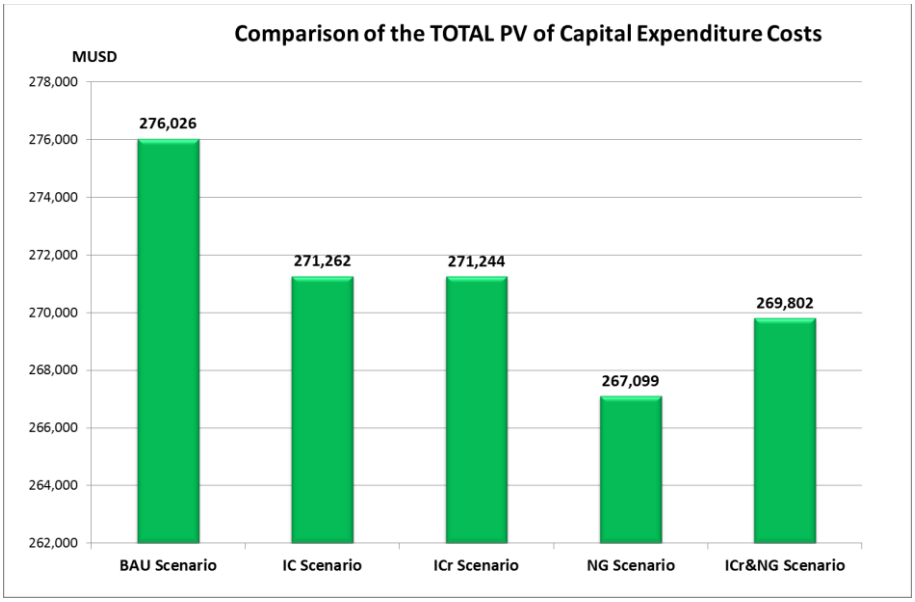

Figure 1 Comparison of the Total Investment Cost (CAPEX)

Table 3 shows the PV of OPEX during the 2012 -2030 period of all scenarios. The operation costs are given for each country, region and for all Arab countries.

Table 3 Operation Cost of all Scenarios during the 2012 -2030 period

Present Value of TOTAL OPEX 2012 - 2030					
Country	BAU Scenario	IC Scenario	ICr Scenario	NG Scenario	ICr&NG Scenario
	MUSD	MUSD	MUSD	MUSD	MUSD
Morocco	21,582	23,414	24,225	23,201	24,334
Algeria	50,882	46,537	46,613	46,547	46,663
Tunisia	16,768	16,564	16,684	16,790	16,635
Libya	45,629	46,687	47,880	46,743	47,657
Egypt	192,611	193,376	192,336	173,266	176,492
Sudan	7,184	7,096	7,042	6,160	6,450
Total North Africa Region and Sudan	**334,657**	**333,675**	**334,781**	**312,707**	**318,231**
Jordan	19,607	20,277	20,955	21,751	20,227
Syria	60,061	61,089	52,025	57,999	51,176
Lebanon	16,651	15,532	15,702	15,454	15,599
Iraq	56,600	58,125	63,706	61,652	63,631
Total JSLI countries	**152,920**	**155,023**	**152,389**	**156,856**	**150,633**
Saudi Arabia	360,965	355,726	353,558	325,321	352,321
Kuwait	97,732	87,420	85,075	79,096	79,294
Bahrain	19,413	21,511	17,884	17,358	14,938
Qatar	22,009	25,594	27,690	25,611	27,825
UAE Abu Dhabi	84,455	87,923	89,902	88,428	90,582
Oman	19,184	19,726	20,174	18,419	19,482
Yemen	21,184	20,070	20,058	19,181	20,026
Total GCC countries and Yemen	**624,942**	**617,970**	**614,341**	**573,415**	**604,468**
TOTAL OPEX of Arab Countries (BUSD)	**1,112.5**	**1,107**	**1,102**	**1,043**	**1,073**

Figure 2 illustrates the total operation costs in the five scenarios. A reduction of costs in all scenarios, compared with the baseline scenario, can be noted, due to two main factors: a) reduction of operation cost as a result of electricity exchanges, and b) reduction of operation costs resulting from the use of additional NG.

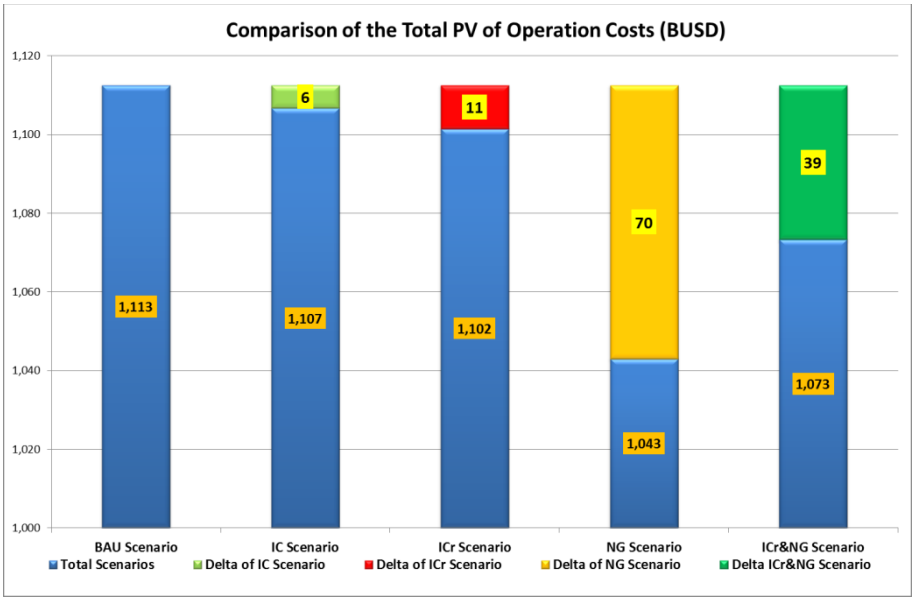

Figure 2 Comparison of the total PV of OPEX of scenarios

Figure 3 illustrates the total electric energy exchanges of the Arab countries for the 2012 – 2030 period in all scenarios. The impact of new investment in electric interconnections is noted in the graphs as an increase of total electricity exchanges in the ICr and ICr&NG scenarios. The benefits from using additional transfer capabilities of new interconnections for economic power exchanges are quantified as saving from operation costs, improved utilization of the generation capacities, and reduction of installed capacities.

Compared with the Integrated Electrical Scenario (IC and ICr), the Preferred Scenario shows a remarkable reduction of total costs (operation costs and capital disbursement costs) related to least cost generation expansion and development of cross-border interconnections (electrical and NG) of the Arab countries.

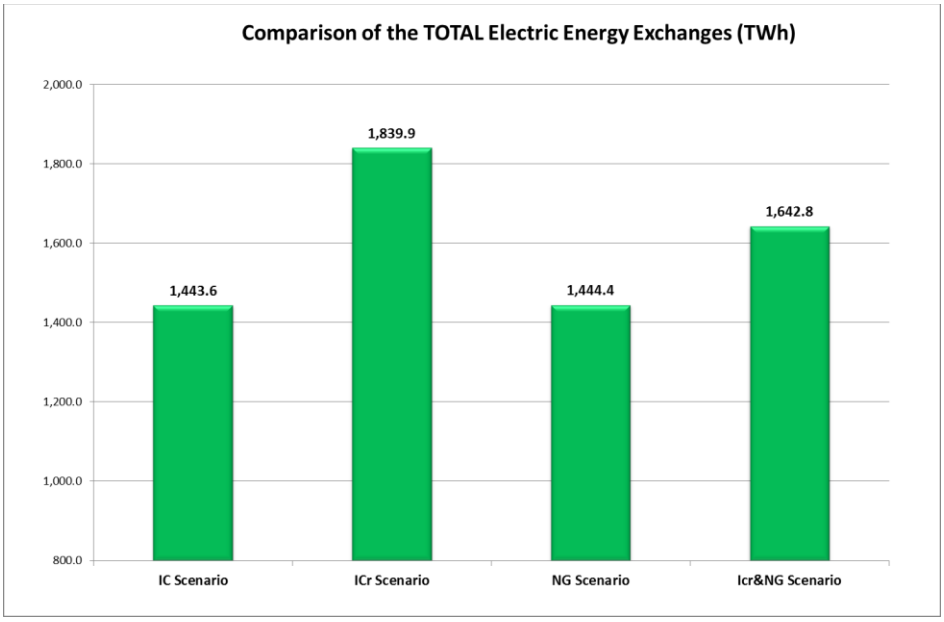

Figure 3 Comparison of the Total Regional Exchanges in all Scenarios

Figure 4 shows the total CO_2 emissions due to electricity generation in the Arab countries during the period 2012-2030. The total CO_2 emission is lowest in NG scenario 17,457 Mton and highest in BAU scenario 18,417 Mton. The distribution of the total CO_2 emissions among the regions of the Arab countries in ICr&NG scenario is as follows: 28.3% in the North Africa region (including Sudan), 14.5% in the JSLI region, and the remaining 57.2% in the GCC region (including Yemen). The reduction of the total carbon dioxide emissions constitutes one of the additional benefits of the economic exchanges of electricity among countries and interconnection mode of operation in the preferred scenario.

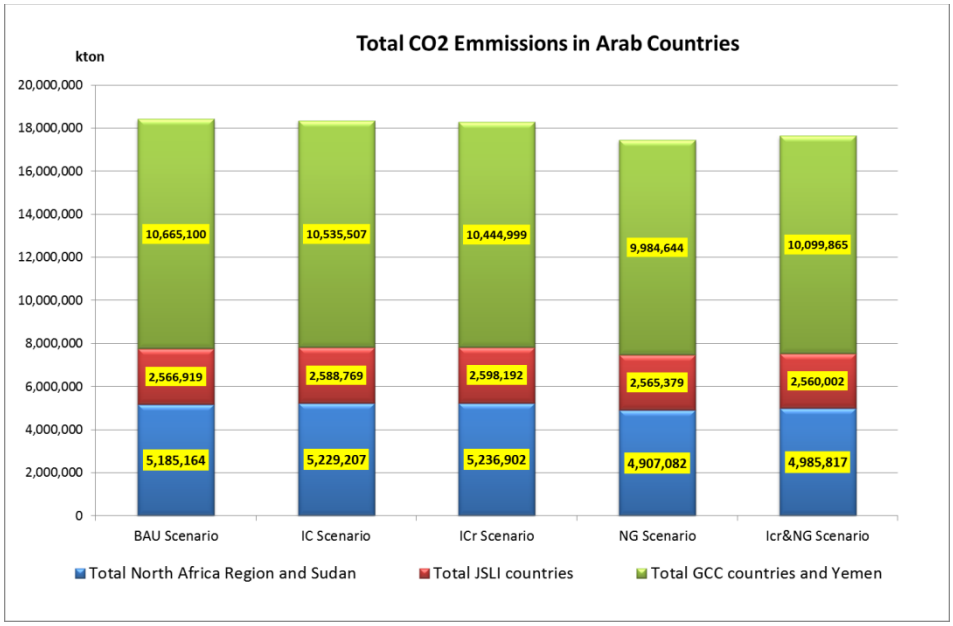

Figure 4 Total CO_2 emissions by Power Generation in Arab Power Sector

The "Preferred Scenario" showed outstanding advantages, with respect to the IC scenario, that were quantified in 35,493 MUSD as reduction of total costs (PV of OPEX and capital disbursement costs) over the study period 2012-2030. The largest share of savings derives from the OPEX (33,336 MUSD), coming from additional NG supplies and the increase of economic electric energy exchanges. The reduction of CAPEX was quantified as 1,460 MUSD.

Furthermore, additional environmental benefits were assessed in terms of reduction of carbon dioxide emissions, which are estimated in 708 millions of CO_2 tons. Assuming the CO_2 price at a level of 15 USD/t the total environmental benefit was quantified in 10,617 MUSD.

The least cost generation-interconnection expansion plan worked out in the "Preferred Scenario" entails an increase in the consumption of NG, which attains 136,993 Tbtu with respect to 126,681 Tbtu estimated in the IC scenario.

The above benefits were achieved by constructing three new NG infrastructures and eleven new electricity cross-border transmission lines.

Finally, it is worth mentioning that additional benefits from and integrated electricity and NG trade with the Arab countries can be attained by adding new NG transport infrastructure as shown in the NG scenario. Nevertheless the recommended scenario is the Preferred Scenario and not NG scenario. The reason is because many of the assumptions made for the NG scenario, derived from available public information and are outcomes of expert understanding, not validated or endorsed by the Arab countries. Hence, the NG scenario should be rather considered as a challenge to evaluate the possible evolution of the electricity production and electricity exchanges under improvement of NG supplies

conditions in Arab countries. Instead the "Preferred Scenario" (ICr & NG Scenario) was agreed to be the recommended scenario, being the related new electrical and NG infrastructures considered feasible also from the implementation plan point of view.

FEASIBILITY OF ELECTRICAL ENERGY TRADING AND POWER EXCHANGES BETWEEN THE ARAB COUNTRIES

The feasibility of electrical energy trading was carried out using as input data, the findings of the Preferred Scenario. The feasibility of electrical energy trading and power exchanges between the Arab countries and with the neighboring regions was investigated based on identified potential electrical energy trading among Arab countries. Also assessment of the transmission adequacy was performed investigating whether or not the transmission system is sufficiently sized to accommodate the potential imports and exports resulting from the various national power balances, and the recommendations to improve the reliability of the interconnected power system.

Market Simulations

The results of analysis regarding the optimal hourly operation schedule of the interconnected system were obtained by Electricity Market Simulator calculating the optimal operation schedule of the interconnected system for four target years: 2015, 2020, 2025 and 2030. Detailed market simulations provided improvement of the planning solution because the operation of the power system was investigated hour by hour; namely the impact on the electrical system of hourly demand profile and hourly power exchanges, RES production and technical restrictions of power plants. The PROMED software tool was used for detailed analysis on an hourly basis.

Simulations of annual operation of selected years allowed the Consultant to quantify the expected annual energy and power exchanges (hourly based) between the Arab countries and with the neighboring regions. Thanks to the simulations, the Consultant updated the generation investments plan, previously obtained with OPTGEN, in target year 2030 for Algeria, Morocco, Sudan and Syria. The simulation results underlined the need for additional generation in these 4 countries. These updates were necessary to manage the non-programmable production of RES and the most stressing peaks of load. Market simulations showed that the most remarkable events in the pan-Arab power system are:

- Investments in Nuclear power plants lead to a decrease in the cost of energy. Countries that benefit from these investments were Egypt and Jordan.
- Investments in renewable energies lead to a decrease in the cost of energy. Nevertheless, it is important to underline that a high share of RES generation requires more investments in new additional thermal generation, in order to manage uncertainty and variability of the primary resources.
- Investments in new electrical interconnections and NG infrastructures lead to a decrease in the energy prices and costs of electricity.

The sensitivity analyses were performed for four additional scenarios starting from the ICr&NG year 2030 scenario, investigating the interconnection of the pan-Arab region to other countries, such as Spain, Turkey and Iran.

Model of Pan Arab interconnected system

The objective of the Consultant was to set up a common data base for the transmission network including all Arab data bases for the target years 2015, 2020, 2025 and 2030. The transmission network

models for year 2015, 2020, 2025 and horizon year 2030 constituted reference base cases for network analysis and the evaluation of technical alternatives of interconnection developments regarding adequacy and security of the interconnected transmission systems.

A detailed model of transmission network in PSS/E computation tool was set up representing the Pan Arab interconnected grid from Morocco to GCCIA and Yemen, while considering the location of the load centers and the power plants. The model of the network was enhanced passing from super-nodes model representing each Arab country with its demand, the generation mix and its interconnections used in OPTGEN simulations, to the explicit detailed transmission network model for interconnected countries with thousands of nodes, loads, internal lines, transformers, generators, etc.

Power Flow Analysis

The reliability and security criteria of the Planning Memorandum, based on fundamental requirements for planning reliable interconnected bulk electric systems, were adopted in the evaluation of the adequacy of the transmission network in all Arab countries. At the regional level, the transmission system adequacy analysis was focused on the interconnections and on the internal lines, which have a direct effect on the power exchanges.

The power flow studies calculated active and reactive flows on transmission lines and transformers, the overall voltage profile of the transmission network, bus voltage magnitudes and phase angles, line currents, line losses, violation of generation capability limits, and other steady-state variables, related to the expected characteristic network operating conditions for the target years.

The steady state power flow study addressed the implementation of economic dispatch of generation units and its impact on the network model of Pan Arab interconnected system taking into account the introduction of the new interconnections. The study assessed the expected cross-border power exchanges in peak load conditions.

The analysis of the future national networks showed that, in general, the branches of EHV/HV network were loaded typically less than their thermal limits. In some countries reinforcements of the internal network would be needed, such as in case of Saudi Arabia, Abu Dhabi, Kuwait, Bahrain and Iraq. Some corrections to the optimal power dispatch, for example in Egypt, Bahrain, Jordan and Iraq, were necessary to make the dispatch feasible in compliance with the transmission network constraints.

Transfer Capacity of Interconnection Corridors among Arab Countries

The Consultant performed the Transmission Transfer Limit Analysis in order to evaluate the adequacy of the national and regional transmission systems and their ability to transport the power from exporting to receiving countries. This was done to estimate the maximum level of power that can be transferred across a network from identified sending and receiving areas or systems. Limits were estimated for both normal and contingency conditions.

The analysis quantified the Total Transfer Capacities (TTC) for each pair of interconnected Arab countries in target years, 2020, 2025 and 2030 for two situation of the internal network of each Arab country: in N condition and in N-1 condition.

For determination of network response, the increased generation in exporting country was simulated; its impact on transmission line flows was monitored, and the maximum transfer was found as the limiting solution that satisfied the thermal criteria. This was done for the base case with normal limits enforced (N conditions), plus all specified contingencies with emergency limits enforced (N-1 conditions).

The values of TTCs were reported for each pair of interconnected Arab Countries. The estimated transfer capacity took in consideration the initial power transferred between two countries, the

maximum incremental power transfer from country A to country B (and vice-versa) and the network element which constrains the transfer due to its overload.

Table 4 lists the values of TTCs in N-1 conditions for each pair of interconnected Arab Countries. The estimated values are related to the transfer capacity of the internal networks and are not limited to the transfer capacity of the interconnections.

Table 4 TTC of the Interconnected Network in N-1 Conditions in Target Years

Interconnection	Country		Requested NTC	Total Transfer Capacity (MW) in N-1 conditions		
	From	To	MW	2020	2025	2030
MA -> DZ -> MA	Morocco	Algeria	800	1,097	1,290	25
	Algeria	Morocco	800	1,357	1,161	951
DZ -> TN -> DZ	Algeria	Tunisia	300	633	454	585
	Tunisia	Algeria	300	374	208	122
TN -> LY -> TN	Tunisia	Libya	500	93	<0	327
	Libya	Tunisia	500	1,105	622	1,008
LY -> EG -> LY	Libya	Egypt	550	1,575	1,681	1,216
	Egypt	Libya	550	879	462	1,809
EG -> SD -> EG	Egypt	Sudan	1,200	235	2,039	669
	Sudan	Egypt	1,200	210	1,292	2,385
EG -> JO -> EG	Egypt	Jordan	600	1,012	1,752	9,607
	Jordan	Egypt	600	209	493	1,202
EG -> SA -> EG	Egypt	Saudi Arabia	2,500	2,733	8,622	>5000
	Saudi Arabia	Egypt	2,500	698	796	<0
JO -> SY -> JO	Jordan	Syria	600	983	<0	1,826
	Syria	Jordan	600	2,212	2,497	2,294
JO -> SA -> JO	Jordan	Saudi Arabia	500	<0	<0	<0
	Saudi Arabia	Jordan	500	920	4,310	3,683
SY -> IQ -> SY	Syria	Iraq	500	1,317	1,728	2,072
	Iraq	Syria	500	274	<0	<0
IQ -> KW -> IQ	Iraq	Kuwait	500	<0	<0	<0
	Kuwait	Iraq	500	2,180	2,301	<0
SA -> GCC -> SA	Saudi Arabia	GCCIA	1,200	1,985	2,418	2,202
	GCCIA	Saudi Arabia	1,200	336	1,551	2,785
KW -> GCC -> KW	Kuwait	GCCIA	1,200	2,029	2,737	1,966
	GCCIA	Kuwait	1,200	742	882	616
BH -> GCC -> BH	Bahrain	GCCIA	600	<0	491	364
	GCCIA	Bahrain	600	14	254	750
QA -> GCC -> QA	Qatar	GCCIA	1,200	1,050	1,050	1,049
	GCCIA	Qatar	1,200	3,058	3,099	367
AD -> GCC -> AD	UAE Abu Dhabi	GCCIA	1,200	4,071	>5000	>5000
	GCCIA	UAE Abu Dhabi	1,200	1,806	1,995	1,663
AD -> OM -> AD	UAE Abu Dhabi	Oman	600	185	410	<0
	Oman	UAE Abu Dhabi	600	3,284	3,421	3,493
SA -> YE -> SA	Saudi Arabia	Yemen	500		<0	1,436
	Yemen	Saudi Arabia	500		60	<0

The analysis identified bottlenecks within national networks. In the following countries reinforcements of the internal network would be necessary to ensure the transfer capacities:

- Morocco
- Tunisia
- Saudi Arabia
- Jordan
- Iraq
- Kuwait
- Bahrain
- UAE-Abu Dhabi
- Yemen.

FINANCIAL ANALYSIS OF SELECTED INTERCONNECTIONS

The objective of the task was to highlight the financial aspects of the selected NG and electric interconnection options. For this purpose the input data are the findings of the Preferred Scenario simulations.

Financial Analysis of Selected NG Project

As a result of the multi-criteria analysis (demand & supply balance, security of supply, market development and maturity of the project), and following analysis of synergies between the identified NG projects and the electricity interconnection scenario, three NG projects were identified for further studies:

- An interconnection between Libya and Egypt, with investment costs 1,980 MUSD;
- An interconnection between Iraq and Kuwait with investment costs 330 MUSD; and
- A LNG import terminal in Bahrain with investment costs 611 MUSD.

For the gas projects it is evident that in order to succeed, intergovernmental agreements must be made between the involved countries. To achieve this detailed feasibility studies must be carried out.

The financing structure of these projects was discussed and presented, with focus on the sources of financing and the applied practice in financing of other gas infrastructure projects. It was found that several regional banks, Arab developments funds, and international finance institutions already have participated in financing of the existing regional pipelines, the Arab Gas Pipeline and the Dolphin pipeline. These experiences where utilized in defining the potential financing structure. The applied financing structure assumes a 70/30 debt/equity split and real returns of 4% and 10% respectively.

Regarding ownership of the pipelines it was recommended that the national companies took a majority share and role in the projects - potentially supplemented by participation from regional or international companies with interests in, and benefits from transport of gas.

The projects are at a relatively early stage in the project cycle thus, the financing analysis for the natural gas projects were aimed at demonstrating feasibility with respect to the following points:

- generate sufficient revenues to cover operating costs, financing costs and the costs of on-going maintenance/asset replacements;
- meet necessary returns for equity holders and lenders;
- implement the project and maintain acceptable tariffs to end users

For each project, balancing tariffs were calculated with the objective of limiting project costs and impacts on the end-users to the greatest extent possible. In this context a NPV=0 approach was deemed most appropriate in determining tariff levels. That is, a breakeven surcharge (per MMBTU gas) that allows for full cost recovery of all annual operating, maintenance and debt service costs throughout the planning period and allows for sufficient returns to equity providers. Based on costs of approximately 2,000 MUSD, 330 MUSD, and 611 USD, respectively for Libya-Egypt, Iraq-Kuwait, and LNG import terminal in Bahrain, the tariffs for usage of the infrastructure for the projects were estimated to 0.44 USD/MMBTU (Libya-Egypt), 0.12 USD MMBTU (Iraq-Kuwait), and 0.65 USD/MMBTU (LNG terminal Bahrain). At the end of the day, the projects' feasibility will depend on the ability of end users to pay tariffs within these ranges. Compared to the economic prices of gas, the above transportation costs were found to be small. Thus it is anticipated that the three projects will be feasible in terms of affordability. Both the cost and the exact transport volume must, however, be further detailed and updated in a full scale feasibility studies.

Regarding the structure and ownership of the pipelines both pipelines are envisaged to start out with a special purpose vehicle structure and later to be divided into two coordinated national projects. However, in the startup phase it is of importance that the companies on both sides of the borders come together to take the necessary decisions and define the project structure and the feasibility study to be undertaken. In order to maximize the probability of the projects being implemented, a strong leading partner preferably with upstream interests is needed.

Financial Analysis of Selected Electrical Interconnections

The analysis of the financial schemes for cross-border interconnector investment covered alternative project financing plans, and determined for each project its' financial rate of return and the overall financial performance for the involved parties, as well as the return on equity in order to ensure the financial/commercial viability of the projects.

The electrical alternatives were selected and analyzed in previous tasks, which showed that they were economically and socially beneficial, but this does not mean that interconnection links will be built unless proper financial incentives that adequately remunerate the project are put in place.

In case of constructing a new interconnector, the basic question is the decision to find financing resources and the distribution of costs of the interconnection between different parties through transmission and/or national grid tariffs. The study indicated several alternative ways to find a solution.

We recommend making use of the regulated investment approach for new interconnectors between the Arab countries. Under the regulated investment approach, generally the organizations responsible for the development of the cross-border capacity are the Transmission System Operators (TSOs) which following appropriate cost-benefit analysis, decide to build interconnection links to mitigate the congestion in transfer capacities for cross-border trade. The investment should be approved by the relevant national Authorities (Ministry and/or Regulators) who determine the amount of the investment that is subject to the "regulated" remuneration (Regulated Asset Base -RAB) and the Rate of Return (RoR, or WACC) applied to the RAB. The cost of a project is usually recovered through regulated tariffs charged to users of the whole system.

There are a number of International Financial Institutions (IFIs) which could be interested in co-financing the electrical interconnection infrastructure. In particular, one of the priorities of the AFESD is to promote electricity trade by energy exchanges and the loans to finance Inter-Arab Projects in the past included several electric power cross-border interconnection projects.

The Consultant developed a financial model for analyzing the financial performance for each of the interconnection projects. The financial analysis examined the financial viability and financial performance of the identified interconnection projects. The financial model takes into account the capital structure (debt /equity), annual required revenues, financing charges and taxes paid. The project profitability and its financials indices such as financial IRR, NPV expected return on equity and PBP that were evaluated over the lifetime of each interconnection projects.

For a given interconnection project the initiative to build new infrastructure may come from two involved TSOs of both countries. The new interconnector can be realized as a public-private partnership (PPP) as a mix of public investment and private investment. The ownership of the interconnection should optimally be a mix of the private investment that holds something less than simple majority, two involved TSOs of both countries and possibly International Financing Institutions. The model was implemented in the form of Consortium or Joint Venture through the establishment of a dedicated company, a Special Purpose Vehicle (SPV) among Private Investors and TSO(s) and International Financing Institutions that participate directly as shareholder of the SPV.

Table 5 shows the main outputs of the Differential Financial Analysis. For each project the table shows the estimated investment cost and its financials indices such as financial IRR, NPV expected return on

equity and PBP. All the projects are financially viable and the financial projection for each project shows values of Equity IRR higher than the Expected Equity Remuneration (12%).

Table 5 Results of Financial Analysis of Selected Electrical Interconnections

Nr	New Interconnections / reinforcements	CAPEX	IRR Before-Finance, Pre Tax	IRR Before Finance, Post Tax	Average Debt Service Cov. Rate	Equity NPV	Equity IRR	PBP
		MUSD	%	%	%	MUSD	%	Year
1	Libya (Tobruk) - Egypt (Saloum) BtB + AC OHL 500 kV	267.45	11.19%	10.07%	126.90%	357.71	15.14%	14.2
2	Tunisia (Bouchemma) - Libya (Rowis) AC OHL 400kV	112.00	11.23%	10.06%	126.61%	138.41	15.49%	13.7
3	Second circuit of Egypt (Taba) - Jordan (Aqaba) AC link 400 kV	61.42	14.80%	12.74%	197.05%	79.36	24.27%	6.2
4	Second circuit of Jordan (Amman North) - Syria (Dir Ali) AC OHL 400 kV	60.41	11.12%	9.74%	124.62%	60.36	18.12%	13.3
5	Iraq (Faw) - Kuwait (Subiya) AC double circuit OHL 400 kV	60.015	12.14%	10.81%	148.85%	188.26	18.04%	10.7
6	Saudi Arabia (Qurayyat) – Jordan (Qatranah) BtB + AC double circuit OHL 400 kV	134.44	12.14%	10.81%	148.85%	188.26	18.04%	10.7
7	Saudi Arabia (Kudmi) – Yemen (Bani Hoshish) BtB + AC double circuit OHL 400 kV	383.27	10.70%	9.56%	121.39%	405.81	13.77%	10.6

BILATERAL AND MULTILATERAL TRADE MODEL

Electricity Cross-border Trading Model

The Consultant presented a model for fair compensation of the TSO facing power transits deriving from the electric energy trade between Arab countries, and provided rules for congestion management. The results of a "dry-run" implementation of the proposed Inter TSO Compensation (ITC) mechanism were presented for a sample year.

The definition of a bilateral/multilateral trading model is of paramount importance. Indeed, so far the lack of clear trading models between Arab Countries (especially in the Mediterranean Arab Countries) hindered the exchange of electricity causing poor exploitation of the existing interconnections. The exploitation rate of interconnections between the Mediterranean Arab Countries in the actual situation is below 10% of their NTC (Net Transfer Capacity). Furthermore, in some cases interconnections are exploited only for mutual support with remuneration in kind.

As a matter of fact, the lack of common rules was considered as the major barrier for Cross Border Trading (CBT) among Arab Countries. Lengthy negotiations for power wheeling across a third country delayed or even prevented cross border trading and actually, the agreements are negotiated separately between the concerned parties. In general, to foster CBT, clear rules are needed for:

- Inter-TSO compensation
- Capacity allocation (CA) across interconnectors;
- Congestion Management (CM).

Actually, in the Arab region, just the Gulf Cooperation Council (GCC) is nearing the "launch pad" of the Electricity Market integrating the power systems of Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman. To this purpose, an initial analysis of the market was proposed in this study referring to the previous studies performed by the GCC Interconnection Authority.

Concerning equal access to information and transparency, it is worth recalling that at present, not even the NTC between countries are published. Thus, some steps can be undertaken immediately, e.g.: publishing of the NTC, the hourly power flows and the procedure adopted for network access.

The final objective is the identification of a CBT model applicable to the Arab countries for the trading of electric energy. After examination of the possible models for bilateral/multilateral energy trading, the Consultant elaborated a model for the fair compensation of the TSO facing power transits deriving from the electric energy trade between the Arab countries. This model takes into account the use of the network assets affected by the energy transactions as well as their annualized cost and including their depreciation. The mechanism for the settlement of the inter-TSO compensations was also addressed.

The Consultant recommended that, considering the geographical proximity and the trend towards the full integration of the Arab regional power systems with Europe, the experience developed in Europe since the year 2000 within ENTSO-E and its predecessors can be fruitfully exploited and taken as a reference. It is worthwhile to mention that generally, when describing how the fund for the inter-TSO compensation is financed, it may be necessary to define different types of countries for which different fees could be proposed:

- ITC Party – A country which is a member of the ITC Agreement.
- Internal ITC Parties – An ITC Party not having any electrical border to any Perimeter Country.
- Perimeter Country – A country, which is not party to the ITC Agreement, but which has an electrical border to an ITC Party.
- Edge Country – An ITC Party which has at least one electrical border with a Perimeter Country.

Perimeter flows should contribute to the fund by paying an annual, ex-ante defined fee for their imports and exports of electricity into/from the ITC area.

In addition, to better define the framework fund for compensation, a financial institution that provides clearing and settlement services for securing transactions, needs to be constituted. This institution, where members of each Arab Country should be represented, will assume the role of a "clearing house" with the obligation of guaranteeing the transfer of compensation to the recipient TSOs.

Finally, the Consultant proposed a time schedule of the setting up of rules for the cross-border trading (CBT) of electricity based on the evolution of CBT procedures towards more market oriented solutions (explicit actions, implicit auctions, market coupling, daily auctions, etc.).

NG Cross-border Trading Model

From a natural gas perspective, the most important part of a trade model is the creation of fundamentals and institutions which facilitate a breakdown of the physical and institutional barriers which today prevent gas from being produced and traded between countries.

In the case of the Libya-Egypt pipeline the largest identified barrier at the moment is the lacking incentives to produce gas. Gas is believed to be in abundance in Libya and in order to utilize these resources, which Libya is believed to possess, it is recommended to introduce a feed-in price for gas export to Egypt. A price which at one hand gives an incentive for producers to engage in exploration of gas and reduce flaring, and on the other hand allows the buying entity to earn a profit on transporting and reselling the gas to shippers on the Egyptian side. It is recommended that the NOC takes the role of national gas exporter, following the same practice applied in Algeria (SONATRACH) and Russia (GAZPROM).

In the case of Iraq-Kuwait to enable export from Iraqi fields to Kuwait, it would most likely require some treatment. Current treatment possibilities in the south are limited to the treatment facilities owned by Basrah Gas Company (BGC). It is not known whether any spare capacity exist at this facility, furthermore third party access is in most likelihood not permitted. Thus for export to take place treatment capacity must be made available.

The preferred contract structure for the pipelines is take or pay contracts ensuring income for a minimum share of the capacity – this would lower risks and ensure cheaper financing. Sale of gas in both pipeline projects should be made on commercial terms under the restrictions that the feed-in price should be high enough to facilitate production of gas in both Libya and Iraq, while at the same time low enough to compete with alternative sources of gas and energy in Egypt and Kuwait.

For the LNG terminal in Bahrain, it should be noted that work already is being undertaken with regards to costing and siting of the terminal. The detailed feasibility study should build on this information. The ownership of the terminal is best placed with the State but other commercial entities such as shippers or large consumers may also have an interest in participating. International companies could have a role since the construction and the operation of the terminal is relatively complex and requires expert knowledge.

A key point to consider with regard to the ownership structure and the operational mode is the risk of not selling enough capacity to cover the cost of the terminal. In particular it should be noted that the project could be competing with pipeline import from Qatar, if the Moratorium on gas export is lifted.

In order for the project developers to alleviate this risk, it is recommended that long term capacity contracts are signed. In this respect the state could have an important role - through one of its subsidiaries it could place long term capacity bookings in the terminal and potential reserve some of the storage capacity for security of supply and strategic purposes This could contribute both to project economics but also to the security of supply in Bahrain, thus imposing a uniform security of supply tariff on all consumers should be considered. The most appropriate operational mode of the terminal was concluded to be a tolling facility. A tolling facility would be less risky than a merchant facility as the operator does not own the gas but merely sells the capacity to interested parties. Due to the lower level of risk financing would also become less expensive.

IMPLEMENTATION PLAN

Finally the study proposed suitable implementation plans estimating the total cost and time schedule for various implementation stages of all proposed interconnections among Arab countries both electric and NG.

Time Schedules of NG Cross-border Projects

The report presented a conceptual timeline for planning and constructing the natural gas pipelines and the related facilities. The overall timeline spans several years, from the start of project planning to mechanical completion, commissioning and commencement of commercial operations (first gas deliveries). The plan is premised on a success-case schedule, i.e. it is based on the assumption that each major activity will be successfully completed in a timely manner. The key underlying premises to this schedule are:

- Fast and clear definition of ownership of the projects.
- There are no unanticipated delays in gaining access and obtaining key permits/approvals for all components of the project scope; and

- project sanction, which triggers most procurement and construction spending, is contingent on receiving access and key permits/approvals.

If some issues arise or unanticipated delays occur, the schedule would be extended accordingly. During project planning, the participants need to do additional work to establish a more definitive project timeline.

The corresponding NG project capacity, capital costs, and completion dates, are as illustrated in Table 6 below.

Table 6 NG Projects Capacity, Capital costs Estimation and Completion Date

	New NG Project	Capacity	Estimated Length (km)	Estimated Costs (MUSD)	Completion date
1	NG cross-border Libya-Egypt pipeline (variant 1)	20 BCM/y, 48"	794	1,818	2018
	NG cross-border Libya-Egypt pipeline (variant 2)		907	1,980	2018
2	NG cross-border Iraq-Kuwait pipeline section 1 (Al Rumaila, Iraq to Kuwait City)	10 BCM/y 38"	172	330,8	2017
	NG cross-border Iraq-Kuwait pipeline section 2 (Kuwait City- Shuiba Industrial Center)	10 BCM/y 38"	55	159	2017
3	LNG Terminal in Bahrain	5 BCM		611	2018

Time Schedules of Electrical Interconnections

With regards to the foreseen interconnections, the following aspects were examined in detail in the study:

- Suitable plans, specific implementation steps and means for expediting the implementation of the pan-Arab electrical interconnection,
- Credible and workable management structures for the interconnections,
- A suitable time schedule for implementing stages of the various pan-Arab interconnections,
- The total cost for planned and proposed interconnections among the involved Arab countries.

Each interconnection was considered as a complete sub-project which, in turn, could be broken into discrete contracts which would allow a number of prequalified international contractors to participate in the implementation of the project.

Therefore after a preliminary activity of setting bilateral agreements between the involved Countries stating the organization of the project and the responsibilities of each member, the main components (lines, substations, converter stations) were analyzed and the main activities (as applicable) were defined with the relevant expected durations and relationships, so as to arrive to a Gantt schedule of each interconnection Project.

In the detailed analysis, the Consultant tried to assume reasonable hypotheses on the time required for all the steps necessary to reach the operation dates for each of the new interconnections foreseen in the economic analysis. More detailed schedules shall be evaluated during the feasibility studies that will be performed for each project by the relevant developers after the decision to go on with the project.

As it can be easily noted on the detailed analysis, the critical path of each interconnection is given by the overhead lines and/or the back-to-back converter stations. In case of urgency, for the overhead lines, the foreseen times can be significantly reduced by a coordinated action with local authorities and stakeholders whilst for the back-to-back converter stations the times are dictated by the market conditions, since their execution is limited to few high technologies specialized contractors.

Figure 5 summarizes the time schedules coming from the detailed analysis of the single interconnection projects.

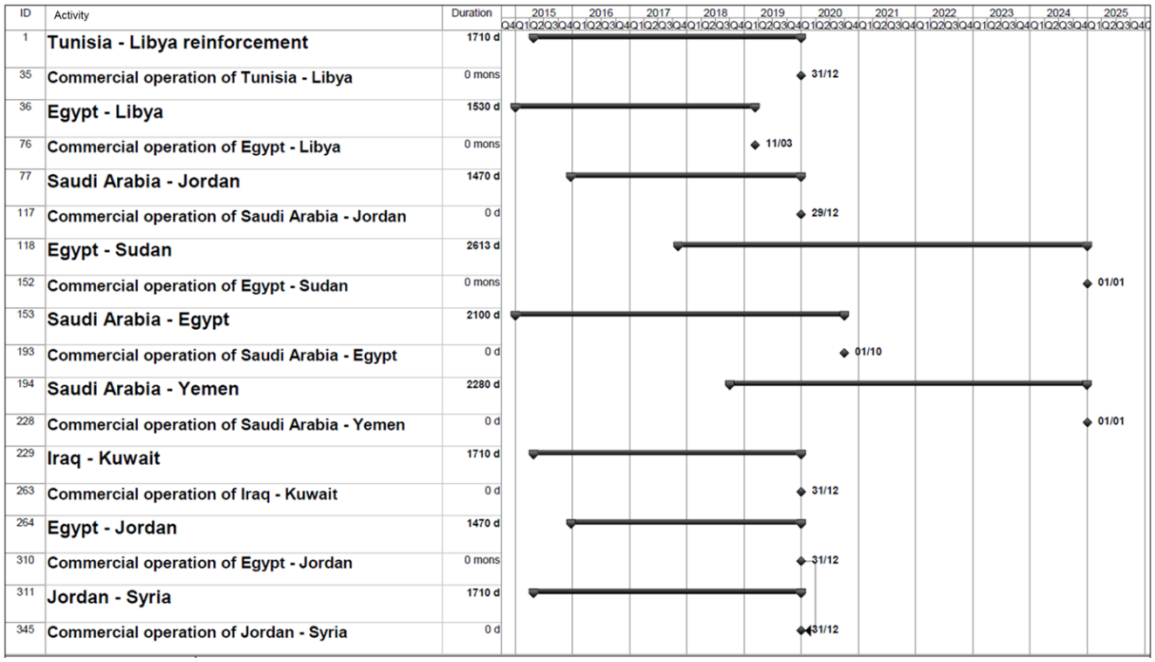

Figure 5 Summary Time Schedule

Table 7 shows the key dates emerging from the time schedules simulating each interconnection project indicating the element (or elements) representing the critical path, in addition to the preliminary feasibility studies, which are always on the critical path.

It should be noted that, whilst for the majority of interconnection projects the starting date is assumed as the maximum date assuring the respect of the final commissioning date expected in the economic study, for the interconnections Libya – Egypt and Egypt – Saudi Arabia the starting date is considered April 2014, being the minimum reasonable date for project commencement, and consequently the completion date is later than the operation date assumed in the economic study.

Table 7 Summary of Execution Time / Dates / Critical Path

	Additional Interconnections/reinforcements	Operation year in economic Study	Calculated schedule (months)	Starting date	Completion date	Critical path
1	Tunisia - Libya	2020	57	April 2015	January 2020	400 kV OHL
2	Libya - Egypt	2017	50	January 2015	March 2019	500 kV OHL & BtB
3	Saudi Arabia – Jordan	2020	50	December 2015	January 2020	400 kV OHL & BtB
4	Egypt – Sudan	2025	86	November 2017	January 2025	500 kV OHL
5	Egypt – Saudi Arabia (*)	2017	69	January 2015	October 2020(*)	500 kV OHL & HVDC stations
6	Saudi Arabia – Yemen	2025	75	October 2018	January 2025	400 kV OHL
7	Iraq - Kuwait	2020	46	February 2016	January 2020	400 kV OHL
8	Second circuit of Egypt - Jordan	2020	49	December 2015	January 2020	Submarine cable
9	Second circuit of Jordan - Syria	2020	52	September 2015	January 2020	400 kV OHL

(*) actually, the implementation plan has already started and the completion date can be closer in time depending on the actual progress of the implementation plan.

The analysis of the planned and proposed interconnections allows to estimate the total capital cost (CAPEX) for the implementation of each interconnection project among the involved Arab countries, which are presented in Table 8 below.

The costs considered in the following analysis are based on average prevailing values present on international market and are very preliminary. A more detailed estimation can be done in the following stages of the feasibility studies, when the project characteristics and market conditions are better defined and the financial and administrative costs (not considered in this estimation) are known and can be added.

Table 8 Capital Costs Estimation

Description	Length of interconnection (km)	Total Cost (MUS)
Single circuit 400 kV reinforcement Tunisia - Libya	280	111.97
Single circuit 500 kV AC reinforcement Egypt - Libya	165	267.45
Double circuit 400 kV Saudi Arabia - Jordan connection	127	134.43
Double circuit 500 kV AC Interconnection Egypt – Sudan	775	538.3
500 kV HVDC Interconnection Egypt - Saudi Arabia	1370	1,518
Double circuit 400 kV Saudi Arabia - Yemen	416	383.3
Double circuit 400 kV Iraq - Kuwait	110	65
Single circuit 400 kV Egypt - Jordan	24	61.4
Single circuit 400 kV Jordan – Syria	145	60.4

CONCLUSIONS AND RECOMMENDATIONS

The main conclusion and recommendation for Arab countries is to adopt the least cost generation-interconnection expansion plan worked out in the "Preferred Scenario" as the best option for new electricity and natural gas interconnections for each country separately, and for all Arab countries combined, in order to maximize the use of their gas resources.

To achieve the benefits identified in the "Preferred Scenario" and the subsequent analyses, a number of actions and recommendations are suggested:

- **Recommendations on the necessary grid reinforcements upstream and downstream the cross-border lines**: The internal reinforcements needed within various Arab Countries should be carefully identified through the elaboration of national (or regional) master plans. Once the internal grid expansions will be identified, technical specifications and tender documents should be prepared for a swift construction of the necessary transmission equipment.
- **Recommendations on the timely start of the various projects (see Construction Implementation Plan)**: To avoid a delayed commissioning of the NG and electricity infrastructures proposed in the "Preferred Scenario", a number of issues should be addressed such as financing schemes and procedure to recover the invested capital, preparation of technical specifications, environmental impact study and, finally, preparation of tender documents.
- **Recommendations on the setting up of rules for the cross-border trading of electricity and NG:** Particularly, for electricity, a number of steps can be undertaken:
    - Starting as soon as possible, countries should, on periodical basis, publish the NTC at the borders;
    - Definition of clear, transparent and non-discriminatory rules for capacity allocation on the cross-border lines; the explicit auction mechanism is the most appropriate mechanism, at least in a first stage;
    - Definition of clear, transparent and non-discriminatory rules for congestion management;
    - Agreement on Inter-TSO compensation mechanism for power transits. To this purpose, a series of multilateral actions should be undertaken.
- **Recommendations on how to take the natural gas projects to the next stage:**
    - Ownership of the projects must be clarified;
    - In depth feasibility studies should be undertaken to confirm estimates on gas market, supply, routing/siting, and costs;
    - A gas master plan for Libya is recommended to be carried out.

This study was performed based on a methodology of least cost integrated development of generation and interconnections (electrical and natural gas) of the Arab countries. One of the achievements of the study was the preparation of the Planning Memorandum and the implementation of the unified planning criteria and methodology for the generation and the transmission network in all analyzed countries. Based on the gained experience the Consultant proposes the following recommendations for the preparation of similar studies in the future:

Recommendations on System Data for Planning Studies

Country databases: The data collection phase was challenging. Our recommendation is to set up and keep updated country databases to be used as starting point for the elaboration of the master plans on transmission and on generation expansion. Databases shall be as much as possible compatible with

each other for an easy and efficient data exchange (see in Europe the adoption of CIM: Common Interface Module).

Recommendations on Coordinated Planning Studies

The future of the Arab regional electricity market also depends on the ability to perform transmission planning on a regional basis in order that network reinforcement projects not only benefit each national interest, but also the region as a whole. Thus, we recommend, as a crucial need, to setup regional transmission planning organizations to be eventually merged into a Pan-Arab association of TSOs with the necessary databases, tools and procedures suitable for the changing conditions and the growing interest in Arab countries for a common electricity market.

Generation and transmission plans: Harmonization among Arab countries regarding the periodical updating of the generation and transmission plans based on coherent scenarios and adequacy criteria for generation and transmission expansion analysis (see in Europe the TYNDP updated every 2 years).

In other regions of the world, common generation-transmission planning capabilities have proven to be the technical promoter for improved regional electric planning standards, better understanding of least cost solutions and the basis for the proposal of bankable projects.

Possible Planning Study Cycle:

- Each year: update of the national transmission plans and generation adequacy outlook;
- Every two years: update of regional transmission plans;
- Every five years: update of Pan-Arab Strategic generation and transmission plan for the whole study period (e.g. with a planning horizon 15 years in advance) accounting for economic, technical and practical implementation considerations.

Grid Codes

In order to promote regional cooperation in transmission planning, the development of a regional grid code is recommended. It implies the creation of a working group which will define rules for planning and operation of the network on a regional level, especially addressing attention towards interconnection lines and those internal lines that have a large impact on transfer capacities between different countries.