



# Final Report

13255-RPT-PM-004 Rev 1

Feasibility Study for the  
Extension of Gas Pipeline  
Network in West Africa

Economic Community of  
West African States  
(ECOWAS)



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**Document Approval**

Rev	Date	Description	By	Chkd	PM
0	31/07/2016	Issued for Client Review as Draft Final Report (DFR)	YB/PH	JD	JD
1	30/09/2016	Revised following DFR workshop and post WS comments as Final	PH	JD	JD

## 1. Executive Summary

### 1.1 Final Report (13255-RPT-PM-004 Rev 1)

This report responds fully to the Terms of Reference issued by ECOWAS and the execution plan defined by the consultant. For the Final Report the contents use and expand on the earlier Draft Final and Preliminary Report and cover all the elements of the scope of work as follows:

Terms of Reference	Section of this Report
<i>Identify all the problems in the functioning of the current pipeline: structuring, partners involved, justification for contracts, availability of gas, safety of the pipeline, possible breaches of contractual arrangements; Propose solutions to problems below for optimizing the operation of the pipeline;</i>	<b>4</b>
<i>Target countries with a clear interest for the study either in terms of supply or in terms of demand; Conduct an overall estimate on a 20-year horizon of the supply of natural gas in the countries of the sub-region; Make an estimate of the demand for natural gas over a time horizon of 20 years in the target countries of the study; These estimates will include: •Supply and demand of electric energy in the sub-region as well as identifying gaps where applicable; •Various energy options to reduce the deficit in electricity and the share of the thermal gas in the resorption of that deficit; •Industries demand for natural gas especially for the production of heat.</i>	<b>5 &amp; 6</b>
<i>Develop concepts for additional pipeline network to be put in place to serve the identified market.</i>	<b>7 &amp; 8</b>
<i>Estimate the network length as well as its cost.</i>	<b>9</b>
<i>Determine the price of the delivered gas.</i>	<b>10</b>

The Final Report builds on the earlier deliverables of the Data Collection Report and the Preliminary Report which have been reviewed in two client workshops (Data Collection Report Accra 02-03 March 2016 and Preliminary Report Ougadougou 27-28 April 2016). The Final Report includes the outputs from the Draft Final Report Validation Workshop held in Dakar, Senegal 30-31 August.

The early work has been developed in the Final Report to provide an overall summary of:

- Key issues affecting WAGP pipeline and recommendations for improving the operation and throughput of the system
- Energy and gas demand across ECOWAS countries and an assessment of future gas demand that an expanded gas system might address
- Gas supply that reflects all possible entry points known at the time of this study and includes WAGP expanded supply, LNG imports into Benin, Ghana, Cote d'Ivoire and Senegal plus, offshore gas from Ghana, Cote d'Ivoire and Senegal.
- A gas transmission network to be developed in phases to address the gas demand with calculations of pipeline and compressor sizes from a hydraulic model

- Calculation of the CAPEX cost of this network and compressors and an estimate of the OPEX
- Economic and financial analysis to calculate the delivered cost of gas

1.1.1

Conclusions

The Final Report concludes as follows:

- Future Use of WAGP
  - As part of the overall ECOWAS gas network, WAGP will have an important role in transporting gas at its full capacity which is 474MMSCFD approximately.
  - Such a volumetric flow assumes that WAGP Company will make investments particularly in their system as Lagos Beach Compressor Station where approximately 40,000HP of additional compression is required to reach the flow and outlet pressure for 474MMSCFD
  - There are a number of suggested actions in this report to undertake that should improve WAGP security of supply and reliability.
- Gas Demands and Supplies
  - Gas supplies into the network are assumed to come from:
    - WAGP fed by Nigerian gas;
    - Offshore gas fields in Ghana, Cote d'Ivoire, Senegal;
    - LNG imports into Benin, Ghana, Cote d'Ivoire and Senegal
  - By 2036 it is estimated that the gas demand that the system can address will be over 55% of the calculated gas demand;
  - The calculated gas demand assumes gas markets in countries where none currently exists, anticipating the uptake in energy demand that the development of the gas network is likely to inspire
  - The projected gas demand for the network will need imports of LNG in addition to new offshore gas discoveries;
  - The offshore gas alone is insufficient to meet future gas demands.
  - Planned LNG developments should be sufficient to meet the forecast gas demand without any need for future (beyond 2036) investments in LNG
- Gas Network Size and Configuration
  - In line with Draft Final Report Workshop comments, three scenarios have been developed in the Final Report for the possible network configuration and scenario 3 selected for further analysis. All networks comprise a coastal pipeline from Ghana to Senegal with alternative inland routes to reach landlocked ECOWAS countries.
  - The network has been considered as an investment over 5 phases covering 16 years duration commencing in 2020 and ending 2036. Each phase respects the normal maximum size of pipeline construction possible during a season by a contractor;
  - The construction of a deep water pipeline to reach Cape Verde should be separately studied to see if a pipeline is economically viable against possible alternatives using LNG or CNG delivered by ship;
  - A ring concept has been adopted where possible as this offers strong security of supply benefits;

- A total network of 5453km length x 28,30" and 36" diameter class 600 pipelines is proposed;
  - 4 compressor stations are required to move the gas to demand centres with a total required power of 52.5MW; this is a 26% reduction in power requirement over that calculated in the DFR
  - The estimated CAPEX cost of the network in 2016 prices is \$M 8386
  - The estimated OPEX cost for the completed network is \$M 249.6/year.
- Gas Prices and Economic Analysis
    - The use of imported LNG will incline network gas prices to plateau at world LNG prices + cost of gas transportation whether the gas comes from offshore or LNG;
    - At present LNG prices are at a low point of US\$3-4 MMBtu but rises can be expected and in the analysis a future price of US\$ 6MMBtu has been adopted;
    - The cost of transportation through the gas network to ECOWAS countries in accordance with the proposed phasing gives a transportation charge of US\$5.6MMBtu (under historic costs accounting)
    - The resulting economic and financial modeling predicts a range of gas delivered prices (gas inlet price+gas transport charge) of US\$11.6 MMBtu approximately over the period of gas network construction (2020-2036);
    - The estimated prices are sensitive to the investment phasing whereby a shorter investment period to construct the network would result in a lower price of gas but higher cash flow requirements to construct the network in a shorter timescale
    - Study into gas by pipeline versus gas by wire support gas by pipeline concept as offering best overall unit cost

Three different concepts for a gas network have been developed and considered in response to the client comments on the DFR made at Dakar 30-31 August 2016. The proposed gas network will connect all ECOWAS countries<sup>1</sup> (as requested by client at Ougadougou workshop April 2016) and is illustrated in the following figure taken from section 7.

<sup>1</sup> Note that for Capo Verde alternatives to gas pipeline need to be considered



**Table 1-1 Proposed ECOWAS Gas Transmission Network (Scenario 3) (colours represent phases of development)**

The majority of the network has been sized at 30” diameter and compression requirements calculated at 52.5MW approximately in four compressor stations. This is a 26% reduction in compressor capacity over that calculated for the DFR.

The total estimated CAPEX is \$8.38Bn approximately for 5453km of network and four compressor stations which would be installed over five main phases of construction.

1.1.2

Recommendations

It is recommended that ECOWAS after a review of this report consider the following:

- Review report recommendations made for the improvement of protection to WAGP pipeline and after prioritising allocate actions to implement;
- Hold meeting(s) with Nigerian stakeholders to review security of supply for gas to WAGP and agreements on reaching the full potential of required gas supply (474MMSCFD);
- Review existing member country plans for LNG import and regas terminals that are described in this report and discuss with developers plans for LNG imports now and future. It may be that early consultation could lead to developers looking to enlarge their plans for LNG imports to account for this project.
- Monitor and correlate offshore gas field developments including updated predictions of gas supply dates and volumes;

- Investigate possible funding sources for the gas network development (this could be part of a feasibility study);
- Commission a feasibility study of the first (or additional) phase of the gas network and develop an overall roadmap of the complete gas network development with an emphasis on refining the proposed phasing of the network investment.

## 1.2 Draft Final Report (13255-RPT-PM-004 Rev 0)

The Final Report was issued as a Draft in August and reviewed at a workshop in Dakar, Senegal 30-31 August 2016. Various comments, observations and recommendations were recorded and in the Final Report these have been actioned as appropriate. In the workshop notes issued at the close of the workshop it was noted that:

***‘The participants underlined the quality of the work done, as well as its consistency and alignment with the study’s objectives and expected results.’***

Amongst the Post-Workshop comments participants included the following:

***‘Congratulations to Penspen for the quality of the preliminary report and the relevance of the arguments that have allowed him to make choices, often, very difficult.’***

## 1.3 Preliminary Report (13255-RPT-PM-003)

### 1.3.1 First Issue (Rev. 0)

The Preliminary Report should be read in conjunction with the Data Collection Report. The Preliminary Report concluded as follows:

- WAGP
  - Nigeria as the source of gas into WAGP has abundant proven natural gas reserves of 188TCF<sup>2</sup>. This quantity of gas is sufficient to supply the entire ECOWAS current demand for gas over 20 years. It can supply the required contractual maximum quantity of gas for WAGP (474 MMSCFD).
  - There are several key issues affecting Nigeria’s ability to utilise the proven gas reserves in the required quantities and ensure that, *inter alia*, gas reaches WAGP in the required quantities. Amongst the issues are Nigeria’s large domestic demand for gas to power (as well as industry directly), sabotage and vandalism to existing gas and oil (affecting associated gas production) pipelines, capacity of the existing upstream system together with the natural gas power demands on that system.
  - The foregoing issues of demands for gas and capacity of the upstream system together with supply interruptions have meant that in practice despite ample gas reserves, insufficient gas has reached the inlet to the WAGP system in the contracted quantities.
  - Actual WAGP throughput has averaged at between one half to one third the contracted pipeline quantity due to the cited issues.
  - The report makes a number of recommendations that should improve security of supply for WAGP customers if adopted.
  - The report makes a number of recommendations concerning gas supplies to WAGP for ECOWAS to consider in holding future

<sup>2</sup> MPR, BP Statistical Review of World Energy 2016

meetings with key stakeholders involved in the Nigerian gas industry upstream of WAGP.

- WAGP extension countries
  - All the 11 countries not part of the existing WAGP system have been examined as part of an analysis using data from the data collection report together with further relevant data to present a comprehensive picture of gas supply, energy demand, electricity production and demand and the prediction of demand for gas over the next 20 years.
  - In response to the request from ECOWAS the energy analysis has been expanded to include existing WAGP countries
  - Combining this data together with other significant factors such as distance from the existing WAGP termination point, alternative sources of power production such as renewables, GDP predictions, proximity to neighbours (for ease of expansion of a future enlarged WAGP system and using a multi-criteria decision analysis approach the consultant has proposed criteria and marks to compare countries in an objective way. This approach was endorsed without amendment at the Preliminary Report review workshop.
  - The criteria chosen are as follows:
    - Distance from WAGP termination point (offshore + onshore)
    - Market size at 2035
    - Population at 2035
    - Average GDP growth rate to 2035
    - Proximity to other ECOWAS countries
    - Lack of significant alternative and competing energy sources (eg hydro)
  - This analysis has identified the following candidate countries which are proposed following the review workshop to be taken forward for analysis in the next deliverable the draft final report. The first pair of countries are:
    - Cote d'Ivoire
    - Burkina Faso

The next lower threshold countries identified are:

- Niger
- Guinea
- Mali

It should be noted that following the workshop for the Preliminary Report and the request to include all ECOWAS countries in the network, the above selections have been used only to order the phasing of the network development.

### 1.3.2

#### Second Issue (Rev.1)

The Preliminary Report at Rev 0 issue was reviewed in a two day workshop held in Ouagadougou, Burkina Faso 27-28 April 2016 by ECOWAS and representatives from most of the ECOWAS countries. In the workshop notes issued at the close of the workshop it was noted that:

***'The participants acknowledged the quality of the work done by the consultant, which provided relevant analysis relating to the conditions for the extension of the West African Gas Pipeline System.'***

A number of observations and recommendations were made in the workshop and in the Rev 1 issue of the Preliminary Report and Draft Final Report these have been addressed.

#### **1.4 Data Collection Report (13255-RPT-PM-002)**

The first deliverable Data Collection Report presented data collected from all ECOWAS countries concerning energy demand, supply and other items. The data was collected in extensive site visits which started in 2Q2015 but with health issues affecting some countries was finally completed in 2Q2016. The rev 0 report was issued in November 2015 and reviewed at a workshop in Accra 02-03 March 2016 and following final site visits issued at rev 1 to ECOWAS June 2016. The data has been used in the analysis of energy demand and calculations for gas demand in the Preliminary Report and Draft Final Reports.