The Optimization of Natural Gas for Power Generation in Nigeria: A Sustainable Synergy with Other Options

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Abstract: *This paper posits natural gas as the major option for the sustainable generation of electric power in Nigeria; a key input to the effective development of this nation. At present, the generation of power, the upstream sector of the electrical power industry, is beset with challenges and difficulties, which can be met with a synergy of natural gas and other options. This paper presents an effective optimization of power synergy; the key to unlocking unlimited megawatts of electricity for Nigeria. This will be enhanced through best practices, innovativeness and a free market system.*

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INTRODUCTION

Nigeria is a nation of over 140 million people. In 2010 - 2011, an average of 3500MW/day of electric power was collectively generated by the PHCN, IPPs, and small scale industrial providers, for domestic, commercial and industrial purposes [(1)]. This was grossly inadequate for a population of over 140 million people. At present, about 4000MW/day of electric power is being collectively generated. Before now, the Federal Government of Nigeria had set December 2009 as a target to generating 6000MW/day of electric power, which was not met [(2)]. How feasible and reliable then, are the attempts being made by the Federal Government to achieving its envisioned minimum power needs of the country, put at 10000MW/day of electricity [(2)]? As petroleum engineers, we posit an analogy between the petroleum and power industries. Table 1 shows this analogy:

Table 1: The Analogy between the Two Industries – Petroleum and Electric Power

Sector	Petroleum Industry	Electric Power Industry
Upstream	Exploration & Production of Petroleum	Exploration & Generation of Power
Midstream	Transportation – Pipelines, etc.	Transmission of Power – Power Lines
Downstream	Processing, Distribution, Marketing	Step-down, Distribution, Marketing

Innovation, technology and best practices are key elements that drive and sustain the petroleum industry, worldwide. Can these elements successfully drive the various sectors of the power industry, especially the upstream sector, in Nigeria? The upstream sector of the power industry can righty be

designated as "exploration & generation" (E & G), the equivalent of the exploration & production (E & P) of the petroleum industry. Here, for any country, options for electric power are first explored (exploration) and then certified to be technologically, economically, and environmentally feasible and sustainable, before the actual generation of power. At present, the Federal Government of Nigeria is aggressively looking at various options for the sustainable generation of electric power. Innovation will play a keep part in these options. Will these options be technologically, economically, and environmentally feasible? Will each option bring real value to the system – the availability and sustainability of electric power in Nigeria? Over the past two decades, the generation of power in Nigeria has been grossly erratic and inadequate to

meet the needs of domestic, commercial and industrial users. We ask the following questions:

- What are the feasible options that can generate electric power cost effectively, with properly defined QHSSE policies?
- Can a model through innovation be developed for sustainable generation of electric power that will add value to the economy?
- Can a sustained research for reliable power alternatives to hydro- energy, through local innovations, especially in green energy, be achieved?
- How can the IPPs effectively contribute to the generation of power in Nigeria?
- What are best practices, and can they be successfully cultured into the E & G of power?
- Can the right pricing for electricity initiate a major change in power generation, through effective private investor interest and participation?
- Are they lessons to learn from the E & P activities of the petroleum industry?

We believe objective answers to these questions will greatly help re-position the generation of electric power in Nigeria. The IPPs, which were planned to be actively involved in the private sector generation of electric power, have not fulfilled their potential and mission [(1)]. We posit that few lessons can be learned from the petroleum industry, especially, through phase development of the upstream sector, the E & G, of the power industry [(2, 3)].

Challenges to the Generation of Electric Power in Nigeria

The generation of electric power in Nigeria has been based over the past few years solely on hydro- and then, natural gas (thermal) energies. The major challenge has been the reliable and sustainable supply of both water and natural gas [(1)]. The natural gas challenge is hopefully been addressed by the NNPC through an increase in the supply of natural gas to generation stations – PHCN and IPPs [(4)]. However, other challenges persist, namely:

- No real investments in power generation for the past twenty years,
- Achieving sustainable rehabilitation and development of the power industry, especially the E & G sector,
- The lack of a sustainable policy and an effective model for power generation in Nigeria,
    - Inconsistent policies by the Federal Government

  - Low Level of Private Sector participation
  - The absence of other options
- The national grid nature of power generation – Kainji, Jebba, and soon to be commissioned Mambilla, IPPs, etc.
  - This has been very ineffective and un-sustainable
  - Functional Regional and local Grids, etc?
- Best practices – Government and Corporate responsibilities, financial responsibilities; effective utilization of local content; ethics in awarding contracts; respect to the environment, etc.,
- Lack of effective and coordinated research and development in innovations and feasible options for electric power, and
- Lack of pro-active management solutions for power assets in generation, especially the big hydro facilities.

How much electric power/day will Nigeria need to achieve and sustain long-term, the desired development – Vision 20:2020? Maybe the country will need 6,000MW, 10,000MW, 25,000MW, 60,000MW or 100,000MW of electric power. How will this power be generated? How long can the generated power be sustained – short term, long term? These questions will be effectively answered when the above challenges are solved. The following difficulties may arise:

- Implementation of sustainable policies on generation of electric power – the "will" to implement the gas master plan, the optimization of natural gas for power generation, etc.,
- Willingness to use and adapt local technology, effectively, and
- Meeting targets through best practices.

The IPPs were and are still expected to play a major role in the total rehabilitation and sustainability of the generation of electric power in Nigeria, if and when properly empowered [1]. Tables 2, 3 and 4 show the status of some old and new IPPs in Nigeria. Some of the old IPPs are marginally functioning because of the above challenges and difficulties. Most often, the thermal stations are not sufficiently supplied with natural gas for such reasons as:

- Missing critical infrastructures – gas pipelines, gas plants, etc.
- The capacities/output of some gas plants are not enough to meet the requirements of the intended IPPs,
- Pro-active management of the facilities, and
- Best practices not fully implemented at the facilities.

As for the hydro-based stations of PHCN, severe shortages of water [1, 2], are often experienced during dry seasons. This often translates to very low power generation. How long do we expect this to continue - the great emphasis on hydro-energy? At present, it is very clear that Nigeria does not have a well articulated model of feasible options for electric power generation, although, the Federal government is actively making efforts to generate more electric power.

Optimization of Natural Gas

We posit that natural gas remains the best option at present and the future, for the generation of electric power in Nigeria.

Fortunately, our natural gas assets, which are very low in carbon dioxide, sulphur dioxide, and the inert gases, are in excess of 200 trillion cubic feet [(2)] of reserves, and these reserves keep increasing as greater exploration for petroleum goes into deeper marine and other environments. At present, the NNPC sources its natural gas for projects, especially the "gas to power" projects, from produced associated dissolved natural gas. Nigeria has excess of 100 trillion cubic feet of non-associated natural gas – conventional and un-conventional. We seek the optimization of natural gas for power generation through:

- A separate natural gas industry, dedicated to gas projects as shown in Figure 1, through
- An effective Gas Master Plan for both conventional and non-conventional gas.
- A free market pricing regime for natural gas, cost effective to the cost of electricity, to guarantee the reliability and sustainability in the supply of the gas.
- Immediate zero gas flare down – policy timetable to be within one year,
- Regional grid system of natural gas plants,
- Private sector participation in the construction and ownership of pipelines to evacuate natural gas to generation stations,
- Active participation of operators of the marginal fields.
- Major sources of natural gas for power generation

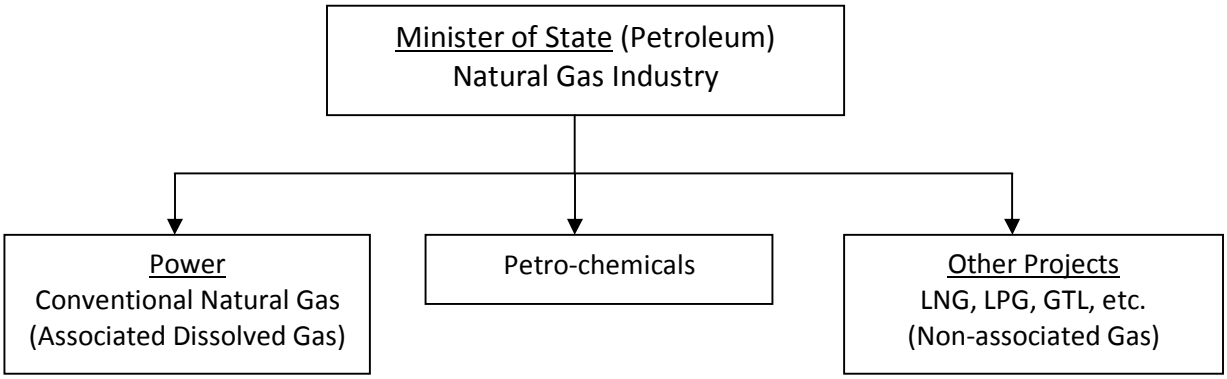

Figure 1: Optimization of Natural Gas

Shale gas, an un-conventional source of natural gas, is available in Nigeria, and we hope, will increasingly form a part of the reserves of natural gas that can be utilized in the future for "gas to products" projects. The United States of America and China are increasingly sourcing a great part of their natural gas needs from shale gas. To guarantee success for the optimization of natural gas for the generation of electric power in Nigeria, Figure 2 shows the various components to our model/plan.

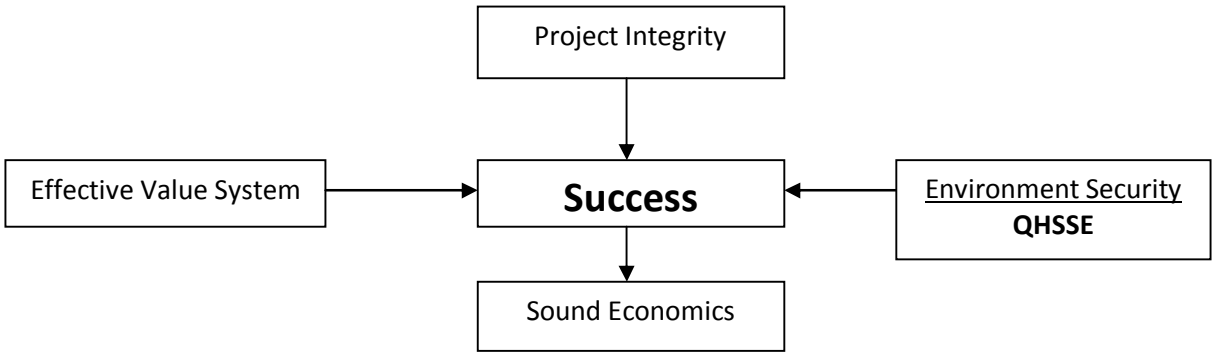

Figure 2: A Model for Success: Natural Gas as Optimum Input to Power E & P

The emission of carbon and sulphur dioxides, remain a major problem to the safety and security of the environment. The capture and storage of carbon dioxide [(5)] in recent electricity projects worldwide, from the utilization of natural gas, is intended to help in the minimization of climate change, but actually impacts on the economy of the project. However, natural gas in Nigeria is very low in these oxides of carbon and sulphur, and thus, if properly planned; the security of the environment is guaranteed.

The effective value system for natural gas ensures effective processing, especially, the proper extraction of hydrocarbon liquids in gas plants, before methane gas is used to generate electric power. We posit that the above model of success for natural gas as a major feed for E & G sector will also be feasible for the other options, especially for coal energy, for the generation on electricity in Nigeria. Figure 3 shows the various sources of natural gas available for the generation of electric power in Nigeria, which are in excess of 200 trillion cubic feet of reserves; however, we posit a plan in which natural gas for power generation is mostly sourced from conventional associated dissolved gas.

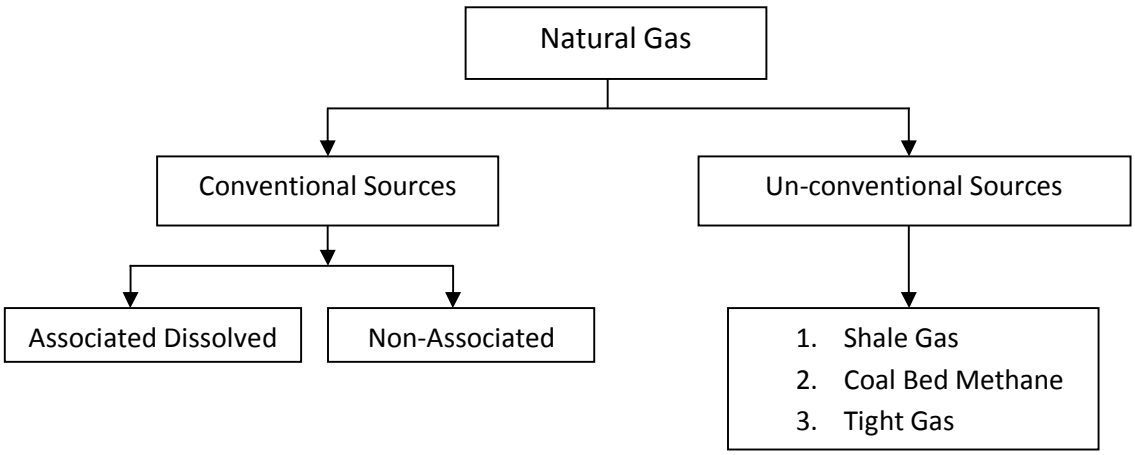

Figure 3: Sources of Natural Gas Available for Generation of Electric Power in Nigeria

To fully optimize the utilization of natural gas in Nigeria, especially, for the generation of electric power, we posit the following:

- Preparation of a comprehensive database of sources of natural gas by DPR
  - Basins/Fields/Reservoirs/Depths metrics
  - Companies/Operators
  - Conventional – Volumes, etc.
  - Un-conventional – Volumes, etc.
- Designated natural gas Companies to produce gas for power generation
- Regional sites for gas plants

Category of Options

We posit three categories of feasible options available to Nigeria, for the reliable and sustainable generation of electric power, as follows:

- Proven Category - Options
  - Natural gas energy
  - Hydro energy
- Probable Category – Options
  - Coal energy – Methane gas
  - Wind
- Emerging Category - Options
  - Solar energy
  - Geothermal energy

Can these options be effectively synergized to evolve a model for the generation of power? At present, the last two options are technologically feasible, but some are not economically and environmentally feasible. Environment security is a major factor against coal energy.

The generation of electric power from coal energy is not new in Nigeria. Methane gas, a hydrocarbon fuel, remains the major source of the energy that is used to generate electric power from coal. The Oji River electric power station is a coal thermal power generation station. At present, it is totally dysfunctional. The raw material, coal, is very much available in great quantity in

Enugu, Benue, Nasarawa and Kogi States of Nigeria. A total rehabilitation of existing coal station(s), with provisions for the capture and storage of carbon, could start and be completed in our suggested timeline.

Wind energy, a green energy, is a very feasible energy source for the generation of electric power in certain parts of Nigeria, namely in the north and continental shelf of Nigeria. Wind farms can be effectively built in these parts of Nigeria. Unfortunately, the use of wind energy for electric power generation in Nigeria is essentially non-existent, although it has been proven to be technologically, economically and environmentally feasible in other countries. Table 5 shows the amount of electric power currently generated by wind energy in some countries [(6)]. Total electricity output from wind energy worldwide is 120,903MW [(6)]. We posit wind energy as a real option which can and should be cultured into a synergy with natural gas, for the generation of electric power. The technology can be locally manufactured, and wind energy is both economically and environmentally feasible.

Solar energy has not translated into what many people had thought. Being abundant and renewable, it was expected to contribute a high level to the generation of power in Nigeria. Two major reasons for this challenge are:

- The technology development for this energy source has not been at the same pace as in hydro, natural gas, and wind, worldwide.
- Still regarded as non-economic, the non-acceptance of this primary energy source by the Federal Government as a major contributor to a feasible power synergy.

The emergence of geothermal energy in Nigeria is due to the increasing discovery of geothermal reservoirs by petroleum operating companies. The optimization of natural gas, and a proper synergy with some options, will play a major part in the generation mix of electric power in Nigeria.

The emerging options can become real options for the generation of power in Nigeria, if and when proper exploration for technology, best practices and local adaptability are put in place. Our model based on a regional grid system of these energy options, can easily be adaptable for an effective and sustainable power generation.

Generation of Electrical Power in Nigeria: Phase Development

As practiced in the petroleum industry, we suggest achieving a sustainable generation in phases, namely:

- Primary phase – Short Term: Natural Gas from Petroleum, and Hydro.
- Secondary phase – Medium Term: Coal and Wind (+ primary phase).
- Tertiary phase – Long Term: Solar and Geo-thermal (+ primary + secondary phases).

We posit development through the following grid system of generation stations:

- Local Grid System:
  - coal, wind, solar, geo-thermal
- Regional Grid System:
  - hydro-, coal, wind
- National Grid System:
  - natural gas

At present, hydro and natural gas energies remain the only sources of electric power generation in Nigeria, which are adapted to the national grid system,

supplying power to major cities, major businesses, etc. This is not sufficient for the nation. With the status quo, the following major problems confront the sustainable generation of power through hydro and natural gas energies, all year around:

- Scarcity of water during the dry season,
- Sustainable availability of natural gas, to feed the available gas plants,
- Increasing volume of clients needing electric power, and
- Poor management culture of stations, facilities, and local content.

In Table 6, we present a model for the generation of electric power in Nigeria, which we believe should be in phases. We advocate a twenty year program to completely rehabilitate and re-position the generation sector (E & G) of the power industry in Nigeria.

A primary phase of about five (5) years: Short term

This short term phase will be characterized by the following activities:

- A comprehensive re-structuring and rehabilitation of the existing hydro- and natural gas- thermal systems, with critical infrastructures in place (three years).
- Completion and commissioning of the Mambilla hydro-station (two years).
- Locate sources and availability of natural gas – designated zones and natural gas producers.
- Construction of new Private sector thermal stations (IPPs) at natural gas producing zones.
- Best practices - Effective management culture in place for facilities and infrastructures.
- Gradual reduction of the contribution of hydro-energy to 10% of total generated power.

To avoid challenges of under-availability of water in our dams, we propose that hydro-energy should supply a maximum of 10% of total generated power after the twenty year period of re-positioning the E & G of the electric power industry [(3)].

A secondary phase of five to ten years: Medium Term

Within this period, and if properly implemented, the Federal Government should achieve:

- A total rehabilitation of all coal generating power stations, with facilities to assure safety and security of the environment.
- A construction of a farm of wind stations in proper regions and places to optimize wind energy

Here, coal and wind generation of electric power are accelerated. These sources of energy are fit for local and regional generation of power to complement the national, which will be characterized by natural gas energy.

A tertiary phase, commencing after ten years: Long Term

With long term planning by the Federal Government, solar and geo-thermal energies will become viable candidates for this phase. Total has commissioned a super-solar plant in Abu Dhabi, for the generation of electric power [(8)]. Solar energy is clearly a local and regional power candidate. In a few years from now, the technology for solar, will become highly innovative and cost

effective, for local and regional generation of electric power in Nigeria.

By the end of the twenty years, Nigeria should have developed an adaptive model of natural gas and other proposed options to reliably and sustainably generate electric power. We posit this is achievable and should be aggressively pursued.

Generation of Electrical Power in Nigeria: Grid Models – Local, Regional and National

As shown in Figure 4, electric power can and should be generated locally and regionally, complementing the present national grid, to supply any region that may not sufficiently generate its electric power requirements.

At present, natural gas - conventional and non-conventional, has been discovered and proven commercially available in the following major basins in Nigeria, namely:

- The Anambra Basin/Benue Trough – Onshore,
- The Bauchi/Gombe Basin– Onshore, and
- The Niger Delta Basin–Onshore and Marine

These basins straddle many of the geo-political regions of Nigeria. New IPPs from the primary phase of the development of power generation should be built around these sources of natural gas, to thermally generate sustainable electric power [9]. Likewise, hydro, coal, wind, solar and geo-thermal energies, will be utilized in locations where they can effectively generate electric power, to meet the power needs of these regions.

These grid model systems will be more functional, easily sustainable and better managed [10]. The unbundling of the PHCN into six generation companies, and the expected privatization of these companies, is a major step in driving and actualizing this model, with each company coordinating the effective generation of power in each region.

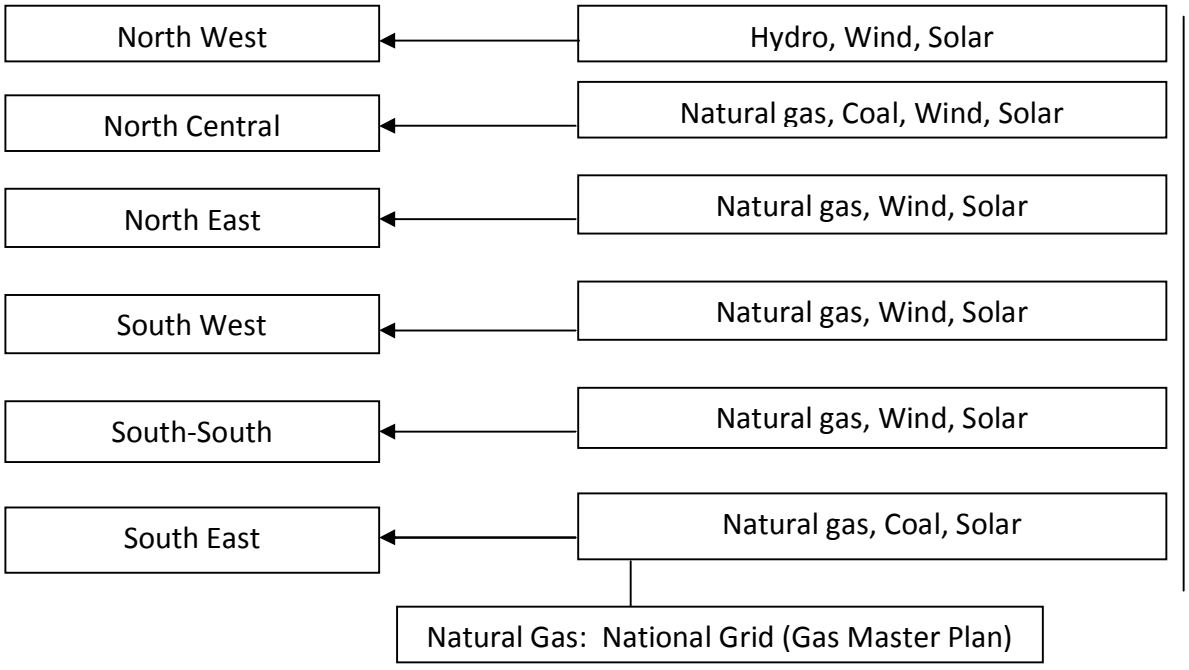

Figure 4: Grid Systems for Power Generation in Nigeria

Generation of Electrical Power in Nigeria: A Free Market System

We ask the following questions that we think should help guide Nigeria in the quest to meeting the goals of vision 2020.

- Who will drive the model we suggested for the phase development of the generation of power in Nigeria, especially, through a regional grid network?
- Who will provide the sustainable funds that will be required to achieve the development and sustainability of the power industry, estimated in trillions of Naira [(11)]?
- How much electric power will Nigeria need to achieve and sustain the sought after economic status by 2020, and beyond?

We posit that the answers to these questions point to the emergence of a free market system for the natural gas and power industries in Nigeria.

A free market system for the generation of electric power in Nigeria will drive the model presented in this paper. The public sector ownership and generation of power has failed over the years. The petroleum industry and the private sector should be encouraged with the right incentives to participate economically priced [(2)], sold and bought. The needed and sustainable funds can only of key industries. Also, key lessons can be learned from the petroleum industry on project funding – JVs, PSCs, etc. A likely option, with equity ownership structure, is shown below:

- Federal Government – 10% of Funds
- Private sector – 70% of Funds
- Petroleum Industry – 20% of Funds

The Federal Government must show responsibility by participation in any funding option, with a maximum contribution of 10% of funds. In Tables 6 and 7, we posit our model and projection for the sustainable supply of electric power in Nigeria, to the year 2030 and beyond.

Generation of Electrical Power in Nigeria: Benefits

in this free market [(11)], where natural gas, and subsequently, power will be be made available by private sector participation – the petroleum industry and private investors; this will guarantee the amount of power that will be needed to achieve and sustain the 2020 vision. The enormous amount of money [(12)] that will be needed to effectively and sustainably generate electric power can only be provided by the petroleum industry and the private sector.

Power should and must be seen as an economic commodity that will only be available if and when it is generated and sold at an economic price, determined by the forces of a free market system. Power must no longer be seen as a commodity that should be generated and then, subsidized by the Federal Government. If the present trend continues, then Nigeria will never be capable of achieving self sufficiency in electric power, a major driver to the welfare

Nigeria is blessed with abundance of resources – natural energies, especially natural gas, which must be harnessed to deliver electric power, for the sustainable development of the country. The country will derive the following benefits from this:

- A greater and effective utilization of our vast natural gas reserves – a natural gas industry, minimization of gas flaring, etc.
- Harnessing of our natural resources – Coal, Wind, Solar and Geothermal energies
- Availability of electric power, to sustain the growth of industries, commercial businesses, etc.
- Capacity building of local content – A better culture of quality training
- Better global outlook for Nigeria – Investors can now come due to the sustainable availability of electric power
- Attaining the 2020 vision of becoming one of the 20 economic powers by year 2020.

CONCLUSIONS

We have looked into the optimization of natural gas and other options available to sustain the generation of electric power in Nigeria. At present and in the future, natural gas remains the major option. We posit that a phase development in the exploration & generation sector of the power industry is a most likely and effective way to go. This is a major lesson from the E & P sector of the petroleum industry, where assets are developed in phases. We suggested a phase period of twenty years based on regional grids of generating stations, after looking at the present challenges and difficulties facing the power industry. Benefits abound, and we believe that the following actions will greatly and quickly drive the power industry to excellence:

- A zero gas flare down within the next one year,
- A separate natural industry to effectively exploit the abundant reserves of our natural gas and provide the sustainable volumes for proper generation of electric power,
- Emergence of green energy options for power generation,
- A free market system for the natural gas and power industries,
- Implementation of sustainable policies on generation of power,
- Meeting targets on construction of facilities, and
- Best practices – Government and Corporate responsibility, financial responsibility, responsibility to the environment, and transparency in the awards of contracts.

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NOMENCLATURE

DPR	-	Department of Petroleum Resources
E & G	-	Exploration and Generation (Power Industry)
E & P	-	Exploration and Production (Petroleum Industry)
IPPs	-	Independent Power Plants
MW	-	Megawatts
Naira	-	Currency of Nigeria
NERC	-	National Electricity Regulatory Commission
PHCN	-	Power Holding Company of Nigeria
QHSSE	-	Quality Health, Safety, Security, and Environment

Table 2: Seven New National Integrated Power projects (NIPPs) in Niger Delta [(1)]

S/N	Power station name	Location/ site	Status	Capacity (MW)
1	Calabar thermal power station	Cross River	Under construction	561
2	Egbema thermal power station	Imo	Under construction	338
3	Eyaen thermal power station	Edo	"	451
4	Gbarain/Ubie thermal power station	Bayelsa	"	225
5	Ikot Abasi thermal (ALSCON)	Akwa Ibom	Yet to be awarded	300
6	Sapele thermal power station	Delta	"	451
7	Omoku thermal power station	Rivers	"	230
8	Ikot Abasi	Akwa Ibom	"	188
	TOTAL			**2,744**

Table 3: Commissioned Independent Power Plants (IPP) Power Projects in Nigeria [(1)]

S/N	Power station name	Location/site	Status	Capacity(MW)
1	AES	Lagos	Commissioned	300
2	AGIP	Delta	"	480
3	Ajaokuta Steel Company Ltd	Kwara	"	80
	Total Capacity			**860**

Table 4: Planned Independent Power Plants (IPPs) [(1)]

S/N	Power station	Location/site	Status	Capacity (MW)
1	Geregu	Kogi	Some units commissioned	828
2	Mobil	Akwa-Ibom		350
3	Eagle	South		560
4	Papalanto	Ogun	Some units commissioned	670
5	Ibom	Akwa- Ibom		620
6	Gombe	Gombe		500
7	Shell/APP	Afam	Some units commissioned	1000
8	Kaduna	Kaduna		1000
9	Bali	North		500
10	Okitipupa	Ogun		670
11	Agbara-Otor	Delta		450
12	Omotosho	Osun	Some units commissioned	
	Total without Omotosho			**7,148**

Table 5: Worldwide Production Capacity of Wind Energy [6]

Units	United States	Germany	Spain	China	India
MW	25,369.00	23,902.00	16,740.00	12,200.00	9,645.00

Table 6: Our Proposed Model for Electric Power Generation in Nigeria

Time	Hydro (%)	Natural Gas (Thermal Stations) (%)	Coal (%)	Wind (%)	Geo-thermal (%)	Solar (%)
2009/2010	≈36	50 + 14 = 64	0	0	0	≈0.01
2020-2030	10	65	10	10	2.5	2.5

2009/2010: Avg. Generated/day = 3736.54MW [1]**; PHCN thermal = 50%; IPPs thermal = 14%;**

Table 7: Projected Power Availability between 2020 and 2030

Installed Capacity (MW)	Hydro (10%)	Natural Gas (65%)	Coal (10%)	Wind (10%)	Geo-thermal (2.5%)	Solar (2.5%)
30,000 **(Yr 2020)**	3000*	19500	3000	3000	750	750
45,000 **(Yr 2030)**	4500*	29250	4500	4500	1125	1125

*Hydro – Kainji, Jebba, Mambilla, etc. (Feasible due to the Primary Phase Rehabilitation Project)

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