



REPUBLIC OF GHANA

# ENERGY INFRASTRUCTURE FRAMEWORK 2018-2047



Republic of Ghana

**National Development Planning Commission**

# **ENERGY INFRASTRUCTURE FRAMEWORK**

**of the**

## **GHANA INFRASTRUCTURE PLAN**

**2018-2047**

THE GHANA INFRASTRUCTURE PLAN IS A  
COMPANION DOCUMENT OF THE  
40-Year National Development Plan (2018-2057)

It draws substantially on the National Spatial Development Framework (2015-2035) as a critical complement to infrastructure development through the efficient utilisation of land and the sustainable management of population growth

## ACKNOWLEDGEMENTS

As a long-term document, the Ghana Infrastructure Plan (GIP) is a framework, or a master plan, for the preparation of medium-term and annual infrastructure plans by successive governments up to 2047, 10 years before the completion of its “mother” document, the *40-Year National Development Plan*. It was prepared with the support of many individuals and institutions. The vision and commitment of both the previous and current leadership of the Commission, particularly chairmen P.V. Obeng, Prof. Kwesi Botchwey, Prof. Stephen Adei, Prof. George Gyan-Baffour, and Dr. Nii Moi Thompson, proved highly valuable from the start to the completion of the GIP.

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Last but not least, the staff of the Commission deserve special commendation for burning the proverbial midnight oil to ensure that the contents of the plan conformed to the development aspirations of Ghanaians as outlined in the 40-Year National Development Plan, officially known as “Ghana Rising: Long-term National Development Plan of Ghana (2018-2057).

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**The GIP has been translated into the following frameworks:**

1. Energy Infrastructure Framework
2. Transport Infrastructure Framework
3. Water Infrastructure Framework
4. Human Settlements and Housing Infrastructure Framework
5. Social, Civic and Commercial Infrastructure Framework
6. ICT Infrastructure Framework
7. Institutional Development Framework
8. Results Framework
9. Financing Framework

# ENERGY INFRASTRUCTURE FRAMEWORK

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## LIST OF ACRONYMS AND ABBREVIATIONS

|        |                                                 |       |                                                       |
|--------|-------------------------------------------------|-------|-------------------------------------------------------|
| AMI    | Advanced Metering Infrastructure                | NPI   | Nuclear Power Institute                               |
| BOST   | Bulk Oil Storage and Transportation             | MMSFD | Million Cubic Feet of Gas A Day                       |
| EEE    | Electrical and Electronic Equipment             | MOE   | Ministry of Energy                                    |
| CSS    | Carbon Capture & Storage                        | MW    | Megawatt                                              |
| EC     | Energy Commission                               | OECD  | Organisation for Economic Cooperation and Development |
| ECG    | Electricity Company of Ghana                    | PURC  | Public Utilities Regulation Commission                |
| ESI    | Electricity Supply Industry                     | RE    | Renewable Energy                                      |
| FIT    | Feed-in-Tariff                                  | REEE  | Renewable Electrical and Electronic Equipment         |
| FSRU   | Floating Storage and Regasification Unit        | REPO  | Renewable Energy Purchase Obligation                  |
| GAEC   | Ghana Atomic Energy Commission                  | TOR   | Tema Oil Refinery                                     |
| GMPM   | Ghana Gas Master Plan Model                     | USD   | United States Dollars                                 |
| GIIF   | Ghana Infrastructure Investment Fund            | VRA   | Volta River Authority                                 |
| GIP    | Ghana Infrastructure Plan                       | WAAP  | West Africa Power Pool                                |
| GIS    | Geographic Information Systems                  | WAGP  | West African Gas Pipeline                             |
| GNPPO  | Ghana Nuclear Power Programme Organisation      |       |                                                       |
| GRIDCo | Ghana Grid Company                              |       |                                                       |
| GSA    | Ghana Standards Authority                       |       |                                                       |
| IAEA   | International Atomic Energy Agency              |       |                                                       |
| IEA    | International Energy Agency                     |       |                                                       |
| HELE   | Higher Efficiency, Low Emission                 |       |                                                       |
| LCO    | Light Crude Oil                                 |       |                                                       |
| LED    | Light Emitting Diode                            |       |                                                       |
| LFG    | Land Fill Gas                                   |       |                                                       |
| LHV    | Low Heat Valve                                  |       |                                                       |
| LNG    | Liquefied Natural Gas                           |       |                                                       |
| LPG    | Liquefied Petroleum Gas                         |       |                                                       |
| LTNDP  | Long Term National Development Plan             |       |                                                       |
| NEA    | Nuclear Energy Agency                           |       |                                                       |
| NEDCo  | Northern Electricity Distribution Company       |       |                                                       |
| NERC   | North American Electric Reliability Corporation |       |                                                       |
| NGPP   | Natural Gas Pricing Policy                      |       |                                                       |
| NITS   | National Interconnected Transmissions System    |       |                                                       |
| NNPC   | Nigeria National Petroleum Corporation          |       |                                                       |

# HIGHLIGHTS

## Powering the future for national development

### ELECTRIC POWER

- Total power installed is increased from 3,800MW in 2018 to 50,168 MW by 2047, with energy generation of 297,200 GWh.
- Under the programme, Ghana's electricity generation per capita is expected to increase from 348 kWh in 2016 to 5,850 kWh in 2047.
- Total investments in the energy sector including transmission and distribution will exceed \$168 billion.
- Transmission and distribution losses are expected to reduce from 4.5% and 22.75% in 2016 to 2.5% and 6% by 2057, a 40-year period.
- More than US\$130 billion will be saved over a period of 40 years in the transmission and distribution system by implementing loss reduction measures.
- Clean coal technology based on the highly efficient ultra-supercritical and supercritical methods will be introduced from 2020, and a total of 12,200MW (24%) developed of power will be developed from coal sources.
- Unless new discoveries are made, Ghana's indigenous gas will be depleted within twenty years, and the country will have to resort to imported LNG to make up. Given the highly volatile nature of the LNG price, a generation mix based on a high prominence of LNG would make future electricity prices very uncertain. Therefore, Ghana will rely on nuclear power and coal if it is to create the needed base load energy to power industries, firms and households.
- The relative elastic supply of coal compared to other fuels contributes largely to its relatively lower price volatility. Adding coal to the country's energy mix therefore provides an efficient hedge against fuel volatility, such as expected with gas prices.
- Energy Commission will establish a division to be solely focused on the regulation and development of coal technology, restricting only ultra-supercritical and to a lesser extent supercritical technologies in Ghana.

### Summary of activities and cost of financing the Energy Infrastructure, 2018-2047

#### ELECTRIC POWER

- Total investments (excluding fuel) for coal, oil, gas, renewable, nuclear power and transmission and distribution will exceed \$168 billion.
- Total power generation increased to 50,168 MW.
- Clean coal technology (ultra-supercritical) 12,200MW (24%) developed.
- Transmission and distribution losses reduced to 2.5% and 6% by 2057.

#### RENEWABLE ENERGY

- Increased share of renewable energy from 1% to 18% of national energy mix, from 38MW to 9,000MW by 2047
- Improvement in the efficiency of production and use of woodfuels
- Renewable Energy to be mainstreamed into GIP
- Renewable energy Authority established to implement master plan.

#### NUCLEAR

- Ghana roadmap for nuclear development addresses 19 nuclear infrastructure issues across 3 Phases.
- First nuclear power plant to be in operation by 2029
- 12,800 MW (26%) of nuclear power developed, serving as prime baseload energy to scale-up industrialisation and manufacturing

#### PETROLEUM

- Sustainable exploration, development and production of oil & gas mainly by Ghanaian firms
- Extension oil and gas pipelines across the country
- New gas discoveries made to support declining stock
- LPG for cooking - household penetration increased from 23% to 100%.

#### CROSS-CUTTING ISSUES

Environmental Impact – climate change  
Contribution towards energy diversity and security  
Contribution towards equity in energy access  
Improvement of technical and management capacity of Energy Institutions



## RENEWABLE ENERGY

- The contribution of renewable energy in the national energy mix will increase from 1 percent in 2018 to 18 percent by 2047.
- Increased share of renewable energy (solar, wind, wave & biofuel) from 1% to 18% of national energy mix, from 38MW to 9,000MW by 2047
- Renewable Energy will be mainstream into the GIP and the Renewable Energy Authority will be established.
- A total investment required for implementing renewable energy development is estimated at US\$ 20 billion over the plan period.
- Dependence on biomass as main fuel for thermal energy applications (cooking and heating) will be reduced.
- Local content and participation in the renewable energy industry will be promoted.
- Effective implementation of the Renewable Master Plan is expected to create about 370,000 jobs along the value chains of the various interventions.
- The use of roof space in commercial, industrial, public and private facilities for solar installations will be strongly encouraged and promoted.
- Renewable Energy research and development (R&D) priorities will be established and implemented in partnership with relevant stakeholders.

## NUCLEAR

- About 12,800 MW (26%) of nuclear power developed, serving as prime baseload energy to scale-up industrialisation and manufacturing by 2047.
- It is expected that Ghana's first nuclear power plant will start by 2029.
- The roadmap for Ghana's nuclear power programme identifies actions for each of 19 infrastructure issues spanning the three phases of development. Appropriate agencies have been identified to be responsible for the various infrastructure actions in the roadmap.
- Nuclear power has high energy security mainly due to the low fuel requirement as a result of the high energy density of nuclear fuel.
- A kilogram of nuclear fuel for example can generate 50,000 kWh of electricity whereas that of firewood, coal and crude oil can generate 1 kWh, 3kWh and 4 kWh respectively. This low fuel requirement can also reduce significantly, the risks associated with fuel supply and price instability.
- Even though the capital cost of a nuclear power plant is relatively high, the low cost of nuclear fuel and the relatively long lifetime (about 60 years) make nuclear power economically competitive than thermal power plants in the long run. Nuclear fuel constitutes about 14% of the entire electricity generation cost compared to 89% in gas and 78% in coal. This makes nuclear power systems insensitive to fuel price volatility.
- Nuclear power is a relatively clean source of power emitting no greenhouse gases and gaseous pollutants at the plant operation level. It is also a major contributor to climate change mitigation. Currently the use of nuclear power instead of coal saves the world from an emission of about 2 billion tonnes of CO<sub>2</sub> annually.



## PETROLEUM

- The jubilee fields is being developed in phases, thus there are more wells to be drilled, which will increase the oil and gas production and extend the plateau of production profiles in the country.
- Potentially significant onshore oil resources exist in the voltaian basin, although the exploration and development is a long term proposition.
- The capacity of the Tema oil refinery will be increased from 45,000bpd to 60,000bpd by 2025.
- A new 60,000bpd capacity oil refinery is to be constructed in the Western Region, to process domestic oil finds in the offshore basins.
- The means of transporting crude oil and its finished products from the supply source to the markets, will continue to be via pipelines, road or marine vessels. The same will be used to transport domestically produced oil to the Tema Oil Refinery for processing.

- In addition to the WAGP, which runs from Nigeria through Benin and Togo to Ghana, a national gas transmission pipeline network will be developed comprising the Western, Eastern and Northern corridors, at the cost of US\$563 million, US\$675 million, US\$468 million respectively.
- An oil utilisation plan will be developed to define an allocation scheme for the various industries to help monitor oil demand and to avoid waste.
- To ensure supply security and cost reduction of petroleum products, the GNPC will initiate its own exploration and production business within the next 5-10 years.
- The pipeline infrastructure that transports petroleum products will be expanded to gradually phase out road transportation of petroleum products.







The country's total hydropower potential is estimated to be about 2,420 MW, of which 1580 MW or 65.3 percent of this potential has been exploited. These are the following:

- i) Akosombo power Plant - 1020 MW, with a dependable capacity of 900 MW
- ii) Kpong Hydropower Plant - 160 MW, with a dependable capacity of 148 MW
- iii) Bui Hydropower Plant - 400 MW, with a dependable capacity of 342 MW.

The remaining 840 MW is yet to be exploited and could yield a dependable capacity of 500 MW.

1.3.2 Potential of Renewable Energy

Ghana has several renewable energy resources such as wind, solar, mini and small hydro, tidal wave, biomass and biogas that can be exploited for electricity production and supply in the country. The government has identified renewable energy as one of the options to contribute to the overall energy supply mix and minimise the adverse effects of energy production on the environment.

1.3.3 Domestic Natural Gas

Resources

In 2007, crude oil associated natural gas was discovered in the Jubilee fields, offshore Cape Three Points in the country's sedimentary basins. Natural gas was again discovered in the Tweneboa, Enyenra and Ntomme (TEN) fields; and Sankofa- Gye Nyame (SGN) fields. The total associated and non-associated natural gas reserves-in-place discovered increased from 0.57 Tcf (trillion cubic feet) in 2010 to about 2.38 Tcf in 2014, a four- fold increase. Exploration activities are going on to discover more reserves. Assuming 80 percent of the country's natural gas reserves-in-place would be recovered for electricity generation, that would be adequate to generate electricity for 25 years from a 1,200 MW combined cycle power plant with a heat rate of 7800 BTU/kWh. Table 1.2 shows the reserves and other features of the associated and non-associated natural gas fields discovered.

Table 1.2: Natural gas discoveries and reserves

| Natural Gas Fields | Associated Gas-in-place (BCF) | Non-Associated Gas-in-place (BCF) | Year of discovery | Year of start production | Year of end of production | Expected Peak daily production (mmscf/day) |
|--------------------|-------------------------------|-----------------------------------|-------------------|--------------------------|---------------------------|--------------------------------------------|
| Jubilee            | 568                           | 0                                 | 2007              | 2015                     | 2022                      | 100                                        |
| TE                 | 294                           | 59                                | 2009 - 2012       | 2016                     | 2027                      | 85                                         |
| N                  | 287                           | 1071                              | 2009 - 2012       | 2016                     | 2038                      | 180                                        |
| SGN                |                               |                                   |                   |                          |                           |                                            |

Source: Energy Commission

The main challenges with relying on domestic gas are:

- i. The irregular natural gas supply from the Jubilee Field due to frequent shut-downs of the FPSO and Atuabo gas processing plant.
- ii. The Atuabo gas processing plant, with a name-plate capacity of 150 MMscf/day (150,000 standard cubic feet/day) limits gas supplies from the domestic natural gas fields.
- iii. Natural gas supply from the Jubilee Field is expected to peak in 2019 and then start a terminal decline up to 2035.
- iv. Despite Tweneboa Enyenra Ntomme (TEN) and Sankofa Gye Nyame (SGN) coming online in 2016 and 2018, the long-term supply of domestic natural gas for electricity generation is uncertain unless intense exploration activities are undertaken to discover new fields.
- v. The high price of domestic natural gas, which varies from US\$ 2.50/MMBTU (million BTU) for Jubilee gas to US\$ 9.50/MMBTU for Sankofa gas compared to US\$ 8.00/MMBTU for WAGP gas.

1.3.4 Natural Gas Imports

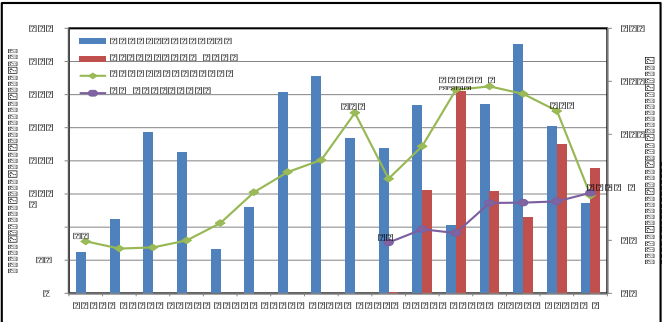
Ghana imports natural gas from Nigeria for electricity generation. Nigeria has proven natural gas reserves of about 180 Tcf<sup>2</sup>. Some experts however put Nigeria's natural gas reserves at about 110 Tcf and some even put it as low as 47 Tcf if strict commerciality criteria are applied<sup>3</sup>. Nigeria's current total natural gas export commitments are about 27 Tcf. However, commitments to increasing domestic gas demand leaves about 12 Tcf of uncommitted natural gas resources, which is sufficient to generate 50 GW of power for 50 years<sup>4</sup>.

N-Gas, a subsidiary of Nigeria National Petroleum Corporation (NNPC) is expected by contract to supply an initial amount of 120 MMscf/day of natural gas through the 678 km West African Gas Pipeline (WAGP). The capacity of WAGP can however accommodate future growth in gas demand up to 474 MMscf/day maximum with compresssion additions. In case the gas volume increases to 474 MMscf/day, this would suffice for a 3,000 MW combined cycle power plant. However, since the commissioning of the pipeline in 2009, it has operated on the average below the contracted volume of 120 MMscf/day (which can generate about 750 MW from a combined cycle power plant) due to gas supply constraints in Nigeria, accidental damage to the pipeline on two occasions and non-payment for gas supplies.

2 BP Statistics 2016  
3 Harnessing Africa's Natural Gas Resources: A New Opportunity for Africa's Energy Agenda by the World Bank  
4 Harnessing Africa's Natural Gas Resources: A New Opportunity for Africa's Energy Agenda by the World Bank

Figure 1.3 shows annual light crude oil and natural gas imports and the prices of these fuels.

Figure 1.3: Annual light crude oil and natural gas imports and their prices



Source: Energy Commission

The key issues, with regards to the purchase of fuels for electricity generation from 2000 to 2016 are summarised as follows:

- i. The average price of light crude oil increased from US\$ 4.9/mmBTU in 2000 by 250 percent to US\$ 17.0/MMBtu in 2008. It then decreased in 2009 before increasing to an all-time high of US\$ 19.5/mmBTU in 2012. The price has however, decreased thereafter to US\$ 9.2/MMBtu in 2015.
- ii. The price of imported natural gas almost doubled from US\$ 4.5/mmBTU in 2009 to US\$ 9.5/MMBtu in 2015.

iii. The price of fuel imports for thermal electricity generation faced the challenges of: (a) foreign exchange erosion; and (b) instability and escalation of prices, which exerted pressure on the cost of procuring these fuels. For example in 2015, the average exchange rate of the Ghana Cedi to the US Dollar was about GHS 3.77 compared to GHS 0.70 in 2000, which means the local currency depreciated by 440 percent and as such the cost of procuring fuels in GHS terms ballooned.

iv. These developments exerted an upward pressure on electricity tariffs and the cost of goods and services in the country.

v. Natural gas supplies through the West African Gas Pipeline since 2012 have been erratic and inadequate leading to periodic generation shortfalls of about 500 MW in 2015 and associated power supply crises<sup>5</sup>.

Due to the existing challenges, it has been projected that domestic demand for natural gas will outstrip supply from domestic fields and imports through WAGP by 2025. Consequently, a Floating Storage and Regasification Unit (FSRU)

will be constructed for the importation of liquefied natural gas (LNG) for electricity generation by 2020.

1.3.5 Nuclear Power

Studies conducted in the 1970s and more recently indicate that there are pockets of uranium deposits in some parts of Ghana. There are ongoing follow up studies to assess the commercial viability of these deposits. If the country is to depend solely on nuclear fuel imports, the supply of nuclear fuel is considered a lesser problem because nuclear fuel is cheap, constituting about 14 percent of the entire electricity generation costs, compared to 89 percent in gas and 78 percent in coal. In addition, a relatively small quantity of fuel is needed per unit of power generated and there is also the possibility of storing nuclear fuel for some time before usage. Nuclear power therefore enhances energy security due to these factors.

5 Energy Commission, National Energy Outlook, 2016

### 1.3.6 Coal

Generally, coal supply to global markets does not vary significantly like that of gas and crude oil. This militates strongly against the price volatility of other fossil fuels. As an example, from Year 2000 to 2014 the cost of coal on the global market remained almost the same, generally below \$5.0 /MMBtu, whereas price of crude oil and LNG rose from about \$5 /MMBtu to above \$15 /MMBtu. This explains why despite its environmental impacts, coal remains the world's number one fuel source for electricity generation.

#### i) Background

Coal has over the centuries formed the backbone of the power sector of most developed countries. It has over the years provided low cost power to underpin their industrialisation. There is now an increasing shift from coal to renewables and natural gas. However, given Ghana's limited reserves of gas, and with low cost hydro sites already developed, coal would have to play a role in the country's effort at ensuring adequate, reliable, competitively electric power for economic development.

#### ii) Technology

Significant advances in coal technology over the past few decades have resulted in increasing efficiency and lower environmental impact. Currently, the main technologies being built are Supercritical and Ultra-supercritical, with efficiencies in excess of 40% net low heat value (LHV) compared to subcritical units, which make up more than 50% of the existing coal fleet that have efficiencies of about 30%. Generally, higher efficiencies mean a smaller quantity of coal is used to generate a unit amount of electricity, and therefore lower emissions per unit.

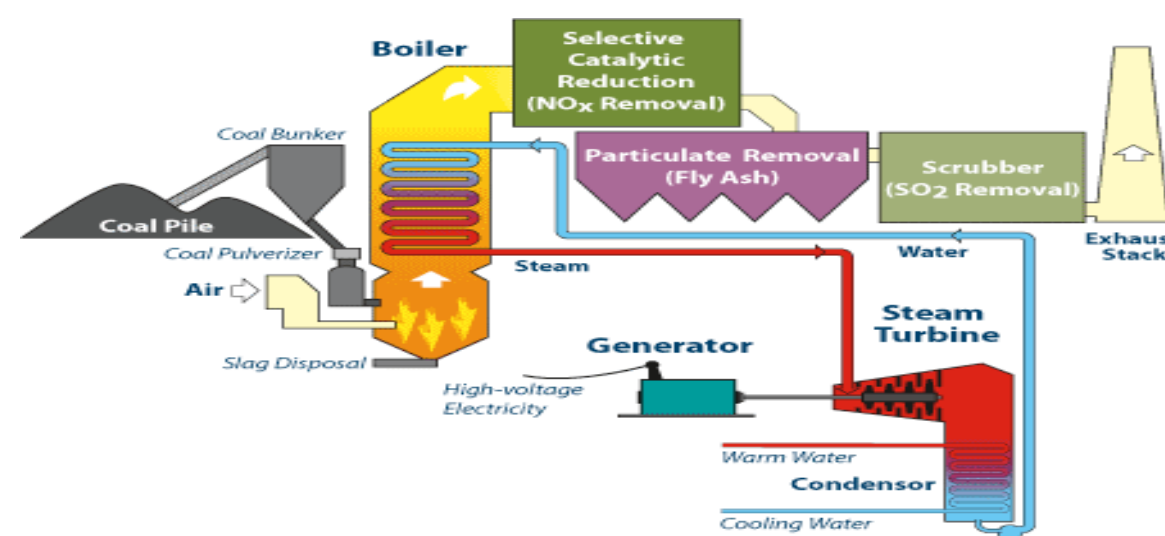
Figure 1.4: Artistic Impression of Coal Plant at Ekumfi Aboano, near Mankesim



Source: ESIA Report - VRA/Shenzhen Energy Coal-Fired Plant, May 2017

Additionally, improvements in pollution abatement technology have considerably reduced other emissions such as SO<sub>x</sub>, NO<sub>x</sub>, particulates and dust, thereby reducing the impact of coal generation on the environment. A schematic diagram of a coal plant is shown in figure 1.5.

Figure 1.5: Schematic of Coal Plant



Source: IEA, 2012

Regardless of the improvements in coal plant efficiencies, coal is noted to produce the highest carbon emission per unit of generation, and increased use of coal will result in an increase in pollution levels. Nonetheless, with the available emission control technologies and a well-balanced energy generation mix, it should be possible to meet the country's greenhouse gas targets, while ensuring reliable cost-effective and stable electricity prices.

Every modern economy needs a well-diversified energy mix to function. To support Ghana's plans to industrialise and create a more mature economy, there is a need to diversify energy sources, while ensuring that power is cheap and sustainable to drive economic activity, and the kind of structural change that advanced countries have experienced in their economies.

Considering the above, and recognising that coal will generally continue to play a substantial power generation role, the International Energy Agency (IEA) in its 2012 Technology Roadmap, Higher Efficiency, Low Emissions Coal Fired Generation Report<sup>6</sup> presents the coal technologies of the future as follows:

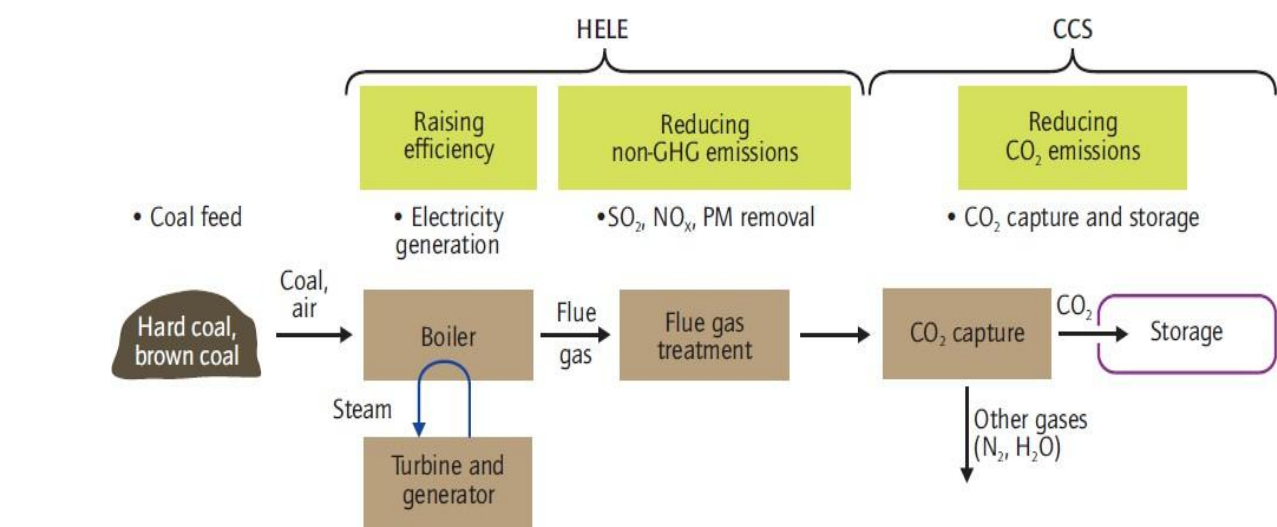
#### iii) Higher efficiency, low emissions (HELE) technologies

Higher efficiency, low emissions (HELE) refers to using high quality hard coal, pulverised to ensure efficient burning, fed into a super critical or ultra-supercritical power plant, and employing the best available technologies to treat the flue gas to remove pollutants such as SO<sub>2</sub>, NO<sub>x</sub> and particulate material. The HELE coal technologies increase the efficiency of a coal-fired power plant and significantly reduce emissions. For example, every 1% efficiency improvement results in 2%-3% reduction in CO<sub>2</sub> emissions. Figure 2.6 gives an illustration of Higher Efficiency, Lower Emissions Coal Technology.

The HELE technologies are very important not just for their emission benefits, but also for the essential factors they incorporate towards carbon capture and storage (CCS), normally carbon dioxide. The CCS technology is the capture and sequestration of carbon dioxide underground to eliminate carbon emissions into the atmosphere. CCS is currently largely under development, and is yet to be commercially deployed anywhere in the world. The expectation is that CCS will become viable and will become an essential part of any new coal plant in future.

<sup>6</sup> International Energy Agency, Technology Roadmap, Higher Efficiency, Low Emissions Coal Fired Generation Report, 2012

Figure 1.6: IEA Illustration of Higher Efficiency, Lower Emissions Coal Technologies



Source: IEA, 2012

The SaskPower Boundary Dam coal-fired CCS project in Canada for example, reduces 100 percent of the power station's SOx emissions, as well as 90 percent of CO2 emissions, and 56 percent of NOx emissions. The project captures one million tonnes of CO2 annually, while producing 115 megawatts (MW) of power, which powers 100,000 homes.

iv) Rationale for Coal

Coal has been considered in Ghana's power system master plans in the past and was also recommended as one of the favourable options by SNEP 2006-2020<sup>7</sup>, but was not approved for construction for a number of reasons including:

- Coal plants come in large sizes and will require significant supporting infrastructure such as ports and storage since Ghana did not have indigenous reserves.
- The small size of Ghana's power system meant it could not achieve the economies of scale required to make coal cost efficient.
- The small size of Ghana's power system placed a limit on the maximum generation unit size required for system stability.
- And recently, coal's environmental impact due to high greenhouse gas emissions.

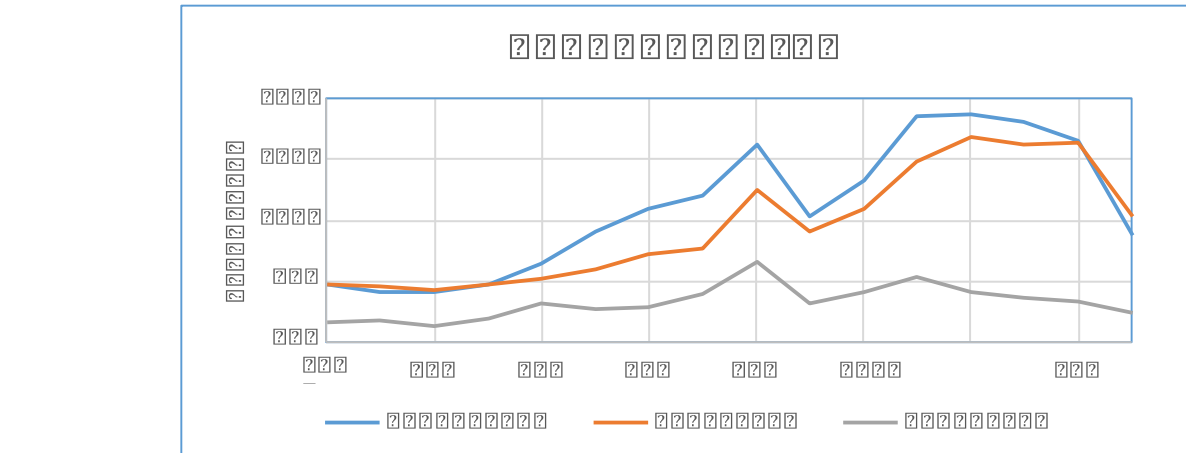
The first three reasons are now no longer valid due to increasing demand and Ghana's quest for strong industrial growth that is being put forward by the GIP.

<sup>7</sup> Strategic National Energy Plan (SNEP) released by Energy Commission in 2006. [www.energycom.gov.gh/planning/SNEP](http://www.energycom.gov.gh/planning/SNEP)

Additionally, as noted in other sections, Ghana's indigenous gas will be depleted within twenty years, and the country will have to resort to imported LNG to make up. Given the highly volatile nature of the LNG price, a generation mix based on a preponderance of LNG would make future electricity prices very uncertain. Ghana will also have to rely on coal if it is to provide the needed base load energy to power industries, firms and households.

Generally, coal supply in global markets is relatively elastic. That is to say that at different price levels, production can easily be adjusted in relation to available demand. The relative elastic supply of coal compared to other fuels contributes largely to its relatively lower price volatility. The relative advantage coal has in terms of price volatility will allow for relatively more stable electricity markets (especially in terms of revenues) and also facilitate energy planning especially in the area of costs and pricing, all other things being equal. Adding coal to the country's energy mix therefore provides an efficient hedge against fuel volatility, such as expected with gas prices.

Figure 1.7: Historical cost of fuels



Source: BP World Energy Statistics, 2015

v) Development of Coal Plants in Ghana

The Volta River Authority (VRA) and its partner Shenzen Energy of China have conducted detailed studies into the feasibility of developing a coal plant in Ghana, and the results show that coal will be competitive to gas fired generation if developed at significant scale. The chosen location of a coal plant is along the coast, at Ekumfi Aboano, near Mankessim in the Central Region. The scope of the project includes a first phase of 2 x 350 MW supercritical units that will eventually be expanded to 2000 MW. Employing the efficient supercritical technology in the first phase of the project is possible due to the unit size. For the second phase, however, the more efficient ultra-supercritical technology would be considered for larger units in the range of 600 MW.

The first phase of the project also includes a dedicated port, fuel storage terminal, and ash storage area. Coal will be brought from South Africa and Colombia. The study shows the project to achieve maximum economies of scale at a capacity of 2000 MW.

Table 1.3: Cost comparison of Ghana's coal plant with plants in other countries

| Plant                 | VRA/Shenzen (Phase 1) | VRA/Shenzen (Phase 1&2) | Medupi       | Moropule    | Safi          | Kot Addu      |
|-----------------------|-----------------------|-------------------------|--------------|-------------|---------------|---------------|
| Location              | Ghana                 | Ghana                   | South Africa | Bostwana    | Morocco       | Pakistan      |
| Capacity (MW)         | 700                   | 2,000                   | 4,800        | 600         | 1,386         | 660           |
| Completion            | 2021                  | 2025                    | 2015         | 2013        | 2018          | 2015          |
| Technology            | Supercritical         | Supercritical           | subcritical  | subcritical | supercritical | supercritical |
| total cost (\$ mill)  | 1,454                 | 3,192                   | 8,000        | 990         | 2,600         | 1,000         |
| specific cost (\$/MW) | 2.08                  | 1.52                    | 1.67         | 1.65        | 1.88          | 1.52          |

Source: Ghana Atomic Energy Commission

The table shows that the specific cost for the first phase is 2.08 \$/MW which reduces to 1.52 \$/MW after full development to 2000 MW. The reduction is due the spreading of the significant infrastructure cost over a larger output. This cost could possibly be reduced further if the available infrastructure such as the port is used to support an even larger capacity of plants. It must be emphasised that these costs do not take into account the cost of carbon emission into the environment. Funding for the project is expected to come from commercial sources including Chinese banks.

vi) Mitigating Environmental Impact

Energy is an enabler of economic growth, development and progress. It must be understood that every technology has associated risk and environmental impacts. Producing energy invariably leads to some degree of environmental impact. Mitigating the environmental impacts associated with such technologies is of the greatest priority.

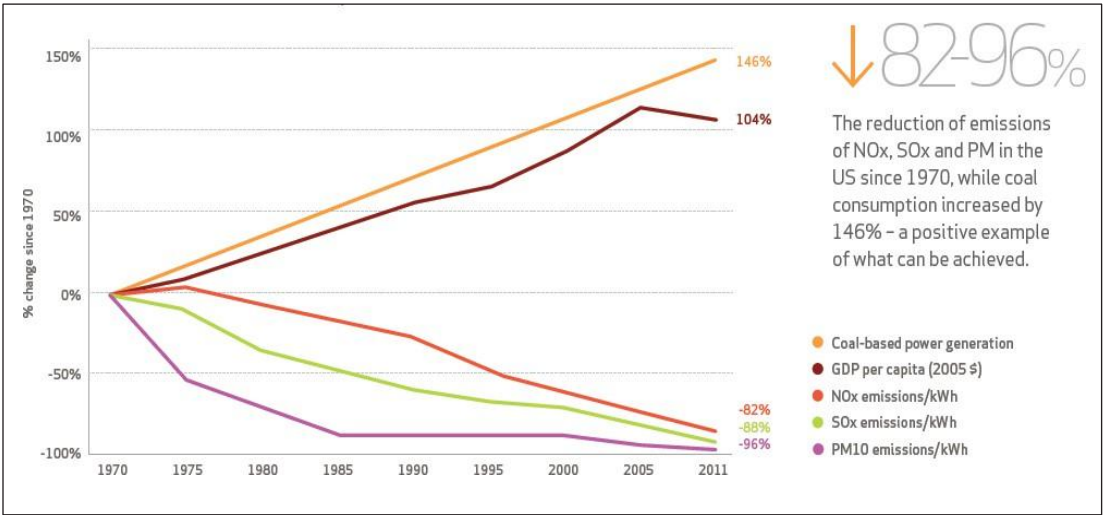
As discussed in the previous section, the use of coal for power generation would cause some associated negative environmental impacts, primarily through greenhouse gas emissions. The new clean coal technologies discussed above are means by which the coal industry is working to ameliorate the impact of coal on the environment. It has been noted in various circles that coal has demonstrated the ability to meet such challenges in the past, and the expectation is that the industry will successfully rise to the occasion to meet certain future environmental challenges.

Figure 2.8, taken from the World Coal Association article, *Coal and Air Quality*, shows the per kWh reduction in CO<sub>2</sub> emissions for coal plants in the US, relative to average emissions in 1970. The figure shows a remarkable reduction in emissions per kWh, mainly due to better generation technology.

As part of efforts to secure a low-carbon future, every year between 2002 and 2011, Alstom saved 207 million tonnes of CO<sub>2</sub> (t CO<sub>2</sub>) from being emitted by retrofitting new technology to existing coal plants<sup>8</sup>. The company is also currently actively involved in developing carbon capture technology methods in order to increase efficiency and combat climate change of existing and yet to be constructed coal power plants.

8 World Coal Association, Leadership and Excellence Awards, 2013, UK.

Figure 1.8: Change in emissions of greenhouse gases per kWh compared to 1970 levels



Source: Loftus et al., 2015<sup>9</sup>

Furthermore, the foundation of the COP21 Paris Agreement was the commitment of countries to do more to lower world greenhouse gas emissions, particularly from coal based energy generation systems. Over forty-four countries pledged to deploy HELE coal technologies to support their commitment to the reduction target.

It is estimated that about two gigatonnes of CO<sub>2</sub> emissions would be saved as a result of raising the average global efficiency of coal power plants from 33% to 40%. It is also noted that the two gigatonnes saved as a result of this intervention would make far more positive impact on climate change, than many of the other actions that are being taken. The comparison is shown in figure 1.9 below.

Figure 1.9: Emissions reductions by policies/actions, t CO<sub>2</sub> eq

| Emission reductions by policies / actions, m tonnes CO <sub>2</sub> equivalent |                      |           |                  |
|--------------------------------------------------------------------------------|----------------------|-----------|------------------|
| Policy / Action                                                                | Cumulative emissions | Period    | Annual emission* |
| Montreal protocol                                                              | 135,000m             | 1989-2013 | 5,600m           |
| Hydropower worldwide                                                           | 2,800m               | 2010      | 22,800m          |
| Nuclear power worldwide                                                        | 2,200m               | 2010      | 2,200m           |
| Increase average global efficiency coal-fired power plant to 40%               |                      |           | 2000m            |
| China one-child policy                                                         | 1300m                | 2005      | 1,300m           |
| Other renewables worldwide                                                     | 600m                 | 2010      | 600m             |
| US vehicle emissions & fuel economy standards <sup>+</sup>                     | 5,000m               | 2012-2025 | 460m             |
| Brazil forest preservation                                                     | 3200m                | 2005-2013 | 400m             |
| India land-use change                                                          | 177m                 | 2007      | 177m             |
| Clean Development mechanism                                                    | 1,500m               | 2004-2014 | 150m             |
| Collapse of USSR                                                               | 709m                 | 1992-1998 | 118m             |
| Global Environment Facility                                                    | 2,300m               | 1991-2014 | 100m             |
| EU energy efficiency                                                           | 230m                 | 2008-2012 | 58m              |
| EU renewables                                                                  | 117m                 | 2008-2012 | 29m              |

\* Annual emissions are cumulative emissions divided by relative period  
The estimate of the current emissions avoided under the Montreal protocol is eight Billion tonnes of CO<sub>2</sub> equivalent  
The annual figure of the collapse of USSR refers to the year 1992-1998, \*Cars and light truck

Source: The Economist 2014 and International Energy Agency 2013

9 Loftus, Peter J., Cohen Armond M., Long Jane C. S., Jenkins Jess D. A critical review of global de-carbonization scenarios: what do they tell us about feasibility? WIREs Climate Change 2015, Vol. 6, Issue 1, pages 93-112

vii) Overcoming Public Resistance

As already discussed, increasing awareness of the impact of climate change as well as global initiatives to reduce greenhouse gas emissions has resulted in increasing public resistance to new coal plants. To overcome this, it is important to ensure transparent dialogue among all stakeholders on the rationale for the need for coal to be part of the country's energy mix. Such measures help efforts to mitigate local and global resistance to the establishment of new coal plants.

Viii) Coal by-products

Apart from the impact coal makes to provide global baseload energy, its by-products are used extensively in the construction industry. Some of these by-products, also called coal combustion products include fly ash, bottom ash, boiler slag, etc. Fly ash, for instance, can be used to replace or supplement cement in concrete. It is important to note that fly ash produced concrete is a supplementary cementitious material in the production of ordinary Portland cement, and is more durable, and resistant to corrosion, alkali- aggregate expansion, sulphate and other forms of chemical attack. The fineness of fly ash contributes to the pozzolanic reactivity of the material.

In the USA, for example, more than half of the concrete produced is blended with fly ash, which is a big industry in itself. Among the most significant environmental benefits of using fly ash over conventional cement is that greenhouse gas emissions can be significantly reduced. That is, for every ton of fly ash used in lieu of Portland cement, approximately one ton of carbon dioxide is prevented from entering the earth's atmosphere. This is because fly ash does not require the energy-intensive kilning process required by Portland cement.

ix) Regulation

The Energy Commission of Ghana exercises regulatory oversight over the development of power plants in the country. The EC will therefore remain the institution responsible for regulatory oversight regarding the introduction of coal power plants in Ghana. To ensure that coal energy is developed in a safe and sustainable manner, a section or division will be detailed specifically for coal power plant regulation. This is significant since it will provide confidence to the public that coal power would be developed in an environmentally acceptable manner.

Among others, the division will work to oversee the role coal plays in the national energy agenda. This is particularly important since similar to nuclear, coal also faces stiff public opposition.

A critical initial requirement of the proposed coal regulatory group is the development of guidelines and requirements for emissions, technology and supporting infrastructure guidelines that prospective developers would have to meet. Noting the need to quicken the development of this energy source, the establishment of proposed coal regulatory division at the Energy Commission must be considered in earnest.

1.4 Electrical Energy Generation

1.4.1 Electricity/Power Generation Overview

The total electricity generation output doubled from 7,223 GWh in 2000 to 16,000 GWh in 2016 at an average annual growth rate of 3.9 percent. The total installed electricity generation capacity more than doubled, increasing from 1,418 MW in 2000 to 3,800 MW by the end of 2016. Table 1.4 shows the development of electricity generation power plants, their installed and dependable generation capacities in 2000, 2010 and 2015.

Table 1.4: Installed capacity of electricity generation systems

| Power Plant          | Fuel Type | 2000                    |                          |                          | 2010                    |                          |                          | 2015                    |                          |                          |
|----------------------|-----------|-------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|
|                      |           | Installed Capacity (MW) | Dependable Capacity (MW) | % of Total Installed Cap | Installed Capacity (MW) | Dependable Capacity (MW) | % of Total Installed Cap | Installed Capacity (MW) | Dependable Capacity (MW) | % of Total Installed Cap |
| Akosombo             | hydro     | 788                     | 700                      | 55.6                     | 1020                    | 900                      | 47.0                     | 1020                    | 900                      | 26.2                     |
| Kpong                | hydro     | 160                     | 148                      | 11.3                     | 160                     | 148                      | 7.4                      | 160                     | 148                      | 4.1                      |
| Bui                  | hydro     | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 400                     | 342                      | 10.3                     |
| Sub-total            |           | 948                     | 848                      | 66.9                     | 1180                    | 1048                     | 54.4                     | 1580                    | 1390                     | 40.6                     |
| Takoradi T1          | LCO/Gas   | 330                     | 300                      | 23.3                     | 330                     | 300                      | 15.2                     | 330                     | 300                      | 8.5                      |
| Takoradi T2          | LCO/Gas   | 110                     | 100                      | 7.8                      | 220                     | 200                      | 10.1                     | 330                     | 300                      | 8.5                      |
| Tema TT1             | LCO/Gas   | 0                       | 0                        | 0                        | 110                     | 100                      | 5.1                      | 110                     | 100                      | 2.8                      |
| Tema TT2             | Gas       | 0                       | 0                        | 0                        | 48                      | 45                       | 2.2                      | 48                      | 45                       | 1.2                      |
| CENIT                | LCO       | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 110                     | 100                      | 2.8                      |
| MRP                  | Gas       | 0                       | 0                        | 0                        | 80                      | 40                       | 3.7                      | 80                      | 40                       | 2.1                      |
| Tema Diesel          | Diesel    | 30                      | 20                       | 2.1                      | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        |
| Sunon Asogli         | Gas       | 0                       | 0                        | 0                        | 200                     | 180                      | 9.2                      | 200                     | 180                      | 5.1                      |
| Sunon Asogli Upgrade | Gas       | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 360                     | 320                      | 9.2                      |
| Kpone                | DFO       | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 230                     | 200                      | 5.9                      |
| Karpower             | HFO       | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 245                     | 210                      | 6.3                      |
| AMERI                | Gas       | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 250                     | 230                      | 6.4                      |
| Sub-total            |           | 470                     | 420                      | 33.1                     | 988                     | 865                      | 45.6                     | 2293                    | 2025                     | 58.9                     |
| VRA Grid Solar PV    | Sunshine  | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 2.5                     | 1.9                      | 0.1                      |
| BXC                  | Sunshine  | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 20                      | 15.2                     | 0.5                      |
| Sub-total            |           | 0                       | 0                        | 0                        | 0                       | 0                        | 0                        | 22.5                    | 17.1                     | 0.6                      |
| Total                |           | 1418                    | 1268                     | 100                      | 2168                    | 1913                     | 100                      | 3895.5                  | 3432.1                   | 100                      |

Source: Energy Commission

1.4.2 Power Generation Challenges

Electricity supply in Ghana has been unreliable over the past three decades, characterised by periodic nationwide power crises as well as localised power outages in certain areas of the country. Droughts have resulted in power generation shortfalls, leading to three major nation-wide power rationing exercises since 1984. Besides the droughts, periodic shortfalls in power supply from the hydroelectric power system have led to three additional major power crises occurring in 1998, 2006 through 2007, and recently 2014 through 2015.

These have compelled a shift to the introduction of thermal power generators since 1997, which run mainly on gas. Unreliable gas supply from Nigeria has in turn plunged the nation into periodic power shortfalls in recent times. As an immediate solution to these crises, efforts have been made to utilise local gas resources from the Atuabo gas project as well as constructing emergency plants, thereby improving the situation.

1.5 Generation Expansion Plan

1.5.1 Power Generation Plan Objectives

The development of the electricity infrastructure plan is based on the vision to transform the country's economy into a high-income status by 2057. The fulfilment of this vision is premised on the availability of adequate, reliable, least- cost and environmentally sustainable electricity to foster sustainable socio-economic growth. Consequently, the objectives of the electricity infrastructure plan are to:

- i. Expand, modernise and maintain an electricity supply infrastructure, which ensures enhanced generation, transmission and distribution of electricity for domestic use and export.
- ii. Develop an optimal electricity generation mix, which can ensure security of electricity supply.
- iii. Exploit all fuels and develop an optimal fuel mix for electricity generation to ensure least-cost energy service delivery.
- iv. Promote efficiency along the electricity supply chain.

The implementation of appropriate energy policies, legal and regulatory frameworks, institutional arrangements, human capacity development and innovative financing schemes would help fulfil these objectives.

1.5.2 Electricity Generation Planning Methodology

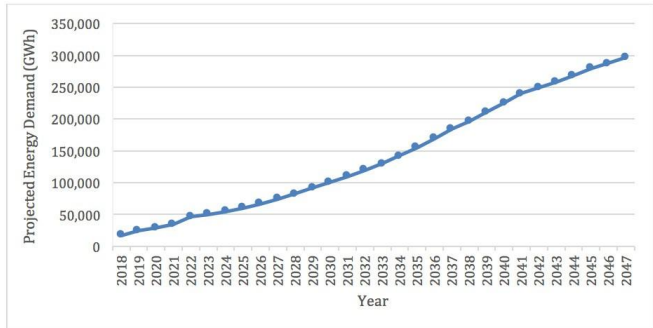
The planning methodology involves the determination of electrical energy demand within the period set for the GIP (i.e. 2018 to 2047). The associated peak load requirement is determined from which an optimal electricity generation mix is also determined. The electrical energy demand projection was done based on demographic factors, macro-economic factors, technological factors

and government policies. Regarding demography, the total population of the country was projected to increase at an average annual rate of 2.1 percent from 28.6 million in 2018 to 51.0 million in 2047<sup>10</sup>. Regarding macro-economics, the total GDP was projected to increase from about US\$ 46.0 billion in 2018 to about US\$ 1,370 billion by 2047 at an average annual rate of 11.8 percent. The per capita GDP was projected to increase from US\$ 1,546 in 2018 to US\$ 27,195 in 2047 at an average rate of 9.9 percent.

<sup>10</sup> National Development Planning Commission, Ghana Infrastructure Plan (2018- 2047), November/December 2016 Progress Report.

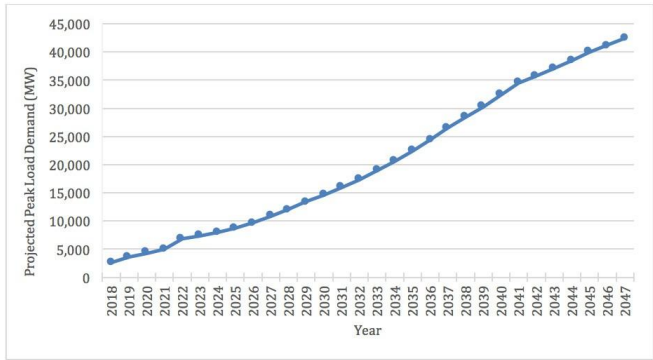
It is also expected that government policy on energy efficiency coupled with the emergence of energy efficient technologies will lead to a significant reduction in energy intensity as the country industrialises to move its economy forward. The projected energy requirements are presented in Figure 1.10 below. Also presented is the associated peak load demand in Figure 1.11.

Figure 1.10: Projected energy demand (2018-2047)



Source: Author's Construct

Figure 1.11: Projected peak load demand (2018-2047)



Source: Energy Commission

An energy demand of about 297,200 GWh is required to meet national developmental objectives in 2047 with a peak load of about 42,479 MW.

### 1.5.3 Optimal Generation Mix

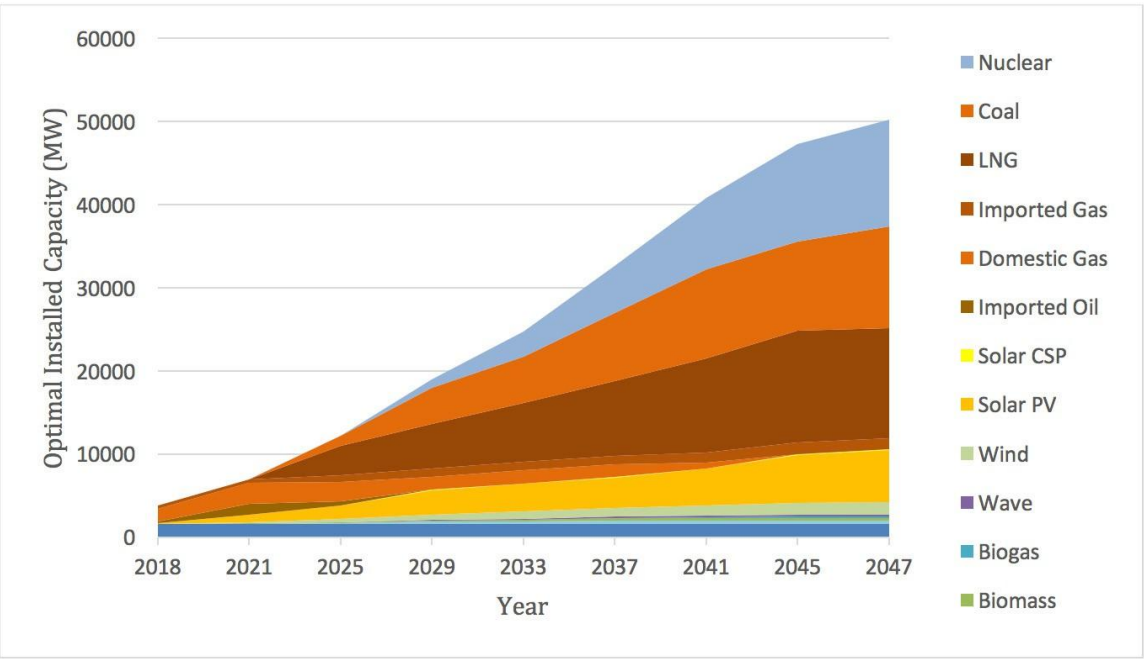
The LEAP model methodology was used to undertake the electricity generation capacity expansion planning. The results of the analysis of energy demand, peak demand requirements, power plant capacities, fuelling options and costs, and other factors influencing electricity generation within the study period 2018 to 2047 are presented in Table 1.5 and Figures 1.11 and 1.12 below. It is important to note the effect of the high capacity factor for nuclear energy, which provides roughly 35 percent of generation with a 25 percent installed capacity of the energy mix at 2047.

Table 1.5: Optimal installed capacity

|              | Installed Capacity (MW) |       |        |        |        |        |        |        |        | % installed at 2047 | % generation at 2047 |
|--------------|-------------------------|-------|--------|--------|--------|--------|--------|--------|--------|---------------------|----------------------|
|              | 2018                    | 2021  | 2025   | 2029   | 2033   | 2037   | 2041   | 2045   | 2047   |                     |                      |
| Large Hydro  | 1,580                   | 1,580 | 1,580  | 1,580  | 1,580  | 1,580  | 1,580  | 1,580  | 1,580  | 3.1                 | 2.8                  |
| Small Hydro  | 0                       | 6     | 114    | 291    | 346    | 446    | 446    | 446    | 446    | 0.9                 | 0.7                  |
| Biomass      | 0                       | 69    | 100    | 150    | 200    | 250    | 300    | 300    | 300    | 0.6                 | 0.6                  |
| Biogas       | 0                       | 4     | 10     | 17     | 20     | 80     | 120    | 150    | 200    | 0.4                 | 0.3                  |
| Wave         | 0                       | 10    | 25     | 75     | 100    | 150    | 200    | 200    | 200    | 0.4                 | 0.2                  |
| Wind         | 0                       | 125   | 400    | 600    | 900    | 1,000  | 1,200  | 1,500  | 1,500  | 3                   | 1.5                  |
| Solar PV     | 88                      | 873   | 1,615  | 2,981  | 3,274  | 3,675  | 4,384  | 5,754  | 6,254  | 12.5                | 5.5                  |
| Solar CSP    | 0                       | 2     | 10     | 10     | 50     | 50     | 50     | 100    | 100    | 0.2                 | 0.1                  |
| Imported Oil | 194                     | 1,387 | 447    | 0      | 0      | 0      | 0      | 0      | 0      | 0                   | 0                    |
| Domestic Gas | 1,545                   | 2,494 | 2,330  | 1,580  | 1,580  | 1,580  | 650    | 0      | 0      | 0                   | 0                    |
| Imported Gas | 393                     | 393   | 786    | 943    | 1,022  | 1,022  | 1,258  | 1,336  | 1,336  | 2.7                 | 2                    |
| LNG          | 0                       | 300   | 3,235  | 5,399  | 7,059  | 8,975  | 11,645 | 13,137 | 13,230 | 26.4                | 24.2                 |
| Coal         | 0                       | 700   | 1,250  | 3,618  | 5,579  | 8,179  | 10,661 | 10,722 | 12,222 | 24.4                | 27                   |
| Nuclear      | 0                       | 0     | 0      | 1,000  | 3,000  | 5,600  | 8,600  | 11,800 | 12,800 | 25.5                | 35.1                 |
| Total        | 3,800                   | 6,943 | 12,202 | 18,945 | 24,710 | 32,587 | 40,794 | 47,325 | 50,168 | 100                 | 100                  |

Source: Energy Commission

Figure 1.12: Optimal installed capacity



Source: Energy Commission

The strategies adopted for the supply side are as follows:

#### Existing Hydro Plants

The existing hydro power plants, i.e. Akosombo, Kpong and Bui will be operating at their dependable generation capacities throughout the planning horizon. It is envisaged that the Akosombo plant, which underwent a retrofit in year 2000, will undergo refurbishment during the planning period. In the case of Kpong, its units are currently being retrofitted so it is not expected to undergo any further refurbishment. Bui will also be retrofitted in the course of the planning period. Therefore, the current total hydro capacity of 1580 MW will be maintained. However, their share in the generation mix is expected to drop from the current 26 percent to 3 percent by 2047.

#### Renewable Sources

The capacity of each of the untapped hydro resources is below 100 MW. They are therefore considered as renewable sources per the country's renewable energy law definition. These untapped hydro resources sum up to about 800 MW, including Hemang (90 MW), Juale (90 MW) and Pwalugu (60 MW), and will yield a dependable capacity of 446MW. It is expected that all of these identified mini hydro sources will be developed during the planning period. Their share of the generation mix is expected to be 1 percent in 2047 therefore bringing the total share of hydro, i.e. existing and potential to 4 percent. Not all the total output of hydro plants can contribute to the baseload generation in the mix.

The GIP also includes other renewable sources like solar, wind, and biomass, which are in line with Government policy to promote renewable sources to mitigate greenhouse gas emissions, reduce air pollution and contribute to energy security. It is expected that the full potential of wind, approx. 1,500 MW capacity, will be developed. Installed capacity of solar plants is also expected to exceed 6,300 MW by 2047. The total installed capacity of renewable energy sources by 2047, including mini hydro is projected at 9000 MW, constituting 18 percent of total energy installed capacity, excluding the big hydro plants.

#### Gas

Gas fuelled thermal plants are expected to initially provide the main source of electricity generation by the end of the first decade of the plan. Domestic gas plants, gas obtained from Jubilee and ENI fields, will constitute 19 percent share of the installed capacity whereas imported gas, that is gas obtained from the WAGP, takes 32 percent share. Domestic gas supply is expected to peak by 2021 with a capacity of 1580 MW and will thereafter decline due to limited reserves, grinding to a halt by 2044. Imported gas is capped at 1336 MW from 2035 onwards due to the capacity limit of the West African gas pipeline. It is envisaged that no additional pipeline will be constructed and that gas imports from Nigeria and elsewhere which will be in the form of LNG, will be introduced in 2020. LNG will be the main fuel for gas plants constituting a 26 percent share in the generation mix with installed capacity of 13,230 MW in 2047.

On the technology side, there will be a high proportion of combined cycle plants, which are more cost effective and generate baseload energy. In order to provide the primary frequency regulation, it is expected that there will be a sizable number of single cycle gas turbine plants in the mix. In addition, a number of existing thermal plants will be retired and replaced with new ones.

#### Coal

It can be said that most developed countries around the world have developed and transformed their economies through the use of coal technologies. Ghana is expected to be on the path to developed country status by 2047, and needs a base load energy source like coal. Currently, Ghana has no coal technology but is expected to have its first coal plant in the near future. It is expected that the share of coal, which is expected to be part of the energy mix will come on line in 2020 with a first capacity of 700MW. This share is then expected to grow to 26 percent of the total installed capacity by 2047 with a coal installed capacity of 12,222MW.

#### Nuclear

One key consideration in the proposed plan is to provide for a significant amount of nuclear. This is expected to provide baseload power alongside coal and the hydro plants. In line with the strategic vision to operate a least cost generation mix, it envisaged that coal and nuclear will be the main baseload generation options from 2023 to 2047. In line with the on-going nuclear power planning programme, the entry point of nuclear is expected

to be 2029. Its share will increase to 32 percent by 2047 with a total installed capacity of 12,800MW.

**Reserve Margin**

In order to guarantee supply security and ensure a very reliable and stable power generation system, a reserve margin will be maintained throughout the period. Due to the improved efficiencies and diversities expected in the network, the reserve margin will be reduced gradually from the current 20 percent to below 5 percent. By 2047, the reserve margin will be equivalent to twice the capacity of the largest power plant unit in the installed capacity.

**1.6 Defining Baseload Generation**

Traditionally, the electricity industry refers to baseload generation as power plants that are used to meet the minimum level of electricity that customers demand around the clock. Such plants are normally run at high, sustained output levels and high capacity factors, with limited cycling or ramping. In other words, baseload generation can be defined as generation units that operate the great majority of hours of the year to meet load requirements<sup>11</sup>.

The North American Electric Reliability Corporation (NERC) offers insightful discourse on base load generation. A paraphrased version of this is provided below<sup>12</sup>:

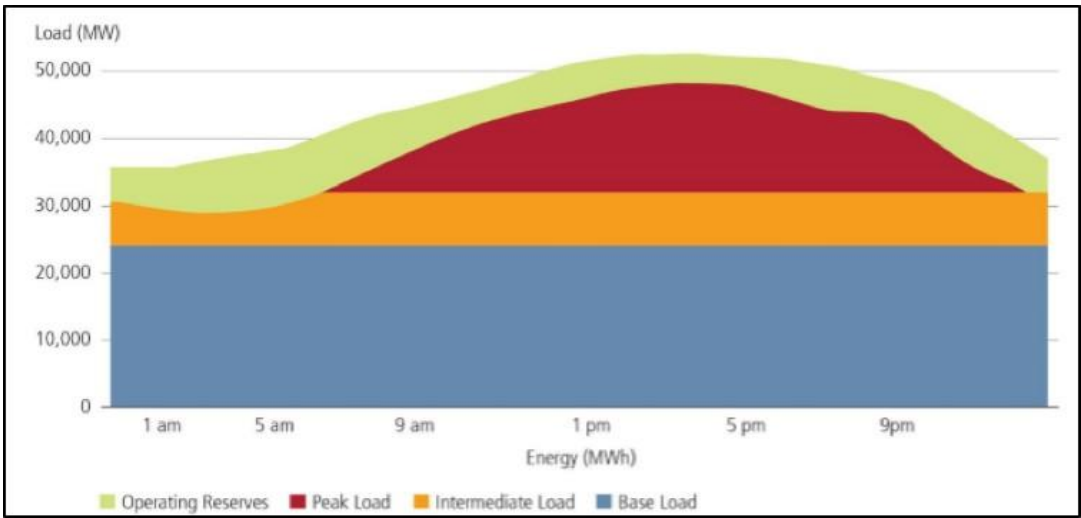
There is a distinction between baseload generation and the characteristics of generation providing reliable 'baseload' power. Baseload as a term refers to generation that falls at the bottom of the economic dispatch stack, meaning power plants that are the most economical to run. Such plants, in the US, traditionally coal and nuclear plants, are by policy, designed for low cost operation and maintenance and continuous operation.

However, it is neither the economics nor the fuel type that make these plants attractive from a reliability perspective. Rather, these plants traditionally have low forced and maintenance outage hours and have low exposure to fuel supply chain issues. This results in a high level of resilience and reliability of electrical energy supply, which is a key requirement of a robust and stable jurisdictional

<sup>11</sup> Staff Report to the Secretary on Electricity Markets and Reliability, US Department of Energy, August 2017.  
<sup>12</sup> North American Electric Reliability Corporation (NERC), "Synopsis of NERC Reliability Assessments, the Changing Resource Mix, and the Impacts of Conventional Generation Retirements," unpublished materials, Department of Energy, May 9, 2017.

electrical energy system. In other words, 'baseload' generation can also be referred to as generation that is more resilient to disruptions in energy generation. Figure 1.13 shows the schematic profile of daily load curve showing the baseload cycle by 2047.

Figure 1.13: Schematic layout of Daily Load Curve showing Base Load by 2047



Source: Staff Report to the Secretary on Electricity Markets and Reliability

Traditionally, intermediate or mid-merit plants are used to do 'load following'. These plants are easier to ramp up and down, and are affected less by load cycling to meet daily variations in demand. Generally, based on the mix of generation resources available in a region, and relative fuel prices, natural gas and/or coal units are typically used for 'load following' (based on the US case). In an ideal system, variable resources such as renewable energy would meet short-duration demand peaks. The time of availability for variable renewable energy, however, does not always make this possible, and there is a need for a balancing act between the dispatch from intermittent sources and that of renewable energy.

Generation from variable renewable energy can change widely over the course of a single day, which requires dispatchable power plants to be operated more nimbly. In a market-based system, over- generation by variable renewable energy can drive prices to very low levels in a short time, and require very quick ramping up levels when it subsidizes. This places a premium on flexible output rather than the steady output of traditional baseload power plants. This can be very challenging for ensuring the reliability and resilience of an electrical grid system. There is therefore the need to ensure that in market-based systems, an additional premium is placed on reliability and resilience of the electrical grid system in regards to the dispatch from different generation sources.

**1.7 Indicative Electricity Supply Plan – 2047**

The vision of the Long Term National Development Plan is to develop a just, free and prosperous nation with high levels of national income and broad based social development, and the objectives of the GIP are to chart a new vision and strategic direction for Ghana's infrastructure to attain a high-income country status.

**1.7.1 Path to High-Income Country Status**

The LTNDP envisages that by 2057, when Ghana celebrates its 100th independence anniversary, the country's economy would be:

- i. Ranked among high-income countries;
- ii. Export-oriented, industrialised, diversified and resilient;
- iii. Driven by Ghanaian entrepreneurship;
- iv. Characterised by high-value services;
- v. Dynamic, with a globally competitive manufacturing sector;
- vi. Have an efficient agricultural sector capable of feeding the nation and exporting to global markets.

By the end of the 40-year planned period, the population is projected to have grown to almost 60 million, while GDP is projected to be \$3.6 trillion, up from US\$45 billion in 2017, and per capita growth from US\$1,500 to US\$62,000 over the same period.

**Demand Factors**

Certain priority areas have been identified to help drive GDP growth over the plan period. These include industrialization, manufacturing and the development of the heavy industries and providing high-value services for the domestic and export markets will require high levels of energy. The following priority areas, therefore, will drive this period:

- i. Steel/Aluminum industry development
- ii. Automobile industry development
- iii. Industrial parks
- iv. Expansion of pharmaceuticals industry
- v. Petrochemicals sector development
- vi. Construction services exports
- vii. Railway development and operations
- viii. Infrastructure research, innovation, and exports
- ix. Export of knowledge services (ICT, animation, digital technology, innovation, etc.)
- x. High value financial services exports (investment banking, insurance, real estate financing, etc.)

Over the past fourteen (14) years, the largest consumers of electricity in Ghana have moved from the industrial to the domestic/residential sector. During the planning period, the largest consumers will revert to the industrial sector. Table 1.6 shows the indicative electricity supply plan by 2045.

Table 1.6: Ghana- Nationwide Indicative Electricity supply plan – 2045

|                                                                                                    | TOTAL MW             |
|----------------------------------------------------------------------------------------------------|----------------------|
| <b><i>INDUSTRIAL</i></b>                                                                           | <b><i>19,220</i></b> |
| <b><i>Manufacturing</i></b>                                                                        |                      |
| 10 Regional Industrial Parks (list of industries attached)                                         | 2,000                |
| 50 Mini District Industrial Parks (list of industries attached)                                    | 2,500                |
| Pharmaceutical companies outside parks - medicines, health products                                | 200                  |
| Agro Industrial manufacturing - Canning, etc.                                                      | 300                  |
| Automobile manufacture + parts (200,000 vehicles per annum)                                        | 500                  |
| Paper and Pulp                                                                                     | 300                  |
| Timber - Lumber, Plywood, veneer processing                                                        | 500                  |
| Tiles - Roofing, Clay, Wall, External                                                              | 400                  |
| <b><i>Production of Steel from Iron Ore</i></b>                                                    |                      |
| 1 million MT at Opon Manse Valley, Central Region                                                  | 160                  |
| 3 million MT at Sheini, near yendi, Northern Region                                                | 480                  |
| 1 million MT Tema Steel recycled plants, Tema                                                      | 150                  |
| <b><i>Production of aluminium from Bauxite</i></b>                                                 |                      |
| Valco Smelter - Alumina to Aluminium - 200,000 MT                                                  | 350                  |
| New Nyinahin Bauxite to Aluminium plant - 500,000 MT                                               | 1,200                |
| Aluworks + other Aluminium integrated industries                                                   | 250                  |
| Fertilizer - Aluminium Sulphate                                                                    | 50                   |
| <b><i>Manufacture of electo-machanical machinery &amp; equipment- outside Industrial parks</i></b> |                      |
| High-End equipment - hospital, educational, etc.                                                   | 60                   |
| Household fittings and fixtures (bathroom equipment, etc.)                                         | 70                   |
| Office equipment - cabinets, computers, printers, furniture,                                       | 80                   |
| Telecom - Phones, cables, etc.                                                                     | 40                   |
| Irrigation - sprinklers, pipes,                                                                    | 30                   |
| Fire - Fire station, etc.                                                                          | 50                   |
| Sports - sportswear and costume, footballs, racquet,                                               | 60                   |
| Light Construction Equipment - Concrete mixers, Dumpers, Wheel barrow,                             | 120                  |
| Waste Management Equipment                                                                         | 110                  |
| Agriculture mechanization Equipment                                                                | 60                   |
| Electronic equipment                                                                               | 40                   |
| Kitchen                                                                                            | 30                   |
| Quarrying Equipment                                                                                | 80                   |
| Electrical                                                                                         | 70                   |
| Water Supply & Sewerage equipment - tankers, emptier                                               | 120                  |

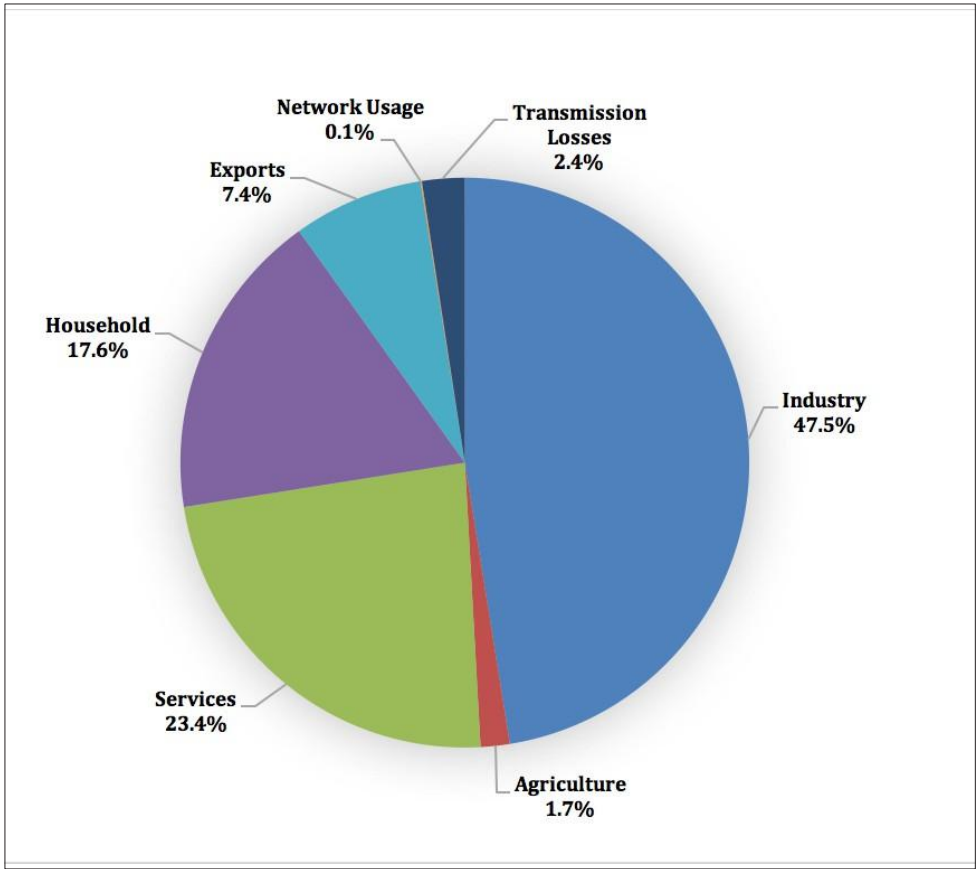
|                                                                        |       |
|------------------------------------------------------------------------|-------|
| Heavy Construction - excavators, pay loaders, etc.                     | 250   |
| <b><i>Silica Sand</i></b>                                              |       |
| Glass making, bottling, blowing & recycling                            | 70    |
| Solar PV Panels                                                        | 150   |
| <b><i>Petrochemical</i></b>                                            |       |
| Oil Refineries - TOR, new 60,000 Barrel Western Region facility        | 200   |
| Chemicals and Plastics                                                 | 100   |
| Bitumen production                                                     | 50    |
| Salt - Caustic Soda & Chlorine, other                                  | 50    |
| Paint and other cleaning products- Acrylic, oil, emulsion, etc.        | 150   |
| Fertilizer - Urea                                                      | 50    |
| Electrochemical – Oxygen and Nitrogen plants                           | 20    |
| <b><i>Limestone and Kaolin</i></b>                                     |       |
| Cement production                                                      | 300   |
| <b><i>Phosphate</i></b>                                                |       |
| Fertilizer - Phosphorus                                                | 60    |
| <b><i>Food processing</i></b>                                          | 100   |
| Fish, floor, poultry, Meat processing, Abattoir                        | 100   |
| Garment and leather                                                    | 50    |
| Construction Industry activities                                       | 450   |
| <b><i>Mining and Quarrying</i></b>                                     |       |
| Ghana Mines various - Gold, Diamonds, other minerals                   | 500   |
| Gold Refinery and jewelry                                              | 100   |
| Quarrying - concrete products and block making                         | 350   |
| Granite cut                                                            | 50    |
| <b><i>Water and Waste Production</i></b>                               |       |
| Water Resources Management                                             | 25    |
| GWCL - Water Treatment Plants - nationwide                             | 300   |
| Sewerage Treatment Plants & recycling - nationwide                     | 250   |
| <b><i>Breweries, Water production and Beverages</i></b>                |       |
| Breweries                                                              | 50    |
| Water Bottling Plants                                                  | 40    |
| Beverages                                                              | 45    |
| <b><i>Transport</i></b>                                                |       |
| Railway-4,007km network-Electric Train/Station/ Non-core ops           | 1,000 |
| Airport-Prampram/Ankaase, other regional airport                       | 600   |
| Road energy infrastructure                                             | 50    |
| 30% Electric vehicle usage-3.9 mil. Cars @ 300/ MW charge every 5 days | 2,600 |
| Maritime-Tema, Takoradi & Atuabo ports                                 | 600   |
| Tema Shipbuilding                                                      | 50    |
| Research Institutions                                                  | 50    |
| <b><i>Other Industrial establishments</i></b>                          | 50    |

|                                                                                        |                      |
|----------------------------------------------------------------------------------------|----------------------|
| <b><i>AGRICULTURE</i></b>                                                              | <b><i>670</i></b>    |
| Irrigation infrastructure - pumping                                                    | 300                  |
| Poultry and Livestock rearing/lighting & processing                                    | 120                  |
| Fishing rearing, industry                                                              | 70                   |
| Post Harvest processing/Storage                                                        | 180                  |
| <b><i>SERVICES INDUSTRY</i></b>                                                        | <b><i>9,470</i></b>  |
| Central Government Facilities-Flagstaff & State House, Ministries, incl. Region, etc.  | 1,200                |
| Armed Forces, Police, GIS, Fire, Prisons,                                              | 850                  |
| Educational Installations-Universities, Colleges of Edu., Polytechnics, SHS, JHS, etc. | 1,100                |
| Health Facilities – teaching Hospitals, Regional Hospitals, Polyclinics, etc.          | 600                  |
| Telecommunication Companies                                                            | 150                  |
| Media-Radio and TV Stations + Mast, etc.                                               | 120                  |
| Food Service Industry                                                                  | 120                  |
| Hospitality (Hotel, Tourist Sites)                                                     | 800                  |
| Creative Arts-Wood carving, basket, etc.                                               | 180                  |
| Street Lighting (nationwide)                                                           | 1,500                |
| Garages, Mechanical workshop, car wash, etc.                                           | 100                  |
| Tailor and Dressmakers                                                                 | 100                  |
| Shopping Malls, Market and Lorry parks                                                 | 300                  |
| <b><i>Social, Civil and Commercial</i></b>                                             | -                    |
| Offices - Financial, Banks, Other                                                      | 1,500                |
| Sports facilities -various Stadia Football, Tennis, etc., floodlights, etc.            | 400                  |
| Churches and Religious structures                                                      | 200                  |
| Other Commercial enterprise (Theatre, etc.)                                            | 250                  |
| <b><i>HOUSEHOLD – 50 Million</i></b>                                                   | <b><i>7,123</i></b>  |
| 70% Urban, 30% Rural Residential Accommodation                                         |                      |
| Households 52 million@1,000 kWh/cap plus 20%                                           | 7,123                |
| <b><i>EXPORT (WEST AFRICA POWER POOL)</i></b>                                          | <b><i>3,000</i></b>  |
| CEB (Togo/Benin)                                                                       | 1,500                |
| SONABEL (Burkina Faso)                                                                 | 800                  |
| CIE (Cote d'Ivoire)                                                                    | 100                  |
| EDM (Mali)                                                                             | 600                  |
| <b><i>Network Usage</i></b>                                                            | <b><i>30</i></b>     |
| <b><i>Transmission Losses</i></b>                                                      | <b><i>980</i></b>    |
| <b><i>TOTAL</i></b>                                                                    | <b><i>40,493</i></b> |

Source: Author's construct

Almost half (47.5%) of the electricity supply will be consumed by industry and the remaining will be shared by agriculture, services, household etc. (Figure 1.14). A total of 3,000 MW will be exported through the West Africa Power Pool. Major off takers of electricity are presented in Table 1.7 below.

Figure 1.14: Indicative Electricity Supply Plan 2045



Source: Author’s construct

Table 1.7: Bulk Off Takers of Electricity - 2045

| Bulk Off Taker                                                           | MW     |
|--------------------------------------------------------------------------|--------|
| 10 Regional Industrial Parks                                             | 2,000  |
| 50 Mini District Industrial Parks                                        | 2,500  |
| Automobile manufacture + parts (200,000 vehicles per annum)              | 500    |
| 1 million MT Steel Plant at Oppon Manse Valley                           | 160    |
| 3 million MT Steel Plant at Shieni, near Yendi                           | 480    |
| 1 million MT Tema Steel Recycled Plants                                  | 150    |
| VALCO Smelter – Alumina to Aluminium – 200,000 MT                        | 350    |
| New Nyinahin Bauxite to Aluminium Plant – 500,000 MT                     | 1,200  |
| Ghana Mines various – Gold, Diamonds, other minerals                     | 500    |
| Railway – 4,007km network – Electric Trains/Stations/Non-core operations | 1,000  |
| Exports (West Africa Power Pool)                                         | 3,000  |
|                                                                          |        |
| Total                                                                    | 11,840 |

Source: Author’s construct

## 1.8 Transmission System

### 1.8.1 Overview of the Transmission System

Ghana’s transmission system currently comprises four main high voltage levels: 330 kV, 225 kV, 161 kV and 69 kV. The overall transmission network consists of about 5,216 circuit kilometres (km) of high voltage lines interconnecting the generating centres across the country, namely: Akosombo, Kpong, Tema, Bui and Aboadze; and some sixty-four (64) Bulk Supply Points (BSPs). The breakdown of the transmission network per voltage level is as follows:

- 364 circuit-km of 330 kV lines
- 4,636.6 circuit-km of 161 kV lines
- 132.8 circuit-km of 69 kV lines

In addition, there is a 74.3 km single circuit 225 kV tie-line linking Ghana with La Cote d’Ivoire and a double circuit 161 kV line linking Ghana with Togo. The transmission network has about 123 transformers (including spare transformers) installed at various load centres across the country with a total transformation capacity of 5,517 MVA. There are also sixty-four (64) bulk supply points including switching and generating stations across the network.

### 1.8.2 Current Transmission Network Challenges

Due to many years of under-investment, the National Interconnected Transmission System (NITS) is bedevilled with a number of operational challenges. These challenges existed prior to the power sector restructuring and the subsequent operationalisation of the Ghana Grid Company (GRIDCo) and include over-aged equipment, overloaded transformers and transmission lines.

After its operationalisation in 2008, GRIDCo embarked on an ambitious network upgrade and reinforcement project to meet mushrooming challenges imposed by the ever-increasing electricity demand and the need for operational reliability and security improvements. Due to a lack of available funding, there are still major network expansion projects that are yet to be undertaken. This has led to a situation where the NITS does not meet critical industry benchmarks across all segments of the network. Overall transmission losses are high due to high line loading on some transmission corridors, and in some cases occasional overloads and low customer-end power factors.

### 1.8.3 On-going and Planned Projects

As part of efforts to increase overall transfer capacity and improve network reliability and operational flexibility, GRIDCo, as the System Operator (SO), has embarked upon a number of reinforcement and expansionary programmes. Also, in line with the Government of Ghana’s policy objective of making Ghana a net exporter of power, the SO has embarked upon a number of interconnection projects to interconnect the power systems of neighbouring countries with the objective of exporting power to the mostly power deficient neighbours including the Sahelian countries, under the West Africa Power Pool (WAPP) programme.

## 1.9 Electricity Transmission Plan

### 1.9.1 Overview of the Electricity Transmission Plan

A reliable power system is critical to the development of acceptable socio-economic improvement in the lives of the citizenry of every nation. A robust transmission network is the foundation of a stable and reliable power system. In turn, achieving the required level of reliability of any transmission network depends on developing and complying with the Reliability Planning Criteria. GRIDCo together with the key stakeholders in the power sector, particularly the regulatory agencies, has developed the reliability planning criteria over time to accurately plan and operate the transmission system and assess its performance. The Ghana Grid Code served as the basis for the development of the required reliability planning criteria together with other international standards such as the IEEE, IEC and ANSI. The criteria also act as a guide for GRIDCo engineers and operations personnel. In line with the policy objectives and to provide the required level of grid reliability, the foregoing provides the standards to which the NITS of Ghana should be planned, designed and developed. These criteria will be reviewed from time to time in line with current standards in the industry that include the following:

#### Available Transmission Capacity (ATC)

The transmission system shall be so planned, designed and developed to ensure the maintenance of available transmission capacity at all times. This shall take into consideration all corridors from or to generating plants and all major substations and associated load centres.

##### N-1 Criterion

The transmission network shall be planned and designed to meet N-1 criterion and for some sensitive loads and installation, N-2 criterion. This would ensure that in every transmission corridor, when the biggest transmission line goes out of service, the remaining lines would be able to evacuate the full load requirement without any load shedding.

#### Firm Capacity at all Substations

All substations shall be planned and designed such that the station shall comply with the Firm Capacity criterion. This means that if the biggest transformer at the station is lost, the remaining transformers should be able to carry the total load without any incidence of load shedding.

#### Voltage Criteria

The design of the transmission system should be such that its voltage variations meet the criteria used to assess the reliability of the transmission system during normal or contingency conditions. The substation distribution transformers and/ or voltage regulators provide for +/- 10 percent voltage swings about the NITS voltage level of 69 kV, 161 kV, 220 kV and 330 kV. The acceptable voltage range for the transmission system during normal operating conditions is from 95 percent to 105 percent of nominal. Voltages outside this range would still be considered acceptable if they meet the contingency criteria. Based on prudent utility practice, and as recommended in IEEE Standard 1453, capacitor switching should result in a steady-state voltage fluctuation limited to a maximum of 3.3 percent of nominal. An evaluation should be conducted of single contingency conditions considering the strongest area source element or facility (largest contributor of short circuit current).

#### Maximisation of Existing Right-of-Way

The planning and design of new transmission lines should seek to maximise existing right-of- ways. Existing electric transmission, gas pipe line, railroad, and highways corridors should be identified in all comparisons of alternatives and utilised where possible. Environmental features should also be considered.

#### Minimum Clearances for Transmission Lines

Clearance ratings for transmission lines should be assigned based on the minimum allowable clearances as specified by IEEE/ANSI or other governing body in effect at the time of construction, or by GRIDCo transmission line design criteria.

#### Location of Power Plants

In view of the current configuration of the NITS where majority of the generating plants are located in the south apart from Bui which operates typically in peak mode, the planning and design of the power system should take into serious consideration extension of fuel pipelines to the middle part of Ghana. This would facilitate wooing interested IPPs to construct power plants in the middle part of the country, and also improve the overall security and stability of the NITS.

#### Fast, Reliable and High Capacity Communication Infrastructure

In order to improve communication and enhance protection system performance, the transmission grid should be incorporated with a high capacity and reliable fibre optic network. This would also enhance general communication and critical data exchange.

#### Wholesale Electricity Market

In line with on-going and emerging trends in the electricity industry world-wide, the development of Ghana's energy sector to meet the level of reliability required under the 30-year plan should be pursued to enhance efficiency in the wholesale electricity market. This would help deal with the current incidences of non-payment for energy generated, transmitted and sold by the utilities as an effective energy sale clearing house is one of the key aspects of wholesale electricity markets.

#### Reduction in Transmission Losses

To achieve the set objective in the long-term 30- year plan of increasing transmission capacity and reducing transmission losses from the current 4 percent to below 3 percent, power transmission should be based on high capacity transmission networks of mostly double-circuit 330 kV lines and appropriate level compensation. The grid should also be continually improved and upgraded with higher voltage lines to at least 400 kV from the current highest voltage of 330 kV.

#### Supply to High Consuming and Sensitive Loads

As is the practice in most industrialised economies, supply to high power consuming and sensitive loads should be provided with a level of reliability of the order N-2. These loads should also be supplied at the highest voltage possible and be provided with dedicated substations.

## 1.10 Electricity Distribution System

### 1.10.1 Status of Distribution System

Effective and efficient power distribution network infrastructure is critical for the development of the country's economy into that of a higher income nation. Power distribution utilities will be required to play the leading role in developing the distribution network infrastructure to meet best industry standards and bring efficiency into their operations. Over the past years, the power distribution network infrastructure in Ghana has been growing at a rate inadequate to meet the rapidly growing power demand in major cities and rural communities. Baseline figures for the country's power distribution infrastructure at the end of 2015 are shown in Table 1.8 below.

Table 1.8: 2015 Electricity distribution infrastructure in Ghana

| Company | No. of Primary Substations | Circuit Length of 33 kV Network (km) | Circuit Length of 11 kV Network (km) | Circuit Length of Low Voltage Network (km) | Total Capacity of Power Transformers (MVA) | Total Capacity of Distribution Transformers (MVA) |
|---------|----------------------------|--------------------------------------|--------------------------------------|--------------------------------------------|--------------------------------------------|---------------------------------------------------|
| ECG     | 101                        | 17,197                               | 13,975                               | 67,465                                     | 3,297                                      | 3,892                                             |
| NEDCo   | 11                         | 9,438                                | 2,197                                | 16,861                                     | 75                                         | 675                                               |
| Total   | 112                        | 26,635                               | 16,172                               | 84,326                                     | 3,372                                      | 4,567                                             |

Source: ECG & NEDCo

The electricity access rate in Ghana has been growing and this reflects the degree to which the government is making electricity infrastructure accessible to the public. It should be noted that electricity infrastructure accessibility is estimated as the percentage of communities connected with electricity, either through the grid or via off-grid networks in a country. The electricity access rate in the country was about 81percent at the end of 2015. Going forward, the mode of measurement will be changed from percentage of community connections to the percentage of household connections.

### 1.10.2 Distribution System Challenges

Over the years, the country's power distribution utilities have been confronted with many challenges ranging from an absence of modern systems in the power distribution network, perceived interference from the government in the management of the utilities, inefficient payment of electricity bills by state agencies, and inadequate cost reflective tariff by the PURC. In addition to the above challenges, an inadequate and slow rate of investment has resulted in network expansion lagging far behind demand growth, with unavoidable consequences such as high system losses, poor network reliability, poor supply quality and high suppressed demand, to name a few. These challenges have affected the performance of the power utilities. A number of the challenges are expatiated below:

i. The slow growth in investment has resulted in the high demand for electricity catching up and overwhelming the limited infrastructure available. Without any redundancy, the system has no cushion in the event of an unforeseen failure of a network component arising from maintenance

activity or a fault. This condition has made the distribution system vulnerable and unreliable.

ii. ECG and NEDCo's aggregate technical and commercial (AT&C) losses at the end of 2015 were 22.72 percent and 23.10 percent respectively. This gave a weighted AT&C figure of 22.75 percent for the entire power distribution network. This is significantly higher than the benchmark of 13.06 percent projected to be achieved by 2015 for ECG and NEDCo according to a study done by Global Energy Consulting Engineers, India, for the Ministry of Energy in 2012. Power distribution networks with poor reliability indices affect productivity in the economy and also the financial position of the utility companies. For instance, ECG recorded a System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) of 73.5 inter-cust/yr (interruptions-customers/year) and 161.3 hour-cust/yr respectively, which far exceeds the PURC benchmarks of 6 inter-cust/yr and 48 hour-cust/year.

iii. Poor voltage levels and network overloading in some parts of the distribution network have resulted in suppressed demand and high technical losses.

iv. There is a perceived interference from government in the operation and management of the distribution utilities, hindering management from making critical decisions to improve the operational efficiency of the distribution companies. Some state agencies are unable to pay for electricity consumed regularly and timeously, therefore culminating in huge debts to the utilities.

Going into the future, the anticipated population growth coupled with economic growth targeting a high-income country status will result in high growth in power demand in the country. Power distribution utilities in Ghana will therefore be required to adequately plan their networks to cater for the anticipated load growth and also operate in an efficient and effective manner. They will be expected to develop robust and resilient network infrastructure that will meet the projected power demands in agriculture, industry, transport and other sectors in the country.

### 1.10.3 Addressing the Power Distribution Challenges

Critical issues that should be addressed in the country's power distribution sector are as follows:

- Network infrastructure expansion and modernisation
- Distribution system loss reduction
- Distribution network reliability improvement

Finding lasting solutions to the above issues will contribute to achieving the high-income level the country seeks by the end of the plan period.

## 1.11 Electricity Distribution Plan

### 1.10.1 Efficient and Reliable Power Distribution System

An efficient electricity distribution system that provides reliable delivery of power is expected to accomplish the following:

- A robust and modernised power distribution infrastructure with very wide electricity coverage (i.e. having the best electricity access rate in Africa).
- A power distribution network having very low system losses and high reliability performances comparable with the best in the industry.
- Cost effective/affordable electricity tariff for consumers.
- Well trained human resources (i.e. technical & non-technical experts) to effectively and efficiently operate and manage the power distribution system.

With the high power demand projections for Ghana, economic activities in cities and rural communities are expected to increase. This will call for strategic planning of the distribution network infrastructure to meet the anticipated high projected power demands. Electric utility companies are expected to undertake power distribution master plans every ten (10) years to review their plans for providing cost effective

power infrastructure for all sectors of the economy. These plans are to be monitored by a national body to ensure that they are reviewed periodically and implemented on schedule.

### 1.11.2 Modernisation of the Distribution Network Infrastructure

Upgrading and modernisation of power distribution grids has been a major concern for power utilities all over the world due to their immerse benefits. The upgrade/modernisation will boost security, efficiency and reliability of the distribution power grid. Going into the future in the power distribution industry in the country, the under-listed technologies will become very critical in that regard.

### 1.11.3 System Wide Geographic Information System (G.I.S) Platform

In modern times, geographic information systems (GIS) play a very critical role in the effective and efficient operation of electric distribution utilities. GIS platforms are required by power utilities to assist the analyses, management and mapping of spatial data. Deployment of GIS platforms for mega cities will assist power utilities in the following:

- i. Spatial load forecasting and optimization of the planning of substations and feeder locations and their capacities.
- ii. Automated route selection for the construction of power lines.
- iii. Provision of accurate up-to-date information on network assets. This will in turn connect database information such as customer service operations, material auditing, power distribution analyses and studies, outage reporting, power theft detection etc.
- iv. Acts as a platform for the implementation of smart grid technologies in the power distribution network.

### 1.11.4 Smart Grid Technologies

Technological advancements will affect all players in planned mega cities. In light of this, the under-listed Smart Grid<sup>13</sup> technologies will be required to bring efficiency and effectiveness into the operations of the electricity utilities in the country:

#### Distribution Management System (DMS)

Distribution Management System (DMS) is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably. DMS applications such as Distribution SCADA System, Advanced Fault & Network Analysis, Distribution Automation System, Volt-Var. Control, Conservation Voltage Reduction (CVR) etc. should be deployed for the modernisation of the operations of the power distribution networks.

#### Advanced Metering Infrastructure (AMI)

This refers to systems that measure, collect and analyse energy usage from advanced devices such as electricity meters, gas meters, and water meters through various communication media.

The use of AMI will offer the following:

- i. Two-way communication with every customer which enables remote meter reading and home area networks.
- ii. Measurement of site-specific information, allowing utility companies to introduce different tariffs for consumption based on the time of day and the season.
- iii. Remote connection/disconnection of service.
- iv. Estimation of customer bills, which are a major source of complaints for many customers and also serve as a tool to help consumers to better manage their energy purchases.

#### Outage Management System (OMS)

An outage management system (OMS) is a computer system used by operators of electric distribution systems to track outages and assist in restoration of power. These smart grid technologies will be riding on a power distribution GIS platform.

### 1.11.5 Electric Vehicle Charging & Electric Train Systems

An efficient transportation sector will play a critical role in mega cities. Electricity utility companies will have to provide service to modern electric vehicles that will require reliable power supply for their day-to-day activities. The government and electric distribution companies will establish electric vehicle (EV) charging stations in mega cities and towns. Charging stations can be deployed where there is on-street parking, at taxi stands, in parking lots (at places of employment, hotels, airports, shopping centres, convenience shops, fast food restaurants, coffeehouses etc.), as well as in driveways and garages at home. Fuel pump stations should also incorporate charging stations. Their services should address the following<sup>14</sup>:

- i. Provision of residential charging stations where an EV owner plugs in when the vehicle returns home and it recharges overnight.

- ii. Charging while parked (including public charging stations): This is a commercial venture for a fee or free, offered in partnership with the owners of the parking lot. It can include parking stations, parking at malls, small centres, and train stations.
- iii. Fast charging at public charging stations: These chargers may be at rest stops to allow for longer distance trips. They may also be used regularly by commuters in metropolitan areas, and for charging while parked for shorter or longer periods.
- iv. Battery swaps or charge centres: This intends to match the refuelling expectations of regular drivers.
- v. Electric trains system will require a separate power supply network with a dedicated frequency for its day-to-day operations.

### 1.11.6 Greenhouse Gas Reduction Schemes

To address climatic changes and greenhouse gas (GHG) reduction in mega cities, distributed generation from renewable sources such as solar, biomass and wind should be deployed at strategic locations in the electrical distribution system. This will ensure improved electrical efficiency, greater grid resilience and a lower carbon footprint. In consultation with the Ministry of Energy, the Energy Commission and the electricity distribution companies, incentive packages should be planned for solar energy on rooftops of public and commercial buildings and homes to provide additional impetus towards strengthening the distributed generation model. Energy storage technologies (e.g. battery storage systems) should be considered to stockpile excess power from renewable energy sources.

### 1.11.7 Demand Side Management

Demand-side management (DSM) includes activities, programmes, and information systems that are designed to encourage consumers to modify (i.e. reduce) their level and pattern of electricity usage, and/or add distributed generation. Economics also plays a major role in the adoption of DSM. Major capital investment projects with low utilisation are not in the best interest of a developing nation with limited resources. Hence management of demand side factors can be a powerful tool in improving resource adequacy. Some of the DMS techniques that should be considered are as follows:

#### Time of Use (TOU) Tariff

Time of use (TOU) pricing which is also known as dynamic pricing or flexible pricing is a way of pricing electricity depending on the time of day it is used. This reflects the different costs of generating and distributing electricity throughout the day. To benefit from TOU pricing, consumers must have smart meters installed at home. These technologically advanced meters accurately measure when and how energy is used, so that a retailer can offer different prices depending on the time of day. Smart meters have the added benefit of providing real-time information about consumers' energy use, so one can easily monitor and potentially manage when and how much energy is used each day. Implementation of the TOU tariff will encourage peak time customers to shift or level their consumption uniformly over a 24-hour period.

#### Reactive Power Management

This approach will consider improving the overall power factor of a system to a near unity value by the installation of fixed and switchable shunt capacitor banks. It should be noted that during the peak load period of a system, the average system power factors could be very poor and as a result of that, power would be poorly utilised. To ensure efficiency in the usage of power during peak load period, shunt capacitors will be installed at industrial customer ends to improve peak load system power factors.

#### Demand Response

This is any reactive or preventative method to reduce, flatten or shift peak demand. Demand response includes all intentional modifications to consumption patterns of electricity of end user customers that are intended to alter the timing,

level of instantaneous demand, or the total electricity consumption.

<sup>13</sup> Smart Grids are operational systems and applications, field devices and communication networks that work together to add intelligence to the basic electrical

<sup>14</sup> [http://en.wikipedia.org/wiki/charging\\_station](http://en.wikipedia.org/wiki/charging_station) (Accessed on: 28th November, infrastructure. 2016)

Conservation Voltage Reduction (CVR)

It is a proven technology for reducing energy and peak demand. It is a measure implemented upstream of end service points in the distribution system so the efficiency benefits are realised by consumers and the distributor. This is done without any intervention on the part of consumers. CVR is implemented by controlling the voltage on a distribution circuit to the lower end of a tolerance band. Conservation then occurs on the circuit when certain end-use loads draw less power when voltage is lowered. Now, with smart grid technologies and real-time operating systems, utilities can realise energy savings and demand reductions<sup>15</sup> of about 3percent or more on a continual basis.

Replacement of high pressure sodium (HPS) lamps with light emitting diode (LED) lamps: Replacement of the high pressure sodium (HPS) street lamps (with average power rating of 250 W) with light emitting diode (LED) street lamps (with average power rating of 150 W) will reduce the street lighting consumption by about 40 percent. The Ministry of Energy should consider the deployment of LED street lamps in all communities in the country.

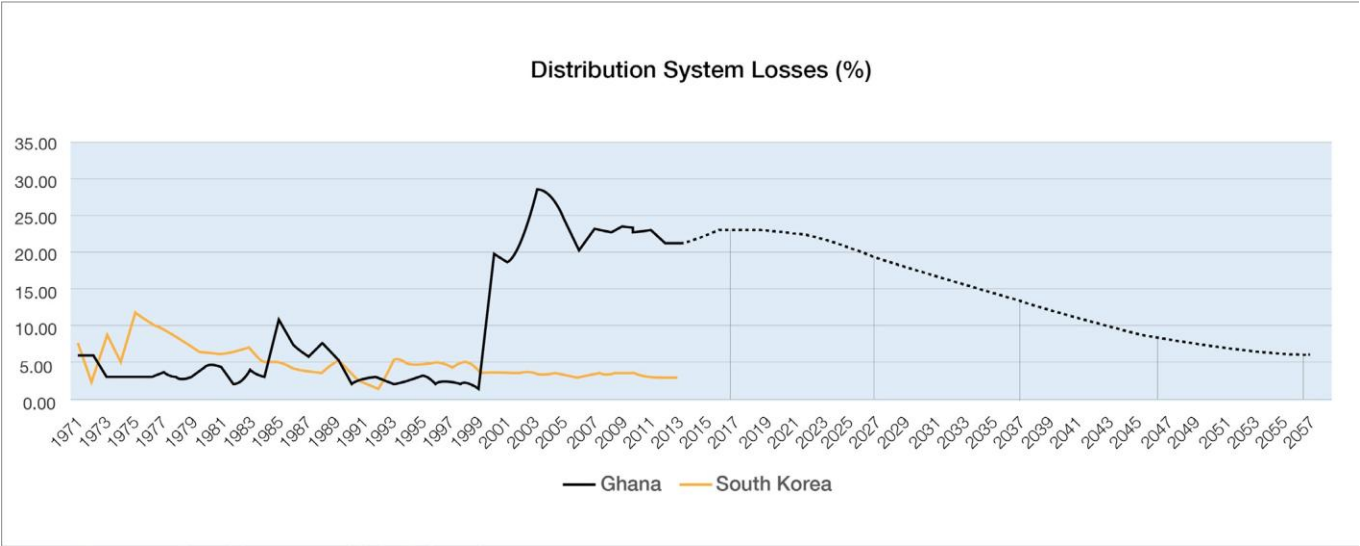
1.11.8 Distribution System Losses Reduction

Distribution system losses or aggregate technical & commercial (AT&C) losses are a transparent measure of the overall efficiency of the power distribution business, as it measures technical as well as commercial losses. This involves the estimation of the difference between the energy purchased and energy sales in particular electric distribution network expressed as a percentage of the energy purchased. Over the years, the AT&C losses of the major electricity distribution utilities in the country have been a major concern as it has been impacting negatively on the finances of these companies.

As at December 2015, the AT&C losses figures of ECG and NEDCo were 22.72 percent and 23.10 percent respectively. This gave a weighted AT&C figure of 22.75 percent for the entire power distribution network in Ghana. Figure 1.15 shows the historical distribution system losses values for Ghana and South Korea.

15 The source of this information is from the Smartgrid.ieee.org/april-2013/842-conservation-voltage-regulation-an-energy-efficiency-resource

Figure 1.15: Historical Distribution Losses for Ghana and South Korea<sup>16</sup>



Source: World Bank, updated by GIP Team

The figure above depicts the historical distribution losses for both Ghana and South Korea. From this figure, it can be seen that Ghana was doing well with an average of 5 percent losses from 1971 through to 1999 comparable to South Korea. However, from the year 2000 to 2013, distribution system losses increased rapidly while that of South Korea held steady. Among factors contributing to the high losses in Ghana are high demand growth, inadequate network expansion investments, insufficient planning of the transmission, sub-transmission and distribution systems with the short term objective of extension of power supply to new areas, large scale rural electrification through long medium and low voltage lines, improper load management, inadequate reactive power compensation, power theft, poor metering systems etc. During the 40-year period, the transmission losses will be reduced to 2.5 percent while the distribution losses will be reduced to 6 percent.

Technical Losses Reduction

Distribution technical losses occur naturally and consist mainly of power dissipated in electricity system components such as transmission and distribution lines, transformers, and measurement systems. A number of solutions have been recommended for addressing electrical distribution networks losses in Ghana.

16 World Bank - <http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS> – Projection by GIP Team

1.11.9 Commercial Losses Reduction

Commercial losses in the electrical network are caused by actions external to the power system. It consists primarily of electricity theft, non-payment by customers, and errors in accounting and record keeping. To handle this canker effectively and efficiently will require the undertaking of the following drastic measures outlined below:

Advanced Metering Infrastructure and Automatic Meter Reading

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers. The deployment of such a system into the operation of distribution utilities will facilitate an efficient and effective means of remotely metering, reading and monitoring customers' electricity consumption. This tool will detect and discourage theft and other modes of unmetered consumption in an enormous way as reflected in the experience of developing countries in Latin America like the Dominican Republic, Chile, Honduras, Brazil and also India<sup>17</sup>.

The Automatic Meter Reading (AMR)

An AMR system will provide a facility for remote disconnection and reconnection of electricity supply from an AMR control centre. With the latest technology, the AMR enables remote disconnection and reconnection of electricity supply to low and medium voltage users of electricity at very competitive prices. This facility will improve revenue collection by instilling the fear of being disconnected automatically in case of default of payment.

Replacement of Legacy Credit Meters

Legacy credit meters will be replaced with pre-payment meters to improve collection efficiency and timely closing of monthly financial statements.

Customised Application Software

Distribution utilities are to develop utility specific application software which will analyse the energy consumption and load survey data and give alerts to customer service managers as well as top management regarding customers who need to be watched based on changes in their consumption patterns.

17 Global Energy Consulting Engineers (GECE), National Technical and Commercial Loss Study for ECG & VRA/NED, Ghana 2012. India.

Customer Installation Sealing

Utilities should photograph details of the seals used for securing meters, sealing of switches/circuit breakers and metering installations. Records shall be kept like specimen signatures similar to those maintained by banking institutions. E.g. photograph of seals, capturing seal number, sealing impression, etc.<sup>17</sup> This will help in analysing any suspected tampering.

Re-routing of Concealed Service Tails

Service wiring from the service pole to customer meter boards concealed in ceilings and walls serve as points of direct connection or meter by-passes. Customers bent on stealing power connect high energy consuming equipment directly on these service tails, thereby bypassing the meter. Therefore, re-routing of concealed service tails will help in reducing the energy theft in the network.

Energy Audits

Distribution utilities are to implement energy audit programmes for regional and district operational boundaries to determine the level of system losses and the sections of the network contributing to such high losses within selected boundaries. The audit exercise should consider the following:

i. Metering of the boundaries (using import and export metering devices) of the selected regions and districts to determine the levels of system losses. Specific loss reduction strategies can then be applied for such regions/districts.

ii. Metering of power and distribution transformers at the incomer and outgoing feeders to determine the total energy units billed for all the customers served by that transformer as compared with the total energy throughput. This will bring out the total energy losses on that transformer. Specific loss reduction methodology can then be applied to remedy the situation.

Legal Measures for Control of Theft

Government is expected to support the utilities in combatting commercial losses by the enactment of special legislation, declaring theft of energy an offence, providing deterrent punishment, summary trials and creation of special courts to deal with energy theft cases. Speedy trials are necessary to address this power theft problem. The case studies of utilities that have achieved substantial commercial loss reduction worldwide show the important role of legislation <sup>17</sup>.

Efficient Payment System

The payment system should aim at reducing the time it takes the customer to make a payment when standing in the queue. The system should be linked to customer mobile phones and must tell how much has been paid and the amount pending to be paid by the customer in real time. Provision must be made available for making payments in cash, via cheques, credit and debit card and bank transfers <sup>17</sup>.

1.11.10 Collection Losses Reduction

Meter Installations for all Non-Metered Customers

All unmetered customers should be provided with meters to reduce misuse of energy and loss of revenue.

Deployment of Electricity Units Scratch Cards

Electricity utilities should modernise the sale of energy by deploying electric meters that are compatible with electricity units scratch cards which work in the same manner as mobile phone scratch cards. These cards should be sold to consumers at appropriate channels such as malls, shops, fuel filling stations and other retail exits. Upon buying a card, the consumers will simply scratch the foil area at the back for the PIN. Consumers will simply send SMS text messages containing their prepayment meter serial numbers plus the scratch card PIN number using their mobile phone, to a designated telephone number on the scratch card. SMS message should be sent to the customers, indicating the energy credit number. This number will then be entered into their prepayment meters to obtain credit for their energy consumption<sup>18</sup>.

Provision of Customer Call Centres

Power distribution utilities must have a call centre for dealing with customers by phone/integrated voice response system (IVRS). The service must include dealing with both reporting of service calls as well as trouble calls. An IVRS should be provided with a unique number and must be programmed to receive the complaints automatically guided by interactive voice response. Adequate numbers of operators to receive the calls must also be provided in case the customer wants to get his complaints recorded manually. Provision for

<sup>18</sup> <https://www.metering.com/scratch-cards-for-pay-as-you-go-electric-custom-ers> (Accessed on 26th November, 2016)

making complaints to the call centre via the internet must also be provided.

After the complaints are resolved, a message must be sent to the customer through SMS/ internet systems if the mobile number or email ID is available. GIS maps should be available which should be linked to the customer master database to provide better interactivity with them<sup>17</sup>.

Credit Card/Debit Card Payments

Provision for bill payment can be made available through credit or debit cards by using bank payment gateways. The utility needs to sign up

with one or more payment gateways that provide data security for customers paying the bills. The amount is credited to the utility's account and receipts generated immediately for the customer's record<sup>17</sup>.

1.11.11 Savings for Implementing Loss Reduction Measures

A reliable power system is critical to the socio-economic improvement in the lives of the citizenry of every nation. A number of measures have been put in place to reduce transmission losses from the current 4.5 percent to 2.5 percent over the next 40 years. The recommendations include incorporating the transmission grid with

a high capacity and reliable fibre optic network. Tables 1.9 and 1.10 show the extent of savings for implementing loss reduction measures in the transmission and distribution systems. It shows that if the appropriate cost reduction measures are put in place and the targets are achieved, more than \$130 Billion of power would be saved over the next 40 years.

Table 1.9: Savings to GRIDCO by implementing transmission system loss-reduction measures

| Year | Energy Generated (GWh) | Transmission losses - Technical & Commercial % | Actual Transmission losses (GWh) | Average price of bulk power transmitted (in US\$) | Annual savings to GRIDCO (US\$ million) | Duration (10 Years) | Savings to GRIDCO for decade (in US\$ million) | Cumulative Total savings to GRIDCO (in US\$ million) |
|------|------------------------|------------------------------------------------|----------------------------------|---------------------------------------------------|-----------------------------------------|---------------------|------------------------------------------------|------------------------------------------------------|
| 2017 | 16,000                 | 4.5                                            | 720                              | 0.1                                               | 72                                      | 0                   | -                                              | -                                                    |
| 2027 | 73,800                 | 4                                              | 2,952                            | 0.1                                               | 295                                     | 10                  | 2,952                                          | 2,952                                                |
| 2037 | 184,000                | 3.5                                            | 6,440                            | 0.1                                               | 644                                     | 10                  | 6,440                                          | 9,392                                                |
| 2047 | 297,200                | 3                                              | 8,916                            | 0.1                                               | 892                                     | 10                  | 8,916                                          | 18,308                                               |
| 2057 | 350,000                | 2.5                                            | 8,750                            | 0.1                                               | 875                                     | 10                  | 8,750                                          | <u>27,058</u>                                        |

Source: GIP Team

Table 1.10: Savings to ECG by implementing distribution system loss-reduction measures

| Year | Energy Generated (GWh) | ECG share of power - % Generated | Energy distributed by ECG (GWh) | ECG Distribution losses - % (Technical & Commercial) | ECG Actual Distribution losses (GWh) | Average price of electricity (in US\$) | ECG Annual savings (in US\$ million) | Duration (No. of Years) | Savings to ECG over duration - 10 years (in US\$ million) | Cumulative Total savings to ECG (in US\$ million) |
|------|------------------------|----------------------------------|---------------------------------|------------------------------------------------------|--------------------------------------|----------------------------------------|--------------------------------------|-------------------------|-----------------------------------------------------------|---------------------------------------------------|
| 2017 | 16,000                 | 70                               | 11,200                          | 22.75                                                | 2,548                                | 0.25                                   | 637                                  | 0                       | -                                                         | -                                                 |
| 2027 | 73,800                 | 67                               | 49,446                          | 19                                                   | 9,395                                | 0.23                                   | 2,161                                | 10                      | 21,608                                                    | 21,608                                            |
| 2037 | 184,000                | 63                               | 115,920                         | 13                                                   | 15,070                               | 0.21                                   | 3,165                                | 10                      | 31,646                                                    | 53,254                                            |
| 2047 | 297,200                | 60                               | 178,320                         | 8                                                    | 14,266                               | 0.2                                    | 2,853                                | 10                      | 28,531                                                    | 81,785                                            |
| 2057 | 350,000                | 59                               | 206,500                         | 6                                                    | 12,390                               | 0.19                                   | 2,354                                | 10                      | 23,541                                                    | <b>105,326</b>                                    |

Source: GIP Team

## 1.12 Energy Efficiency and Conservation

Energy efficiency and conservation play key roles in demand side management. Significant reduction of the total energy consumed can be achieved through aggressive and sustainable energy efficiency and conservation programmes and strategies.

The terms energy efficiency and energy conservation have distinct meanings: Efficiency is available in numerous forms, and can consist of lighting, insulation, home appliances and lots of other alternatives. Using a compact fluorescent light bulb that requires less energy instead of an incandescent bulb to produce the same amount of light is an example of energy efficiency. On the other hand, energy conservation is any behaviour that results in the use of less energy. Turning the lights off when leaving the room, powering down computers and electronic equipment at night and recycling aluminium cans are both ways of conserving energy.

Figure 1.16: Efficiency vs. Conservation

| Efficiency vs. Conservation                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Efficiency                                                                                                                                                                                                                                                                                   | Conservation                                                                                                                                                                                                                                                               |
| <ul style="list-style-type: none"> <li>Energy efficiency involves the use of technology that requires less energy to perform the same function.</li> <li>Focuses on the equipment or machinery being used</li> <li>One example is installing LED light bulbs throughout the house</li> </ul> | <ul style="list-style-type: none"> <li>Energy conservation includes any behavior that results in the use of less energy.</li> <li>Focuses on the behavior of people</li> <li>One example is using daylighting through windows rather than turning on the lights</li> </ul> |

Source: GIP Team

### 1.12.1 Energy Efficiency and Conservation Policy

#### Policy Statement

Government is committed to ensuring efficient production, distribution and use of energy in all sectors of the economy. The goal is to achieve 10 percent savings in energy consumption through the implementation of effective policies and programmes.

#### Policy Objectives

The objectives of the energy efficiency and conservation policy are to:

- Develop and implement programmes and measures to help consumers optimise their energy use.
- Develop and implement measures aimed at causing market transformation to remove market barriers that hinder the mass adoption and use of energy efficient technologies.
- Support a sustained and comprehensive public education and awareness building campaign on the methods and benefits of energy conservation.
- Promote environmentally sustainable energy efficiency programmes including appropriate building codes and green industrial processes.
- Establish appropriate pricing regime for energy services that would encourage (provide incentive) domestic and industrial consumers to voluntarily manage their energy consumption.

### 1.12.2 Strategies for Ensuring Energy Efficiency and Conservation

The following strategies will be used to ensure energy efficiency and conservation:

- Provision of incentives for real estate developers and other construction designers to incorporate energy conservation into buildings.
- Sustained and intensive public education and awareness-raising campaign on the benefits of energy conservation and management.
- Development and implementation of

programmes and measures to help consumers to optimise their use of energy.

- Promotion of LED for community and street lighting and traffic signals.
- Facilitation of access to finance by industry and commercial entities to implement energy efficiency interventions.
- Provision of support to private energy service providers to actively promote energy efficiency and conservation in residential, public, commercial and industrial facilities.

### 1.12.3 Energy Efficiency and Conservation of Electricity

To improve energy efficiency in the electricity sector, Government will:

- Promote through legislation, the local production, importation, marketing and use of energy efficient electricity consuming equipment and appliances.
- Transform the electrical appliance market through the institution and implementation of appliance energy efficiency standards and labels for electrical appliances manufactured or imported for use in Ghana.
- Encourage consumers to implement simple energy conservation and efficiency (housekeeping) measures such as turning off lights when not in use and ironing cloths in bulk.
- Accelerate the introduction and use of energy saving technologies.
- Establish a performance based implementation and financing mechanism for the identification, implementation and financing of energy efficiency retrofits in industrial and commercial sectors.
- Increase public awareness of energy efficiency practices and technologies through public awareness and educational campaigns.
- Develop human resource capacities in energy management in primary, high schools and tertiary Institutions.

1.12.4 Energy Efficiency and Conservation of Petroleum

- Government will develop and implement measures to reduce the quantum and cost of petroleum product consumption in transportation. These will include:
- i. Institution of fiscal measures such as prohibitive import duties on high fuel- consuming luxury vehicles;
  - ii. Institution of legislative measures to prohibit the importation of over-aged vehicles;
  - iii. Promotion of good vehicle maintenance culture and good driving practices;
  - iv. Promotion of natural gas (CNG), liquefied petroleum gas (LPG) and biofuels as alternatives to liquid fossil fuels especially in the industrial sector;
  - v. Promotion of high-capacity public transport systems;
  - vi. Develop human resource capacities in energy management in primary, high schools and tertiary Institutions.

1.12.5 Energy Efficiency and Conservation of Biomass

- With regards to biomass, Government will:
- i. Promote the utilisation of more efficient charcoal production and end-use fuel wood combustion technologies (e.g. cook stoves) through training, fiscal incentives and regulation.
  - ii. Promote the efficient use of biomass in industrial boilers.
  - iii. Promote the establishment of woodlots for sustainable production of charcoal and the conversion of biomass into briquettes.
  - iv. Develop human resource capacities in Energy Management in Primary, High Schools and Tertiary Institutions.

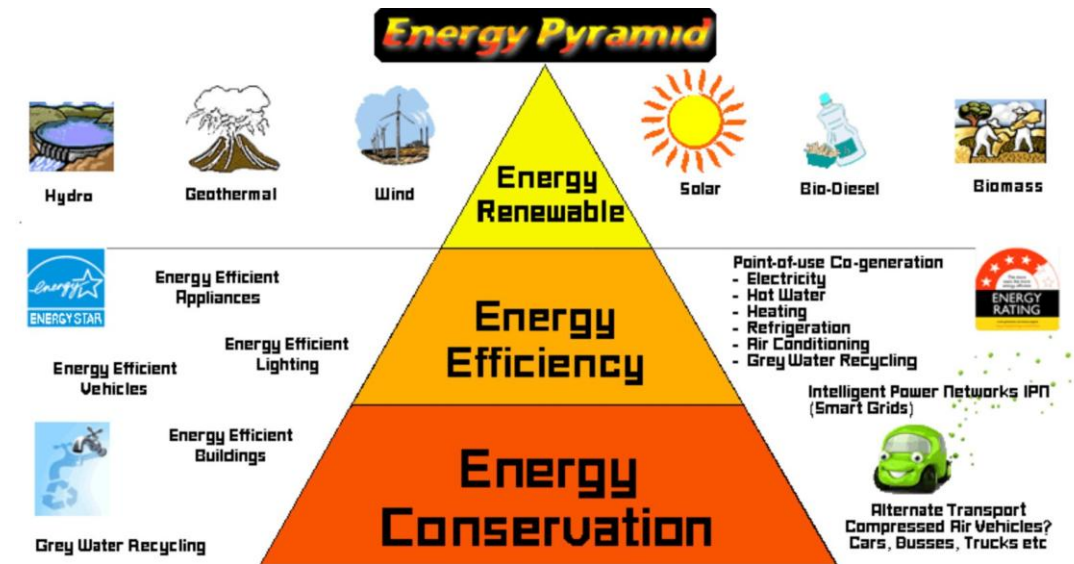
1.12.6 Energy Efficiency Database Programme

The Energy Commission is mandated by ACT 541, 1997 to among other functions, establish a comprehensive database for national decision making on energy. The Commission has established a National Energy Data Processing and Information Centre (NEDPIC) in accordance with section 2 (d) of ACT 541. Under this programme, an energy efficiency component of the NEDPIC will be developed for the collection, collation, processing and storage of data and information from the energy sector stakeholders. Primary data and information on energy use patterns and efficiency will be collected through surveys and studies on the consumption of electricity, petroleum and biomass.

Strategic Focus of the Energy Efficiency Database Programme

- Data and information to be captured and processed include the following:
- i. Energy consumption patterns of industrial establishments.
  - ii. Household energy consumption patterns and specific energy consumption of household electrical and other appliances such as cook stoves and ovens.
  - iii. Energy consumption patterns in the commercial sector and specific energy consumption of energy systems as well as electrical and other appliances such as industrial refrigerators, cook stoves and ovens.
  - iv. Fuel consumption levels and patterns of various transport modes in the transport sector.

Figure 1.17: Energy Pyramid



Source: GIP Team

1.13 Investment Requirements

The huge infrastructure expansion of the electricity network has an associated high investment cost as presented in Table 1.11 below. The required investment covers the entire generation as well as transmission and distribution networks. The cumulative investment requirement for the entire planning period is about 168 billion US dollars.

Table 1.11: Investment Requirements (million US dollars)

|              | 2018-2021 | 2022-2025 | 2026-2029 | 2030-2033 | 2036-2037 | 2038-2041 | 2042 - 2045 | 2046 -2047 | TOTAL   |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|-------------|------------|---------|
| Large Hydro  | 0         | 0         | 80        | 60        | 0         | 0         | 0           | 0          | 140     |
| Small Hydro  | 40        | 822       | 330       | 120       | 115       | 0         | 0           | 0          | 1,427   |
| Biomass      | 294       | 180       | 160       | 165       | 155       | 132       | 0           | 0          | 1,086   |
| Biogas       | 7         | 32        | 45        | 12        | 212       | 185       | 124         | 112        | 729     |
| Wave         | 48        | 63        | 152       | 106       | 173       | 141       | 32          | 0          | 715     |
| Wind         | 450       | 663       | 523       | 785       | 311       | 560       | 760         | 32         | 4,084   |
| Solar PV     | 1,630     | 1,460     | 2,150     | 540       | 840       | 1,140     | 2,460       | 1,270      | 11,490  |
| Solar CSP    | 4         | 18        | 7         | 110       | 25        | 40        | 140         | 25         | 369     |
| Imported Oil | 1,387     | 447       | 12        | 0         | 0         | 0         | 0           | 0          | 1,846   |
| Domestic Gas | 3,650     | 3,450     | 2,230     | 790       | 790       | 220       | 0           | 0          | 11,130  |
| Imported Gas | 650       | 320       | 0         | 0         | 0         | 0         | 0           | 0          | 970     |
| LNG          | 1,200     | 5,800     | 2,750     | 2,660     | 3,960     | 5,400     | 3,800       | 510        | 26,080  |
| Coal         | 2,100     | 1,600     | 1,800     | 3,900     | 4,800     | 3,200     | 1,200       | 2,300      | 20,900  |
| Nuclear      | 568       | 2,274     | 5,500     | 12,700    | 11,800    | 17,800    | 1,600       | 8,800      | 61,042  |
| Transmission | 840       | 1,840     | 1,840     | 1,840     | 1,840     | 1,840     | 1,840       | 1040       | 12,920  |
| Distribution | 800       | 1,800     | 1,800     | 1,800     | 1,800     | 1,800     | 1,800       | 1,800      | 13,400  |
| Total        | 13,668    | 20,769    | 19,379    | 25,588    | 26,821    | 32,458    | 13,756      | 15,889     | 168,328 |

Source: GIP Team

## 1.14 Recommendations

The following recommendations are being made to ensure the development of an effective generation, transmission and distribution infrastructure for the supply of affordable and reliable electricity for the fulfilment of the aims and objectives of Ghana's 40-year development plan:

- i. There is the need to diversify the electricity generation mix to enhance energy security, in view of the issues raised in the report regarding security of fuel supply and the recent energy crises in the country.
- ii. Plans and funding negotiations for the development of the necessary infrastructure in the power sector should be done well ahead of time, considering the length of time taken for infrastructure development in the power sector.
- iii. Develop the appropriate policy guidelines with the necessary enforcement strategies for the promotion and use of energy efficient equipment as well as energy efficient practices.
- iv. There should be effective intra and inter-sectional coordination in the various sections of the power sector to ensure effective implementation of the generation expansion plan.
- v. There must be enough transmission capacity across all corridors so that in case of a loss of the biggest line within a corridor, the network should be able to meet full requirements.
- vi. There must be a conscious scale up of the transmission voltage to 400kV to ensure larger amounts of transmission per line and lower transmission losses.
- vii. All substations should be designed and constructed to meet firm capacity requirements such that the full load of the station can be supplied even when the biggest transformer is out of service.
- viii. Supply to critical and sensitive loads should be at the highest level of reliability to meet the N-2 criteria as pertains to all developed countries.
- ix. Regulatory bodies should effectively monitor power distribution utilities to ensure strict adherence to the implementation of the existing power distribution master plan.

# Chapter 2 Renewable Energy

## 2.1 Introduction

The Government of Ghana has identified renewable energy as one of the options to contribute to the overall energy supply mix and minimise the adverse effects of energy production on the environment. In view of this, efforts towards the creation of a clear regulatory framework for the renewable energy (RE) sector have been on going, with the formulation of policies and strategy documents. A major milestone for the RE industry was the enactment of the Renewable Energy Act (Act 832) in 2011. This, together with targeted policies and strategies, has helped in increasing investments from both the public and private sectors in RE. Section 2 of the Renewable Energy Act, 2011 (Act 832), defines renewable energy as energy obtained from non-depleting sources including:

- i. Wind
- ii. Solar
- iii. Hydro;
- iv. Biomass
- v. Biofuel
- vi. Landfill gas
- vii. Sewage gas
- viii. Geothermal energy
- ix. Ocean energy and any other energy source designated in writing by the Minister

### 2.1.1 Renewable Energy Act, 2011 (Act 832)

The Renewable Energy Act (RE Act) aims to create an enabling regulatory environment to attract private sector involvement in the development, management and utilisation of renewable energy in an efficient and environmentally sustainable manner. The key provisions in the RE Act include:

- i. Feed-in-Tariff (FiT) scheme under which electricity generated from renewable energy sources is offered a guaranteed price.
- ii. Renewable Energy Purchase obligations under which power distribution utilities and bulk electricity consumers must purchase some percentage of their electricity from electricity generated from renewable energy sources.
- iii. Designating biofuel blend as a petroleum product.

- iv. Licensing regime for commercial renewable energy service providers, among others, to ensure transparency of operations in the renewable energy industry.
- v. Establishment of the renewable energy fund to provide incentives for the promotion, development and utilisation of renewable energy resources.
- vi. Establishment of a Renewable Energy Authority.

The latest FiT published on October 1, 2016 is presented in Table 2.1 below.

**Table 2.1: Feed-In-Tariff Rates**

| Type of Technology      | Ghana Pesewas per kWh | US cents equivalent per kWh* |
|-------------------------|-----------------------|------------------------------|
| Wind                    | 65.3529               | 17.02697                     |
| Solar PV                | 59.7750               | 15.57371                     |
| Hydro <=10              | 52.9428               | 13.79365                     |
| Hydro (10MW>and<=100MW) | 56.5312               | 14.72857                     |
| Tidal Wave (Ocean Wave) | 52.9428               | 13.79365                     |

Source: REMP, 2017 \* Exchange rate: 1 USD = 3.8382 GHS (September 2016)

### 2.1.2 RE Institutional Framework

The Ministry of Energy is the policy making body for RE, with a primary responsibility of ensuring policy development, coordination and implementation as well as supervision of operations and activities of sector institutions in the country. A number of existing regulatory agencies have been mandated by the RE Act to perform various roles. The two principal institutions are the Energy Commission and the Public Utilities Regulatory Commission (PURC).

The RE Act defines the roles and responsibilities of key institutions to facilitate implementation of the provisions of the Act. The following have been achieved under the RE Act:

- i. FiTs have been developed and gazetted;
- ii. Framework for the RE Fund has been developed.
- iii. Net metering code and renewable energy sub-codes for transmission and distribution systems have been developed.
- iv. Licensing manual developed for RE service providers.
- v. Guidelines for the Renewable Energy Purchase Obligation have been drafted.

A Renewable Energy Authority is to be established in line with the transitional provision of the RE Act to perform the following functions:

- Oversee the implementation of renewable energy activities in the country.
- Execute renewable energy projects initiated by the State or in which the State has an interest.
- Manage the assets in the renewable energy sector on behalf of the State.

## 2.2 Status of RE Technology Development

### 2.2.1 Grid-Integrated Renewable Energy

More than 24 MW of solar PV grid-connected systems had been installed in Ghana as of 2015. Of this total, 22.5 MW was from two utility-scale projects: a 20 MW plant by BXC Company Ltd. and another 2.5 MW by VRA. The remaining systems are mainly household and institutional grid-connected systems, either self-funded, donor funded, or funded with government support.

Grid-connected systems have also been installed in the biomass industry, notably from oil palm and fruit processing companies in the Eastern and Ashanti Regions. Examples include the Juaben Oil Mills at Juaben in the Ashanti Region and GOPDC at Kwae, which own biogas plants of 2000 m<sup>3</sup> capacity with an electricity generation potential of 4 MW. Grid connected systems also face challenges, including:

- i. High cost of capital
- ii. Lack of access to capital from the local market
- iii. Lack of indigenous investors
- iv. Uncertainties in Feed-in-Tariff (FiT) rates beyond the guaranteed period of ten years

### 2.2.2 Manufacturing/Assembly Capacity

The potential exists for the manufacturing of all renewable energy components in Ghana. The Government has therefore, put in place incentives and created the enabling environment for local manufacturing and/or assembly of renewable energy technologies (RETs). Four companies are taking advantage of these market incentives to locally manufacture and assemble PV modules with details as follows:

- i. Strategic Security Systems International Limited (3SiL), began solar PV module assembly in Ghana in 2015, with a capacity of up to 30 MW of modules per year.
- ii. Halo International also completed a solar PV module plant in 2016 with production capacity of 15 MW per year.

- iii. Tradeworks Ghana Ltd., is in the process of completing a solar PV module assembly plant with 12 MW per year capacity.
- iv. Atlas Business and Energy Systems (ABES) has a smaller scale solar PV module assembly plant in place since 2012.

## 2.3 Scaling up RE Technologies

### 2.3.1 Support for Manufacturing/Assembly Centres

In order to reduce the over reliance on imported RETs, government shall support local manufacturing/assembly initiatives by providing incentives such as tax breaks, capital subsidies, loan guarantees, etc. Specific incentives for renewable energy manufacturing and assembling would be as follows:

- i. Substantial tax reduction for manufacturing and assembling.
- ii. Materials, components, equipment and machinery (that cannot be obtained locally) for manufacturing or assembling, shall be exempted from import duty and VAT, up to the year 2025.
- iii. Materials, components, equipment and machinery that Ghana has competitive advantage over, shall attract the relevant import duty and other applicable taxes to promote the local industry.
- iv. Import of plant and plant parts for electricity generation from renewable energy resources, shall be exempted from import duty and VAT.
- v. Allocation of a quota for local industries in all Government projects to facilitate expansion of the existing market.
- vi. Government shall provide a vehicle through existing facilities such as the Venture Capital Trust Fund to provide soft loans to local industries.

### 2.3.2 Local Content

A Local Content Policy (2017) for the Electricity Supply Industry (ESI), including electricity from renewable energy resources has been drafted. The Government of Ghana is committed to the implementation of an effective local content policy as the platform for achieving the goals for the power sector with full local participation in all aspects of the ESI value chain of at least 60

percent by 2025.

This target is a very ambitious proposal and needs committed resources and programming to see this local content objective being met.

The following shall be in line with the local content policy:

- i. Ownership
- ii. Engineering, procurement and construction contracts
- iii. Construction and installations works
- iv. Post construction works supplies
- v. Services
- vi. Management
- vii. Operations and maintenance staff
- viii. Operation and maintenance contract

The above requirements shall apply to all the

other renewable energy initiatives under the the Renewable Energy Master Plan (REMP).

### 2.3.3 Technical Capacity Development

A sustainable human and institutional capacity building initiative is required for the effective implementation of the development of renewables. Government shall therefore identify and collaborate with relevant training institutions and industries to develop tailor-made technical and entrepreneurial programmes for targeted groups and individuals along the entire renewable energy value chain. Focus will be placed on areas such as assembling, manufacturing and installation of RETs; design, construction and maintenance of biogas digesters, gasifiers, kilns, improved household and institutional cook stoves; and biomass briquetting and pelleting. The private sector shall be the major beneficiary of this intervention.

### 2.3.4 Research and Development

There is limited capacity and technical know-how

in renewable energy research and development (R&D) in Ghanaian universities and research institutions. In addition, funding of R&D activities has not been properly streamlined, and this has led to a lack of focus and duplication of efforts. Currently, total government budgetary support in

terms of GDP for R&D in all sectors is about 0.25 percent according to the World Bank as opposed to over 4 percent in Israel and South Korea. It is therefore imperative that sufficient financial resources are allocated to boost R&D.

Government shall provide adequate support to existing universities, research institutions and incubation centres such as the Ghana Climate Innovation Centre (GCIC), the Brew-Hammond Energy Centre, Centre for Renewable Energy and Energy Efficiency at Kumasi Technical University, Department of Energy Systems Engineering at Koforidua Technical University, Council for Scientific and Industrial Research (CSIR) etc., to deliver on their core mandates.

The key areas for R&D in the renewable energy sector would include:

- i. Existing and new materials for production of the components of RETs.
- ii. Improvement of the technical characteristics of indigenous RETs (cook stoves, kilns, inverters, controllers, etc.).
- iii. Advanced assembling and manufacturing techniques and processes for the components of RETs.
- iv. Innovations in RET solutions.
- v. Policies and socio-economic issues for effective planning and development of the renewable energy and energy efficiency (REEE) sectors.

In consultation with industry, renewable energy R&D priorities would be established and implemented in partnership with the relevant stakeholders. In this regard, efforts would be made to strengthen individual and institutional research capabilities, increase cost sharing in financing proposals, and upgrade equipment and instrumentation.

### 2.3.5 Development of Standards and Codes

Standards and technical codes are needed to

ensure that optimal benefits are derived from the utilisation of RETs. The Ghana Standards Authority (GSA) has adopted standards for solar modules, batteries, inverters, solar lanterns, liquid biofuel and selected electrical appliances, and is also in the process of completing the minimum performance requirements for biomass cook stoves.

The Energy Commission (EC) in collaboration with relevant institutions has developed technical codes for connecting renewable energy generating systems to the transmission and distribution systems. In order to keep pace with emerging trends in the sector, the GSA shall continue to update these standards. The existing laboratory for testing solar systems at the GSA must also be upgraded to provide the full range testing services for all RETs as defined in the RE Act. Standards shall also be adopted for mini-grid development in Ghana.

### 2.3.6 Financing

Limited access to long-term financing and high cost of capital are major constraints to the growth of the renewable energy sector. At the moment, local banks are unable to offer long-term lending for infrastructural projects including RE projects.

Investment and commercial banks in the country would be encouraged to develop long term financing portfolios for renewable energy projects. Having attained lower middle-income status, concessional funding facilities from development partners have dwindled. There is, therefore, the need to develop and explore innovative funding mechanisms to support renewable energy projects. Utility-scale renewable energy projects shall be supported with risk mitigation instruments (e.g. Renewable Energy Put Call Option Agreement (PCOAs), liquidity support, insurance, etc.).

## 2.4 Indicative Strategies for Renewable Energy

In line with the Renewable Energy Act, 2011 (Act 832), the Ministry of Energy and the Renewable and Alternative Energy Directorate will adopt the following strategies in order to meet the stated objectives of the Act:

i. The utilities will play key roles, especially in relation to utility scale projects. The Volta River Authority, Bui Power Authority and the proposed Renewable Energy Authority will be encouraged to grow and expand the renewable energy electricity space through public and private sector led investments.

ii. GRIDCo will drive strategic investments and expansion of the National Interconnected Transmissions System (NITS) to accelerate the interconnection of utility scale renewable energy projects.

iii. The Renewable Energy Purchase Obligation (REPO) will be implemented to ensure that the distribution companies, ECG and NEDCo and all other bulk customers integrate electricity generated from renewable resources in their distribution and consumption mix.

iv. ECG and NEDCo are to ensure that net-metered systems have access to the distribution grid, in line with the 'Net-Metering Code'.

v. Private sector investment is at the centre of the Renewable Energy Master Plan (REMP). Private sector investments toward achieving the targets in the REMP, especially, utility scale projects, will be given the utmost priority. The REMP will continue to create opportunities through the RE-FiTs, competitive procurement of RE projects and purchase obligations to increase investment in the sector.

vi. The government will give financial incentives and procurement preferences to private sector actors engaged in the local assembly and manufacturing of renewable energy technologies and related services. Manufacturing and assembling of renewable energy technologies is pivotal to the overall success of the plan, and strategic links in the renewable energy value chain would be fully implemented.

vii. The Ghana Standards Authority will be strengthened to ensure that local production of renewable energy technologies meet international standards.

## 2.5 Opportunities and Targets

For each of the RET areas (solar, wind, hydro, biomass, etc.), the opportunities and targets to promote it are presented below.

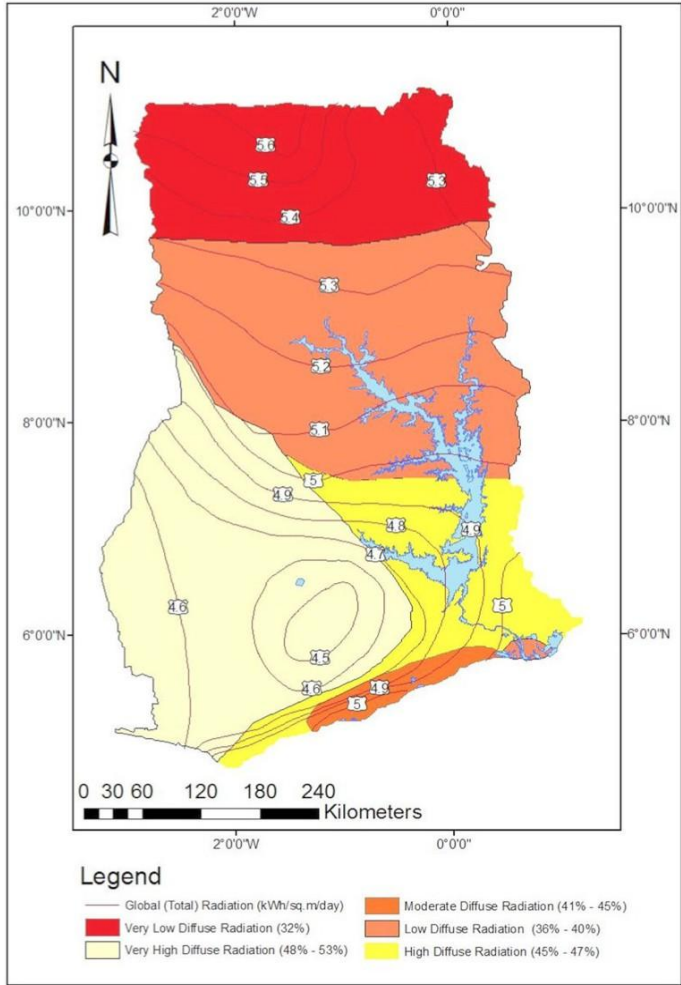
### 2.5.1 Opportunities and Targets for Solar Energy

#### Resource

Ghana's geographical location gives it good exposure to solar radiation, which is ideal for both electricity and thermal energy applications. The country's average solar irradiation ranges from 4.5–6.0 kWh/m<sup>2</sup>/day, with the highest levels of solar irradiation mostly in the northern part of the country. The annual sunshine duration ranges from 1,800–3,000 hours annually. Other information is provided below:

- Daily average sunshine duration varies from 5.3 hours in the cloudy and semi-deciduous forest zones like Kumasi in the middle-belt, to 7.7 hours in the dry and savannah zones like Wa in the northern part of the country<sup>1</sup>.
- Average solar irradiation in other parts of the country ranges between 4.4 and 5.6 kWh/m<sup>2</sup>/day with a very low diffused radiation of about 32 percent.
- Monthly average solar irradiation in different parts of the country ranges from 4.4 to 5.6 kWh/m<sup>2</sup>/day.
- Monthly average solar irradiation in the north, which includes the northern parts of Brong Ahafo and the Volta Regions is considered very high, ranging from 4.0 to 6.5 kWh/m<sup>2</sup>/day.
- Monthly average irradiation ranges from 3.1 to 5.8 kWh/m<sup>2</sup>/day in other parts of the country like Ashanti, parts of Brong Ahafo, Eastern, Western and parts of Central and Volta Regions.
- The monthly average irradiation along the coast of Greater Accra, Central and Volta Regions is moderate and ranges from 4.0 – 6.0 kWh/m<sup>2</sup>/day (Figure 2.1).

Figure 2.1: Solar Radiation Map of Ghana



Source: REMP, 2017

The targets and potentials of solar energy for the plan period are presented in Tables 2.2 and 2.3 respectively.

Figure 2.2: Sample of Solar Utility Installations



Source: Google Images

<sup>1</sup> Togobo, W.A., Investment Opportunities in the Power Sector. 2011.

## Opportunities

Several opportunities exist to develop solar energy in Ghana. These include the following:

- Increase generation capacity – through utility scale projects, mini- grids, standalone applications in street lighting, traffic controls, aviation signals, telecommunication, light electronic devices, etc.
- Demand side management (distributed generation) – integration of solar PV and solar water heaters into existing and new buildings, to reduce increasing cost of conventional power for such purpose.
- Applications in agriculture – irrigation and crop drying.
- Assembling/manufacturing – principally in the areas of solar PV modules and balance of systems, including inverters, batteries, solar water heaters etc., to service both the domestic and the fast-growing ECOWAS market.
- Reuse and recycling of e-wastes resulting from local manufacture and use of renewable energy systems.
- Increase research, development, demonstration and commercialisation of solar energy technologies.

Solar water heaters have the potential to contribute 2GWh of savings from energy demand according to research by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in 2015.

## 2.5.2 Opportunities and Targets for Hydro-Electric Power

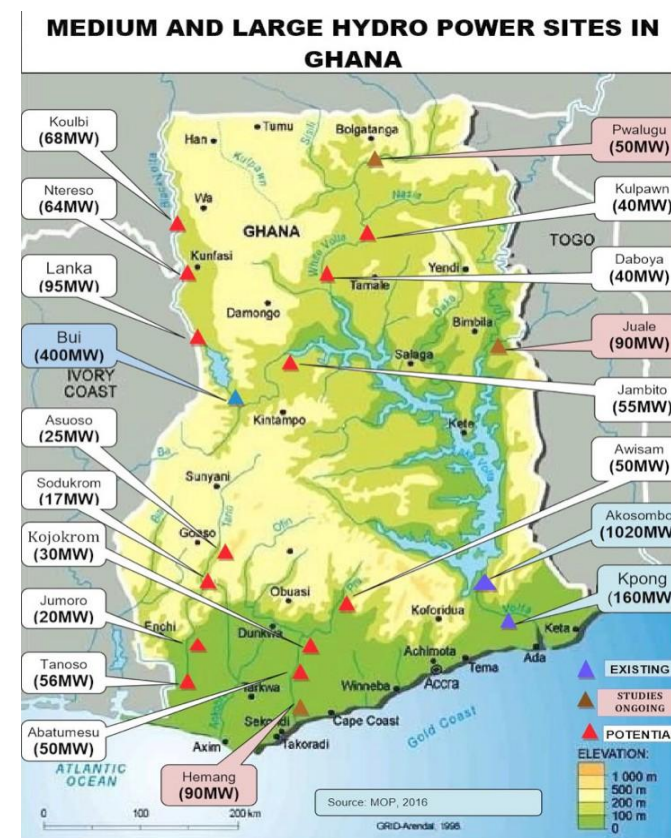
Hydro has been a dominant power source in Ghana, providing cheap power for industrial development post-independence. Currently, all of Ghana's large hydro resources have been exploited. The potential of the remaining sites fall below 100 MW capacity. These sites include Pwalugu (50 MW), Juale (90 MW) and Hemang (90 MW) among others (Figure 3.3). These sites will be developed during the plan period. The targets and potentials of energy from hydro sources for the plan period is presented in Tables 2.2 and 2.3 respectively.

## Opportunities

Opportunities for small and medium hydropower development include the following:

- Increase generation capacity using less variable hydro power
- Export power to neighbouring countries
- Develop irrigation projects as co-benefit
- Develop river transportation as co-benefit
- Create jobs
- Build capacity in small and medium hydro project management

Figure 2.3: Developed and Potential Hydro Sites



## 2.5.3 Opportunities and Targets for Wind Power

The country's wind potential is considered as marginal with average annual wind speeds of between 4m/s to 6m/s at 50m-hub height above sea level especially along the coast, east of Greenwich Meridian and on some island communities in the Volta Lake. According to NREL satellite data, wind speeds in some mountainous regions in the country especially along the Ghana–

Togo border are estimated to be above 8m/s (Figure 2.5).

An assessment of wind resource at eight sites along the coast between 2011 and 2013 indicated average monthly wind speeds at 60m elevation as capable of development of a utility scale wind

farm with a capacity of about 200–400 MW. Total wind energy resource is estimated to be more than 1500 MW. The targets and potentials of energy from wind power for the plan period are presented in Tables 2.2 and 2.3 respectively.

Figure 2.4: Offshore wind turbines



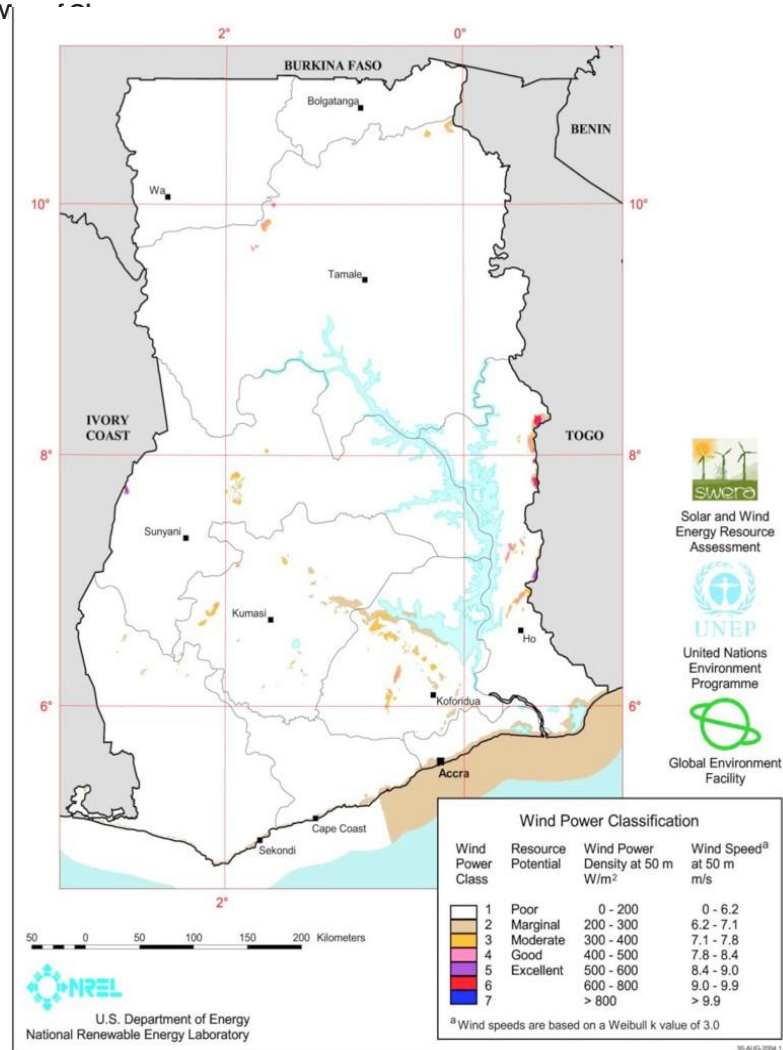
Source: Google Images

## Opportunities

The following are some opportunities for developing wind energy in Ghana:

- Increase generation capacity – like solar, utility scale wind projects and standalone systems can increase generation capacity.
- Application in irrigation – polder wind pumps requiring low operating speeds can be used for irrigation and community water provision in off-grid applications.
- Scale-up manufacturing, research and development of wind energy technologies.

Figure 2.5: Wind Resource Map



Source: REMP, 2017

## 2.5.4 Opportunities and Targets for Wave Power

Preliminary assessment has shown that waves east of the meridian are strong, indicating viable potential for tidal wave development. There is opportunity to develop tidal resources with higher capacity factor than wind and solar which would complement generation capacity. During the plan period, tidal energy will be harnessed from viable sites for power generation. The targets and potentials of wave power for the plan period are presented in Tables 2.2 and 2.3 respectively.

## 2.5.5 Opportunities and Targets for Energy from Biomass Sources

The country produces abundant energy from biomass sources such as (i) wood/plant waste materials, (ii) municipal solid waste such as tires/ landfill gas (LFG), and (iii) other biomass such as agricultural by-products, which can be utilised for the generation of electricity.

### Opportunities

Opportunities for development of energy from biomass sources include the following:

- Increase generation capacity using less variable biomass conversion technologies
- Generate onsite power for industrial use
- Reduce deforestation using dedicated woodlots

iv. Create jobs

v. Build capacity in solid biomass technologies

The targets and potentials of energy from biomass sources for the plan period is presented in Tables 2.2 and 2.3 respectively.

| Renewable Energy Technologies (RETs)                       | Reference 2015 |           | Year 2020    |            | Year 2030    |             | Year 2047    |              |
|------------------------------------------------------------|----------------|-----------|--------------|------------|--------------|-------------|--------------|--------------|
|                                                            | No. of Units   | MW        | No. of Units | MW         | No. of Units | MW          | No. of Units | MW           |
| <b>Solar Energy</b>                                        |                |           |              |            |              |             |              |              |
| Solar utility scale PV                                     | -              | 22.5      | -            | 200        | -            | 1000        | -            | 800          |
| Rooftop/net metering solar PV                              |                |           | 20,000       | 20         | 200,000      | 200         | 1,000,000    | 3,554        |
| Standalone solar PV systems                                |                |           | 7,000        | 2          | 47,000       | 14          |              | 14           |
| Solar PV street/community lighting                         |                | 4.93      | 10,000       | 7          | 40,000       | 25          |              | 25           |
| Solar PV lanterns                                          | 72,000         |           | 200,000      | 0.8        | 2,000,000    | 10          |              | 10           |
| Concentrated solar power                                   |                |           |              |            |              | 100         |              | 100          |
| Railway Corridor solar                                     |                |           |              |            |              | 700         |              | 2,000        |
| Mini-grids                                                 |                |           | 100          | 4          | 500          | 20          | 500          | 20           |
| Solar PV water pumping for irrigation and water supply     |                |           | 100          | 0.5        | 500          | 2.5         | 500          | 2.5          |
| Solar water heaters (thermal)                              | 4700           | -         | 20,000       | -          | 135,000      | -           | 135,000      | -            |
| <b>Wind Energy</b>                                         |                |           |              |            |              |             |              |              |
| Wind utility scale                                         |                |           | -            | 275        | -            | 800         | -            | 1,500        |
| Standalone wind systems (including net-metered)            |                |           | -            | 0.1        | -            | 2           | -            | -            |
| Wind irrigation/water pumping                              |                |           | 35           | -          | 100          | -           | 100          | -            |
| <b>Biomass/Waste-to-Energy</b>                             |                |           |              |            |              |             |              |              |
| Biomass utility-scale (plantations, forest residues, etc.) |                |           | -            | 75         | -            | 150         | -            | 300          |
| Waste-to-energy (utility Scale; solid & liquid)            |                | 0.8       | -            | 12         | -            | 12          | -            | 12           |
| Agricultural/industrial organic waste (biogas)             | <20            | -         | 30           | -          | 200          | -           |              | -            |
| Institutional (biogas)                                     | <100           | -         | 180          | -          | 400          | -           |              | 50           |
| Domestic (biogas)                                          | <50            | -         | 80           | -          | 200          | -           |              | -            |
| Landfill                                                   | 1              | 2         | 3            | 6          | 10           | 20          |              | 150          |
| <b>Hydropower/Wave Power</b>                               |                |           |              |            |              |             |              |              |
| Medium hydropower                                          |                |           | -            | 100        | -            | 300         | -            | 300          |
| Small hydropower                                           |                |           | -            | 1          | -            | 10          | -            | 200          |
| Wave power                                                 |                |           | -            | 10         | -            | 100         | -            | 200          |
| <b>Total RE Installed Capacity (Electricity)</b>           |                | <b>30</b> |              | <b>713</b> |              | <b>3773</b> |              | <b>9,000</b> |

Source: REMP 2007, updated by GIP Team

## 2.6 Economic, Social and Environmental Impacts

### 2.6.1 Economic Impacts

The total investment required for implementing renewable energy development is estimated at US\$ 20 billion over the 30-year period, which translates to an annual average cost of about US\$ 0.7 billion. Effective implementation of the REMP is expected to create about 370,000 jobs along the value chains of the various interventions to ensure the following:

- Boost industrialisation in areas such as manufacturing, assembling, etc.
- Contribute to national energy security.
- Increased productivity in sectors such as agriculture and small scale industries.
- Increase in foreign exchange earnings and improved balance of trade.
- Enhance security and improve quality of life of rural and urban people using indigenous resources.
- Improved public service delivery particularly in the areas of health and education.
- Reduction in household air pollution.
- Creation of a sustainable market for RETs.
- Improved regulatory and fiscal regime to facilitate ease of doing business in the RE sector.
- Increased renewable energy penetration.
- Increased access to modern energy services for un-served and underserved communities.
- Increased energy efficiency (co-benefit – economic and environmental).
- Increased human capacity in the RE sector.
- R&D enhanced to spur innovation, adaptation and localisation of RE technologies.

Other identified benefits include:

- Compost and biochar for the agriculture sector.
- Inputs for the production of organic cosmetics.
- Improved soil fertility and bio-diversity for well-developed woodlot plantation.
- Activated charcoal for the mining sector.
- Tar, as a by-product from improved charcoal production for construction sector.
- Successful implementation of the REMP will serve as a learning curve towards improving activities in other sectors of the economy.
- Improved socio-economic status of women through increased use of modern energy.

### 2.6.2 Environmental Impacts

The success of promoting renewables will lead to significant reductions in carbon dioxide emissions and contribute to the reduction of Ghana's carbon footprint.

#### Land Use

Renewable energy technologies such as utility scale solar and wind, and plantation based schemes, require an appreciable land mass for development with its attendant effect on other land uses. For instance, the land requirement for solar PV installations ranges from 3.5 to 8 acres per MW. Unlike wind facilities, there is less opportunity for solar projects to share land with other economic uses such as agriculture. Through spatial planning, the impacts of utility-scale renewable energy systems could be minimised by siting them at locations where there is less competition for land use, for example degraded lands, abandoned mining sites, transportation and transmission corridors, etc.

The use of roof space in commercial, industrial, public and private facilities for solar installations would be strongly encouraged and promoted.

Economic and multipurpose energy crops and tree species for electricity generation and liquid biofuels would be promoted for optimal land use. Further gains envisaged are listed below:

- Reduction of adverse climate change effects
- Increased forest cover as a result of afforestation and reforestation
- Boost in eco-tourism

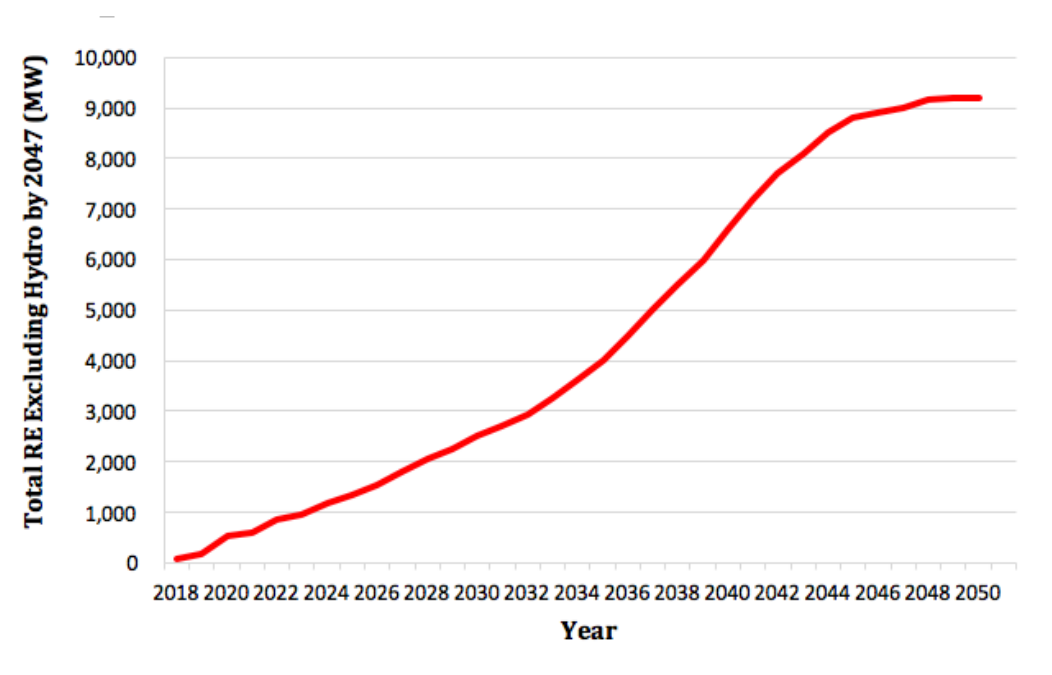
Due to the site-specific nature of wind resources, urgent measures would need to be taken to secure the potential areas where the resource abounds for development. This is to avoid losing such sites, particularly areas along the coastal belts to other competing needs. Several models would be deployed, such as land acquisition through executive instruments or contribution of land as equity by owners in the development of renewable energy projects.

Table 2.3: Renewable Energy Potential 2047

|                     |                 |
|---------------------|-----------------|
| Utility Scale Solar | 800 MW          |
| Rooftop Solar       | 3,554 MW        |
| Conc. Solar Power   | 100 MW          |
| Railway Solar       | 2,000 MW        |
| Wind                | 1,500 MW        |
| Wave                | 200 MW          |
| Small Hydro         | 446 MW          |
| Biomass             | 300 MW          |
| Biogas              | 200 MW          |
| <b>Total</b>        | <b>9,000 MW</b> |

Source: REMP, 2017 and updated by GIP Team

Figure 2.6: Renewable Energy Cumulative Installed Capacity (MW)



Source: GIP Team, 2017

Other recommendations with regards to biofuel are:

- i. Grasslands that are not used for grazing or food production should be demarcated and used to produce solid and liquid biofuels.
- ii. A biofuels plant should be strategically located in Buipe, for transport and delivery of biomass residues via road and railway as well as inland water transport. A plant located in Buipe could receive wood and crop residues from all northern regions and Brong Ahafo, and receive solid waste from Tamale and environs.
- iii. Develop other biofuel energy plants in Accra and Kumasi based on the thousands of tons of solid waste produced daily. To ensure sufficient delivery of solid waste, a shared energy generating plant could be located between Kumasi and Accra along a new railway line connecting to solid waste collection points in Kumasi and Accra located along the urban railway line.

### **Hazardous Materials**

Some materials used in the manufacturing process for solar PV cells could be hazardous. For example, industrial chemicals such as hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone are used to clean and purify the semiconductor surfaces. The indiscriminate disposal of batteries could result in serious environmental and public health perils.

As the country industrialises, the volume of these waste materials would increase significantly and therefore would require an improved and aggressive approach to handling and managing their disposal. This could present economic opportunities particularly in the areas of reuse and recycling. In this regard, the renewable fund should support the expansion of the existing e-waste disposal and recycling plants in the country and the construction of new ones in strategic locations to convert the voluminous waste into usable materials and see to its proper disposal where required.



# Chapter 3 Nuclear Energy

## 3.1 Introduction

The lofty economic development aspiration in Ghana's forty-year development plan definitely infers a steep and sustained growth in energy demand. Experiences regarding shortages in Ghana's power supply sector have shown that it is necessary for the nation to explore other energy sources, in addition to oil and gas, to assure national energy security. In this connection, nuclear power has been identified as an alternative energy source that can generate high capacity base load electricity at an affordable price and enhance energy security. Since the time of independence, the nation has had a vision for peaceful application of nuclear technology in various fields including power generation.

By the turn of the millennium, the country's ambition to achieve and maintain middle-income status was threatened by a series of recurring national electric power crises. As a result, the sector ministry charged with the vision to ensure energy accessibility, security and economy and enhance national development formulated the strategic national energy plan and the energy policy. Experiences in the industrialised economies as well as emerging economies attest to the fact that without sustainable, secure and affordable base load electricity supply, national development is likely not to be realised.

### 3.1.1 History of Nuclear Technology in Ghana

Ghana's quest to utilise nuclear energy for electricity generation dates back to the early 1960s when Ghana's first reactor project, involving the construction of a 2 MW Soviet reactor, was launched in 1963.

The Ghana Atomic Energy Commission (GAEC) was therefore established in the same year to lead this initiative. The nuclear project did not proceed as expected due mainly to political factors. The reactor project was abandoned as a result of the 1966 coup d'etat which ousted the then Nkrumah regime. Even though efforts were made in the succeeding years to revive the project, political interferences put it on a hold. The reactor project however came to fruition in 1995 when the GAEC commissioned the nation's first research reactor, a 30kW reactor built by the Chinese. It was meant among other things to train the necessary manpower and prepare the nation towards any future nuclear power project.

In an effort to promote nuclear knowledge and technology, the GAEC and the University of Ghana with support from the International Atomic Energy Agency (IAEA) established the School of Nuclear and Allied Sciences in 2006.

The nuclear option gained attention during the 2006/2007 energy crisis when a Presidential Commission was set up to consider its viability for power generation in the country. Following the presidential commission's report, cabinet took a decision in 2008 to include nuclear energy and to develop a roadmap for its introduction in the national energy mix. Subsequently nuclear energy was included in the national energy policy and strategy in 2010. The government of Ghana declared its intention to pursue a nuclear power programme for peaceful purposes through a letter submitted to the International Atomic Energy Agency in 2012. The Ghana Nuclear Power Programme Organisation (GNPPO) was then established to see to the planning and implementation of the programme and the development of the necessary nuclear infrastructure in line with International Atomic Energy Agency (IAEA) recommendations, for the successful introduction of nuclear energy into the energy mix. Currently, the GNPPO is under the Ministry of Energy.

In order to accelerate the development of the necessary nuclear infrastructure, the Ghana Atomic Energy Commission acting on behalf of the government of Ghana and the GNPPO, established the Nuclear Power Institute (NPI) to provide technical support to the GNPPO. The NPI has been working to promote the cause of the development of the required nuclear infrastructure for Ghana's nuclear power programme. In addition, Ghana has established an independent Nuclear Regulatory Authority to ensure an effective regulatory regime with respect to nuclear safety, security and safeguards.

The Regulatory Authority has the mandate of regulating all activities associated with the handling and utilisation of all radioactive and ionising radiation sources in Ghana. The country is following the infrastructural milestone approach provided by the IAEA which includes 19 infrastructure issues including, safety, security, national position, management, human resource development, stakeholder involvement, funding &

financing, regulatory issues, legal issues, etc. At

the current pace of progress, it is expected that nuclear power will be introduced in the energy mix for the first time by 2029.

## 3.2 Nuclear Power Outlook

Nuclear power plants (NPPs) generate electricity by splitting heavy atoms such as uranium through a nuclear fission process in a reactor to produce heat. The heat energy so produced is used to boil water to generate steam, which drives a turbine coupled to a generator to generate electricity (Figure 3.1)<sup>1</sup>. Alternatively, gas instead of water may be heated to drive the turbine for electricity generation.

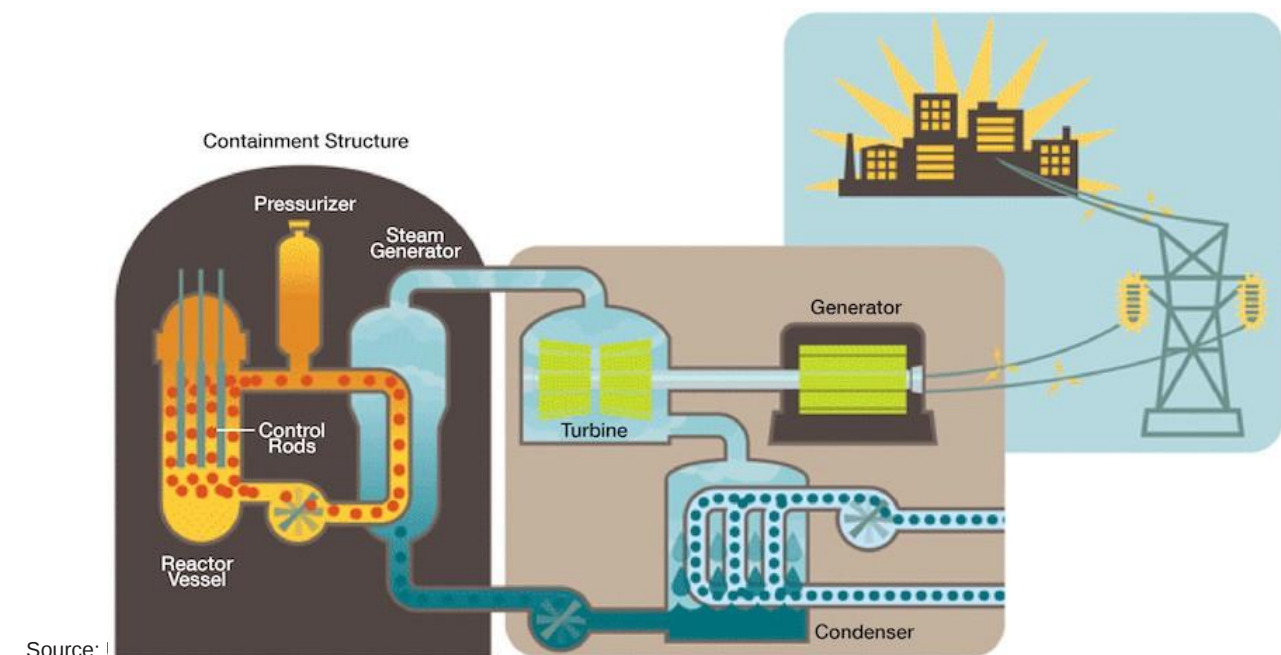
Nuclear power is a clean, safe, reliable and competitive energy source. It is the only source of energy that can replace a significant part of the fossil fuels (coal, oil and gas), which massively pollute the atmosphere and contribute to the greenhouse effect. Nuclear power is a proven technology and it currently accounts for about 12 percent of global electricity generation<sup>2</sup>. Currently 448 reactors are in operation in 33 countries with 58 under construction in 14 countries (Table 3.1)<sup>2</sup>.

Nuclear power has high energy security mainly due to the low fuel requirement as a result of the high energy density of nuclear fuel.

A kilogram of nuclear fuel for example can generate 50,000 kWh of electricity whereas firewood, coal and crude oil can generate 1 kWh, 3kWh and 4 kWh respectively<sup>3</sup>. This low fuel requirement can also reduce significantly, the risks associated with fuel supply and price instability.

In China, 20 reactors with capacity 22,596 MW are under construction with additional nuclear capacity of 46,850 MW planned and 156,000 MW proposed (Table 3.1). In the case of India, 5 reactors with capacity 3,300 MW are under construction with additional nuclear capacity of 18,600 MW planned and 51,000 MW proposed. About 45 countries, most of which are the emerging economies have expressed interest in the nuclear power option<sup>4</sup>. This includes the United Arab Emirates where 4 reactors with a total capacity of 5,600 MW are already under construction, Saudi Arabia, Turkey, Vietnam, Indonesia, Belarus, Kenya, Nigeria, Ghana, Morocco, Egypt, Uganda, Sudan Algeria, Niger, etc.

Figure 3.1: Schematic diagram of a nuclear power plant



Source: I

1 US Nuclear Regulatory Commission <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html> 2 World Nuclear Association, World Nuclear Power Reactors and Uranium Requirements, <http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requirements.aspx>

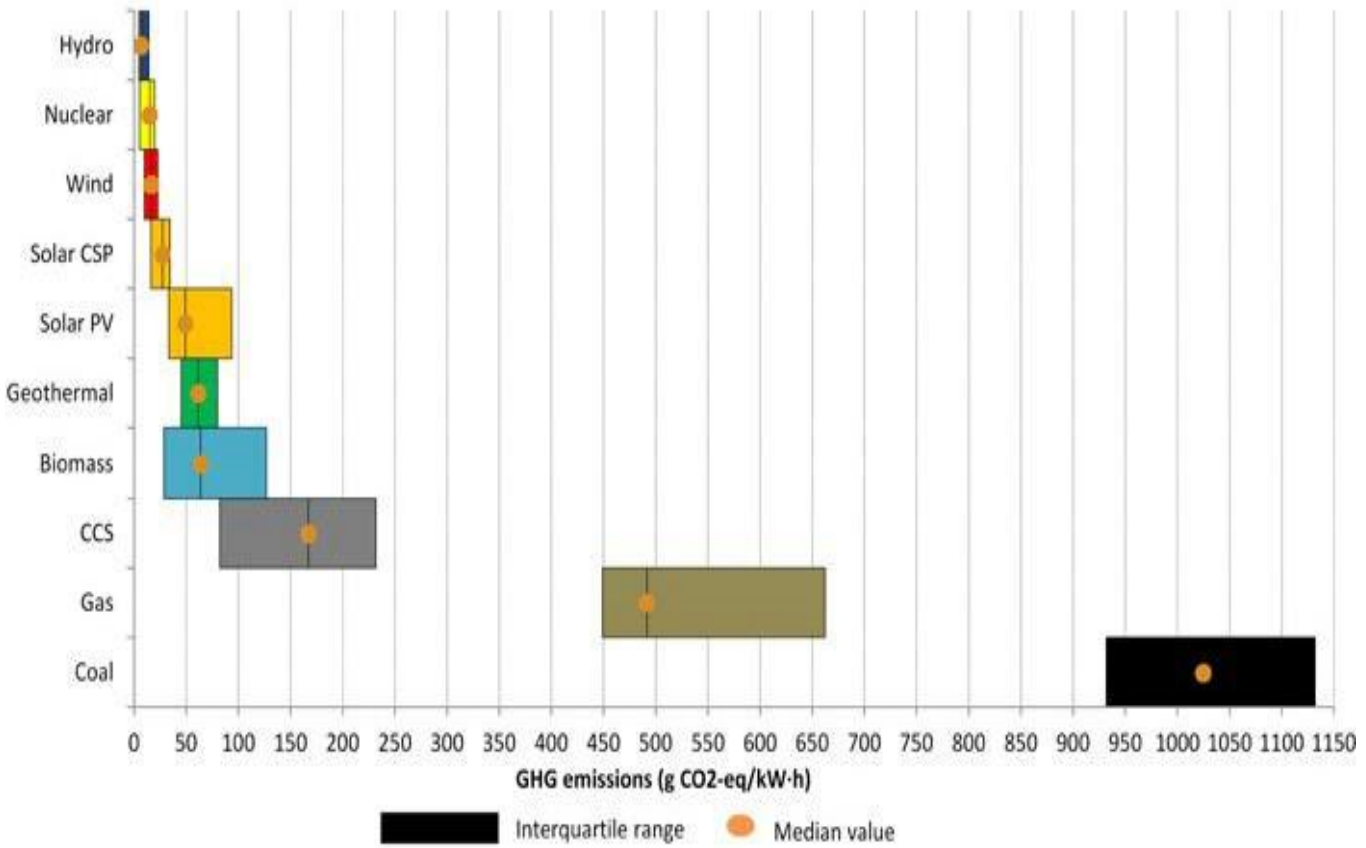
3 International Atomic Energy Agency, Sustainable Development and Nuclear Power, 1997, p 32. 4 World Nuclear Organisation, Emerging Nuclear Energy Countries <http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx>

3.2.1 Nuclear Power Advantages

Health and Environment Impact

Nuclear power is a relatively clean source of power emitting no greenhouse gases and gaseous pollutants at the plant operation level. It is also a major contributor to climate change mitigation. Currently the use of nuclear power instead of coal saves the world from an emission of about 2 billion tonnes of CO<sub>2</sub> annually<sup>5</sup>. With respect to gas, about half of the above value is saved. Studies have shown that the life cycle CO<sub>2</sub> emission of nuclear power is low in comparison with other options (Figure 3.2)<sup>6</sup>. Life cycle CO<sub>2</sub> emission of an energy option is its cradle-to-grave CO<sub>2</sub> emission and deals with the amount of emission during fuel extraction, plant construction, plant operation and plant decommission.

Figure 3.2: Life cycle CO2 emission of various energy options



Source: IAEA

\*Note. CCS = Carbon capture and storage, NGCC= Natural gas combined cycle.

5 World Nuclear Association, Green House Gas Emissions Avoided by Using Nuclear Power <http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx>  
6 International Atomic Energy Agency, Nuclear Power and Climate Change, 2016, p 19 <http://www-pub.iaea.org/MTCD/Publications/PDF/CCANP16web-86692468.pdf>

Figure 3.3: Nuclear Power Plants



Source: Google Images

Table 3.1: World Nuclear Power Plants

| COUNTRY           | Nuclear Electricity Generation |      | Reactors Operable |         | Reactors Under Construction |           | Reactors Planned |           | Reactors Proposed |           | Uranium Required<br>Tonnes U |
|-------------------|--------------------------------|------|-------------------|---------|-----------------------------|-----------|------------------|-----------|-------------------|-----------|------------------------------|
|                   | billion kWh                    | % e  | No.               | MWe net | No.                         | MWe gross | No.              | MWe gross | No.               | MWe gross |                              |
| Argentina         | 6.5                            | 4.8  | 3                 | 1627    | 1                           | 27        | 2                | 1950      | 2                 | 1300      | 215                          |
| Armenia           | 2.6                            | 34.5 | 1                 | 376     | 0                           | 0         | 1                | 1060      |                   |           | 88                           |
| Bangladesh        | 0                              | 0    | 0                 | 0       | 0                           | 0         | 2                | 2400      | 0                 | 0         | -                            |
| Belarus           | 0                              | 0    | 0                 | 0       | 2                           | 2388      | 0                | 0         | 2                 | 2400      | -                            |
| Belgium           | 24.8                           | 37.5 | 7                 | 5943    | 0                           | 0         | 0                | 0         | 0                 | 0         | 1,015                        |
| Brazil            | 13.9                           | 2.8  | 2                 | 1901    | 1                           | 1405      | 0                | 0         | 4                 | 4000      | 329                          |
| Bulgaria          | 14.7                           | 31.3 | 2                 | 1926    | 0                           | 0         | 1                | 950       | 0                 | 0         | 327                          |
| Canada            | 95.6                           | 16.6 | 19                | 13553   | 0                           | 0         | 2                | 1500      | 3                 | 3800      | 1,630                        |
| Chile             | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 4                 | 4400      | -                            |
| China             | 161.2                          | 3.0  | 35                | 31617   | 20                          | 22596     | 41               | 46850     | 136               | 156000    | 5,338                        |
| Czech Republic    | 25.3                           | 32.5 | 6                 | 3904    | 0                           | 0         | 2                | 2400      | 1                 | 1200      | 565                          |
| Egypt             | 0                              | 0    | 0                 | 0       | 0                           | 0         | 2                | 2400      | 2                 | 2400      | -                            |
| Finland           | 22.3                           | 33.7 | 4                 | 2741    | 1                           | 1700      | 1                | 1200      | 1                 | 1500      | 1,126                        |
| France            | 419.0                          | 76.3 | 58                | 63130   | 1                           | 1750      | 0                | 0         | 1                 | 1750      | 9,211                        |
| Germany           | 86.8                           | 14.1 | 8                 | 10728   | 0                           | 0         | 0                | 0         | 0                 | 0         | 1,689                        |
| Hungary           | 15.0                           | 52.7 | 4                 | 1889    | 0                           | 0         | 2                | 2400      | 0                 | 0         | 356                          |
| India             | 34.6                           | 3.5  | 22                | 6219    | 5                           | 3300      | 20               | 18600     | 44                | 51000     | 997                          |
| Indonesia         | 0                              | 0    | 0                 | 0       | 0                           | 0         | 1                | 30        | 4                 | 4000      | -                            |
| Iran              | 3.2                            | 1.3  | 1                 | 915     | 0                           | 0         | 2                | 2000      | 7                 | 6300      | 178                          |
| Israel            | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 1                 | 1200      | -                            |
| Italy             | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 0                 | 0         | -                            |
| Japan             | 4.3                            | 0.5  | 43                | 40480   | 3                           | 3036      | 9                | 12947     | 3                 | 4145      | 680                          |
| Jordan            | 0                              | 0    | 0                 | 0       | 0                           | 0         | 2                | 2000      |                   |           | -                            |
| Kazakhstan        | 0                              | 0    | 0                 | 0       | 0                           | 0         | 2                | 600       | 2                 | 600       | -                            |
| Korea DPR (North) | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 1                 | 950       | -                            |
| Korea RO (South)  | 157.2                          | 31.7 | 25                | 23017   | 3                           | 4200      | 8                | 11600     | 0                 | 0         | 5,018                        |
| Lithuania         | 0                              | 0    | 0                 | 0       | 0                           | 0         | 1                | 1350      | 0                 | 0         | -                            |
| Malaysia          | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 2                 | 2000      | -                            |
| Mexico            | 11.2                           | 6.8  | 2                 | 1600    | 0                           | 0         | 0                | 0         | 2                 | 2000      | 282                          |
| Netherlands       | 3.9                            | 3.7  | 1                 | 485     | 0                           | 0         | 0                | 0         | 1                 | 1000      | 102                          |
| Pakistan          | 4.3                            | 4.4  | 4                 | 1040    | 2                           | 1501      | 1                | 1161      | 0                 | 0         | 270                          |
| Poland            | 0                              | 0    | 0                 | 0       | 0                           | 0         | 6                | 6000      | 0                 | 0         | -                            |
| Romania           | 10.7                           | 17.3 | 2                 | 1310    | 0                           | 0         | 2                | 1440      | 1                 | 655       | 179                          |
| Russia            | 182.8                          | 18.6 | 36                | 27167   | 7                           | 5904      | 25               | 27755     | 23                | 22800     | 6,264                        |
| Saudi Arabia      | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 16                | 17000     | -                            |
| Slovakia          | 14.1                           | 55.9 | 4                 | 1816    | 2                           | 942       | 0                | 0         | 1                 | 1200      | 917                          |
| Slovenia          | 5.4                            | 38.0 | 1                 | 696     | 0                           | 0         | 0                | 0         | 1                 | 1000      | 137                          |
| South Africa      | 11.0                           | 4.7  | 2                 | 1830    | 0                           | 0         | 0                | 0         | 8                 | 9600      | 304                          |
| Spain             | 54.8                           | 20.3 | 7                 | 7121    | 0                           | 0         | 0                | 0         | 0                 | 0         | 1,271                        |
| Sweden            | 54.5                           | 34.3 | 9                 | 8849    | 0                           | 0         | 0                | 0         | 0                 | 0         | 1,471                        |
| Switzerland       | 22.2                           | 33.5 | 5                 | 3333    | 0                           | 0         | 0                | 0         | 3                 | 4000      | 521                          |
| Thailand          | 0                              | 0    | 0                 | 0       | 0                           | 0         | 0                | 0         | 5                 | 5000      | -                            |
| Turkey            | 0                              | 0    | 0                 | 0       | 0                           | 0         | 4                | 4800      | 4                 | 4500      | -                            |

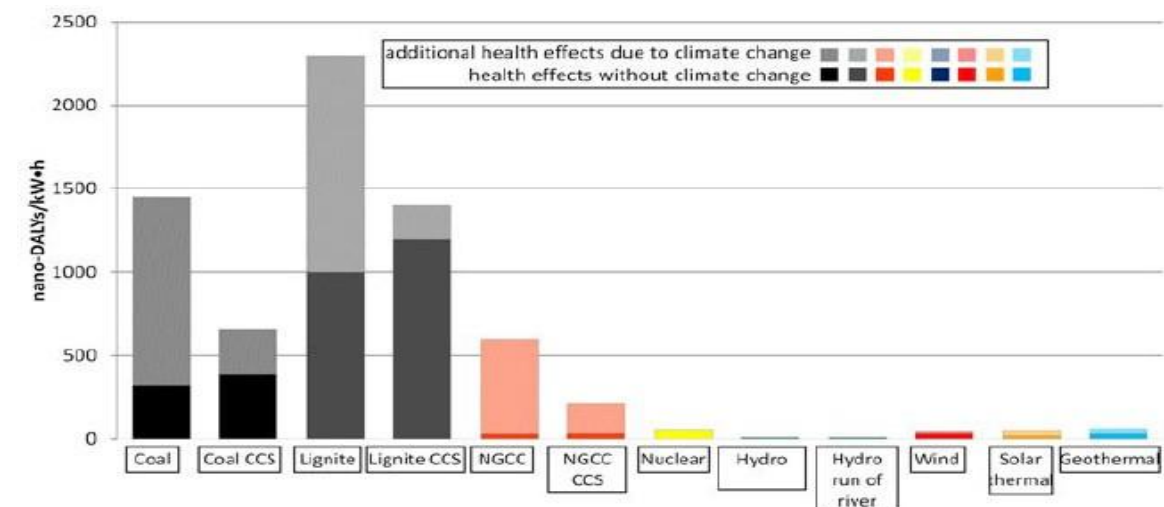
|                |       |      |     |         |    |        |     |         |     |         |        |
|----------------|-------|------|-----|---------|----|--------|-----|---------|-----|---------|--------|
| Ukraine        | 82.4  | 56.5 | 15  | 13107   | 0  | 0      | 2   | 1900    | 11  | 12000   | 2,251  |
| UAE            | 0     | 0    | 0   | 0       | 4  | 5600   | 0   | 0       | 10  | 14400   | -      |
| United Kingdom | 63.9  | 18.9 | 15  | 8883    | 0  | 0      | 4   | 6100    | 9   | 11800   | 1,734  |
| USA            | 798.0 | 19.5 | 99  | 99535   | 4  | 5000   | 18  | 8312    | 24  | 26000   | 18,161 |
| Vietnam        | 0     | 0    | 0   | 0       | 0  | 0      | 4   | 4800    | 6   | 6700    | -      |
| WORLD          | 2,441 | 11.5 | 448 | 391,665 | 58 | 62,049 | 167 | 174,505 | 345 | 388,600 | 63,404 |

Source: World Nuclear Association

\*Note. Operable = First concrete for reactor poured, or major refurbishment underway.  
Under Construction = Approvals, funding or commitment in place, mostly expected in operation within 8-10 years. Proposed = Specific programme or site proposals, timing of start of operation very uncertain.

This assessment is based on the fact that all the energy technologies depend on fossil fuel systems in a way or the other. During fuel extraction and transportation of plant material, a fossil fuelled plant or equipment may be used. Another study conducted by the Paul Scherrer Institute in Switzerland indicates low health effect of nuclear power in comparison with some options; also published by the International Atomic Energy Agency (IAEA)<sup>7</sup> (Figure 3.4). The study considers years of life lost by an individual due to premature death as well as years of disability, which is measured in DALYs. It also accounts for health effects due to climate change.

Figure 3.4: Health effects of power options including that due to climate change (top bars)



Source: IAEA

\*Note. CCS = Carbon capture and storage, NGCC= Natural gas combined cycle.

### Economics of Nuclear Power

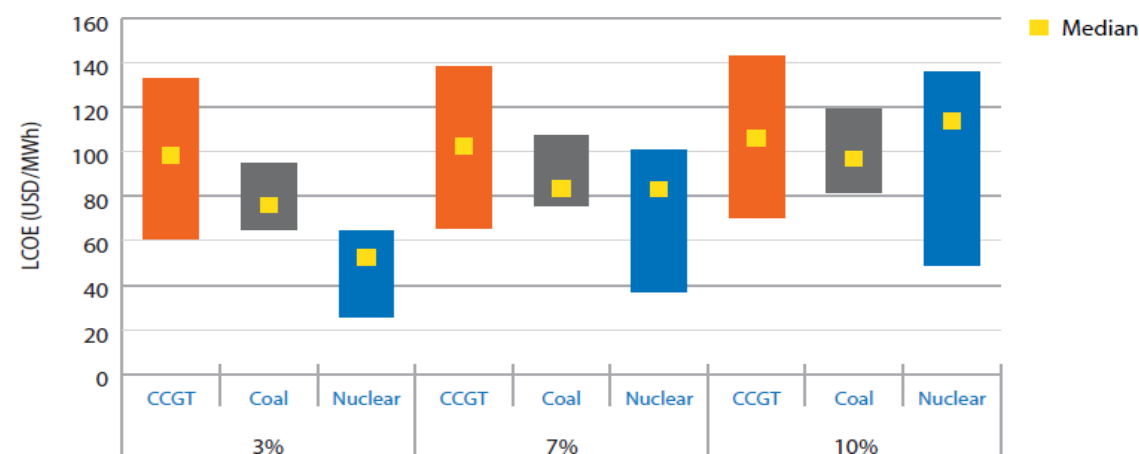
Even though the capital cost of a nuclear power plant is relatively high, the low cost of nuclear fuel and the relatively long lifetime (about 60 years) make nuclear power economically competitive than thermal power plants in the long run. Nuclear fuel constitutes about 14% of the entire electricity generation cost compared to 89% in gas and 78% in coal<sup>8</sup>. This makes nuclear power systems insensitive to fuel price volatility.

The levelised cost of electricity generation of coal, gas and nuclear plants based on a recent study conducted by the International Energy Agency (IEA) is presented in Figure 3.5. The study indicates the cost competitiveness of nuclear power over the other energy options, particularly at low discount rates.

<sup>7</sup> International Atomic Energy Agency, Nuclear Power and Climate Change, 2016, p 55 <http://www-pub.iaea.org/MTCD/Publications/PDF/CCANP16web-86692468.pdf>

<sup>8</sup> International Energy Agency, Projected Cost of Generating Electricity, Paris 2015, p 14

Figure 3.5: Electricity generation cost of nuclear, gas and coal plants at 3%, 7% and 10% discount rates



Source: International Energy Agency (IEA)

The Need for Nuclear Energy

It should be noted that government’s agenda of transforming the economy through industrialisation, cannot be achieved without sufficiently available cost-effective electricity in the country. An example is the Ghana Industrial Development Initiative (GIDI)<sup>9</sup> Project being promoted by the Ghana Infrastructure Investment Fund (GIIF)<sup>10</sup> that seeks to develop a full-cycle alumina project in the country.

Traditionally, Ghana has relied on hydroelectric power and oil/gas thermal power plants as the components of the country’s energy mix. Recently, renewable energy, mainly in the form of solar and wind energy have been proposed. It is well understood that renewable energy does not provide the needed base load energy option for any country. Examining alternative sources of power capable of generating high capacity base load like coal and nuclear energy in the country’s energy mix to ensure reliable power supply and emission cuts is therefore considered important, if Ghana is to be energy-sufficient in the future.

Nuclear power is economically competitive over other energy sources for countries that have little or no indigenous fossil fuel reserves and has enhanced the energy security and energy diversity of countries in this category. This is so for countries like France, Japan, South Korea, etc. This is due to the fact that nuclear power plants require low fuel supply and also the fuel can be stockpiled for some years. This can therefore reduce significantly, the risks associated with fuel supply and price instability.

3.2.2 Issues Affecting Nuclear Power Utilisation

Despite its advantages with regards to cost, energy security and environmental impacts, concerns about nuclear plant safety, waste management and weapons proliferation have affected its expansion in some countries. Concerns about nuclear safety heightened in many countries as a result of the Chernobyl accident which took place in Ukraine in the former Soviet Union in April 1986 and the recent Fukushima accident which took place in Japan in March 2011. In addition, the Three Mile Island (TMI) accident in the US in March 1979 brought nuclear expansion in the US to a virtual halt.

Box 1: Chernobyl accident

The Chernobyl accident occurred when the reactor was subjected to abnormal operational conditions during an experimental run, leading to an extreme power rise far above the designed power limit. This caused a steam explosion, rupture of the reactor vessel and the release of large amounts of radioactive substances into the environment. Post-accident investigations indicated that design flaws, relating to reactor stability, reactor shutdown and control systems led to the accident. Worst of it all, the reactor had no containment structure over it to prevent the release of radioactive substances in case of an accident<sup>11</sup>.

Considering the significant difference between the Chernobyl reactor that was of out-dated Soviet design and that of the Western type of reactors, it can be concluded that the severity of the Chernobyl accident is unique to the type of reactor in question<sup>12</sup>, . Since that accident, the Chernobyl type of reactors has been phased out. Also, the few existing ones have been retrofitted to improve their safety. Russia has also come out with new designs with improved safety features, conforming to Western standards. The accident claimed 31 fatalities that were plant workers (most of them were the fire fighters) within the first months<sup>13</sup>.

In 2005, almost two decades after the accident, the estimated number of radiation related deaths had increased to almost 50.

Box 2: Fukushima accident

The Fukushima accident was caused by destruction of the emergency power supply and reactor cooling systems by a tsunami, which flooded the reactor site after a severe earthquake. The earthquake shook the Eastern part of Japan including the Fukushima Daichi plant site where 6 nuclear power plants were located with 3 of them in operation. In response to the earthquake, all the reactors shut down automatically and were all physically and mechanically intact. There was however loss of grid power to the plants because the earthquake destroyed the grid network.

As a result of this, the reactors had to depend on emergency generators for cooling of the reactor core<sup>14</sup>. Cooling of reactors after shutdown is very essential because reactor cores heat up as a result of radioactive decay. About 45 minutes after the earthquake, a 15 m tsunami wave, triggered by the earthquake, swept through the site. Being higher than the 5.7m sea defence wall of the plant site, it completely inundated the site destroying the emergency power supply and cooling systems. This led to the cores of the 3 operating reactors overheating, resulting in their partial meltdown.

The venting of gas by the operators to prevent pressure build up in the reactor facilities as well as the discharge of contaminated coolant water into the sea, caused the released of radioactive substances into the environment. To date no fatalities have occurred as a result of the accident. According to post-accident investigations, the amount of radiation received by the emergency workers and the public is too low to cause any discernible increase in radiation related health effects to the members of the public and their descendants<sup>15</sup>.

<sup>9</sup> GIDI, Ghana Infrastructure Development Initiative Information Document, Ghana Infrastructure Investment Fund, December 2015.  
<sup>10</sup> Government of Ghana, Ghana Infrastructure Investment Fund Act, Act (877) 2014, Ghana.

<sup>11</sup> World Nuclear Association, Chernobyl Accident  
<sup>12</sup> Hirschberg, S. and Srupsczewski, A., Comparison of Accident Risks in Different Energy Systems-How Acceptable? IAEA Bulletin Vol. 41-1 March 1999, pp  
<sup>13</sup> <https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull41-1/41102782530.pdf>.  
<sup>14</sup> World Nuclear Association Fukushima Accident <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-accident.aspx>  
<sup>15</sup> United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), A 68/64, p11, UN New York, 2013. [http://www.unscear.org/docs/GAreports/A-68-46\\_e\\_V1385727.pdf](http://www.unscear.org/docs/GAreports/A-68-46_e_V1385727.pdf)

### Box 3: The Three - Mile Island accident

In the case of the Three - Mile Island accident, malfunctioning of certain components of the reactor cooling system and miscommunication of the instrumentation system, caused the operators of the reactor to take actions which led to loss of coolant. This resulted in the partial melting of the reactor core<sup>16</sup>.

There were no fatalities in the TMI accident because no radioactive substances were released into the environment. This is due to the presence of a containment structure (Figure 4.6) over the reactor, which by design, is to prevent the release of radioactive substances into the environment in case of an accident.

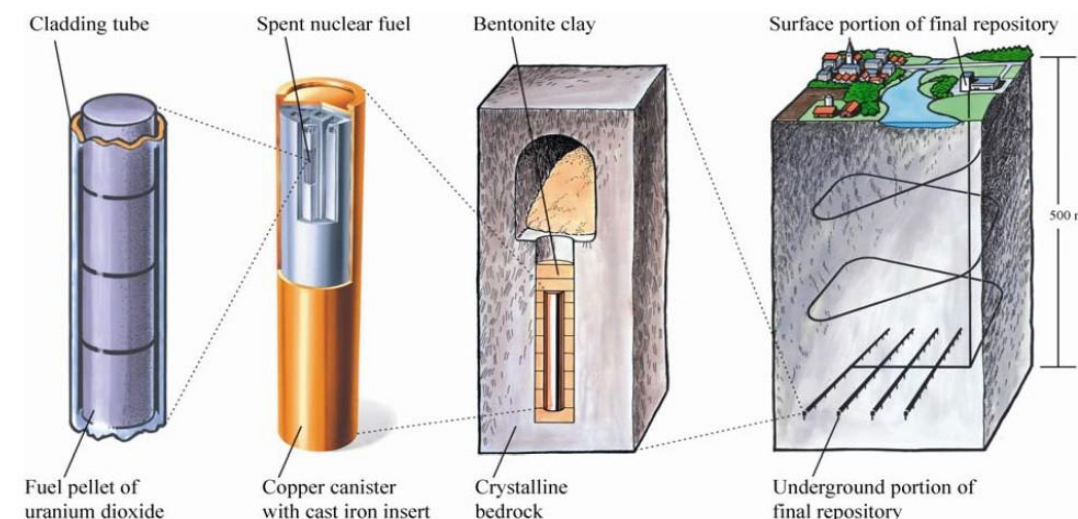
In addition, the containment structure is designed to withstand the crash of heavy objects including large aircraft.

It is worth noting that all the reactors in the 3 major accidents were not of modern design. They were designed in the 1960s and therefore susceptible to the kind of accidents which occurred. On the contrary, modern reactors have improved safety features. These include passive cooling and passive control systems which employ the force of gravity for control during emergencies as well as natural convection for coolant flow, instead of active systems like pumps, motors, human intervention.

### Disposal of Nuclear Waste

In addition to nuclear power plant safety, disposal of nuclear waste is a major public concern. Managing nuclear waste is less of a problem because the quantities of waste involved are remarkably small relative to the energy produced. The small quantities permit a “confinement” strategy for the radioactive material, beginning with the nuclear fission process and through to waste disposal, essentially isolated from the environment. Disposal techniques exist and the hazard decreases with time owing to radioactive decay. The main disposal options are engineered structures, mined cavities, and deep geological repositories (Figure 3.6)<sup>17</sup>. However, disposal is blocked not by technical, but by political obstacles as a result of the “Not in my backyard” (NIMBY) syndrome. The public concern about nuclear waste should therefore be addressed through education.

Figure 3.6: Nuclear Waste Disposal Concept



Source: GAEC

<sup>16</sup> US Nuclear Regulatory Commission, Background on the Three Mile Accident. <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html>

<sup>17</sup> International Atomic Energy Agency, Nuclear Power and Sustainable Development, 2006, p. 18.

### Proliferation of nuclear weapons

Proliferation of nuclear weapons is another public concern to be addressed when going in for the nuclear option. The major proliferation concern is risk associated with the fuel cycle, particularly fuel enrichment, fabrication and reprocessing, in which a part of the nuclear material may be diverted to, or stolen for non-peaceful uses. The US ATOMS FOR PEACE policy announced in 1953 promoted a policy of international nuclear co-operation based on the condition that nuclear technology transfer would be used exclusively for peaceful purposes. The 1970 Treaty on Non-Proliferation of Nuclear Weapons or NPT also binds signatory countries from engaging in nuclear weapon manufacture and deployment activities. The IAEA has also introduced binding safeguards protocols, which involve on-site inspections of nuclear facilities. Ghana is a signatory to the Non-Proliferation Treaty and IAEA safeguard protocols.

Ghana's nuclear power programme may not involve fuel enrichment and fabrication of uranium or the reprocessing of spent fuel. It is possible to seek reliable fuel supply and reprocessing arrangements through bilateral or international agreements, such as the Global Nuclear Energy Partnership (GNEP) or as part of contractual arrangements with the vendor country. It is worth noting that similar arrangement was made for the supply of fresh fuel and the return of spent fuel to the supplier of Ghana's Research Reactor 1, which has been operated successfully since 1995. This reactor is one of the nuclear facilities in Ghana that are regularly subjected to necessary inspections and monitoring by IAEA inspectors to ensure safety and also that there is no diversion of nuclear material.

It is clear that public apprehension against the nuclear power option is due to their misconceptions about the technology. Studies have shown that the nuclear option has a relatively low health and environmental impact. In addition, the accounts on nuclear accidents indicate that the occurrence of catastrophic events in the use of nuclear power technology is virtually impossible particularly in modern advance reactors.

### 3.2.3 What Makes Nuclear Power Unique

1. Long-term Government commitment - '100 years +'
2. Public perception/acceptance and public trust
3. Start-up phase is significant in length and effort, some 5-15 years before the shovel hits the ground
4. Highest level of safety and security. Without nuclear safety, there cannot be safe production of nuclear energy. Without nuclear fuel, there cannot be production of nuclear energy
5. Safety and security are always a work in progress (continuous improvement). Highest level of safety and security required
6. Safety, Security and Safeguards are national responsibilities, but the consequences of a nuclear accident or of a terrorist act are global
7. Capital intensive investment
8. Well trained human resources
9. Control of nuclear materials
10. Long-term nuclear waste management
11. No quick fix solution in developing a nuclear power programme
12. Nuclear power's characteristics require special attention
13. Strong national leadership to ensure coordination and broad political and popular support
14. Leadership and commitment are important to ensure both the required funds and the coordinated effort needed for success
15. The penalties of interruptions and restarts are significant

3.2.4 Addressing Public Concern about Nuclear Power Operation

The fear of adverse health effects from radiation, particularly in the event of severe accidents and from radioactive waste, is central to public concerns about nuclear power activities. Major issues of concern to government and the public are nuclear safety, radioactive waste management, human resource capacity and public perception/ acceptance. There is also proliferation of nuclear materials into unauthorised hands, which has been addressed under Section 4.2.2.

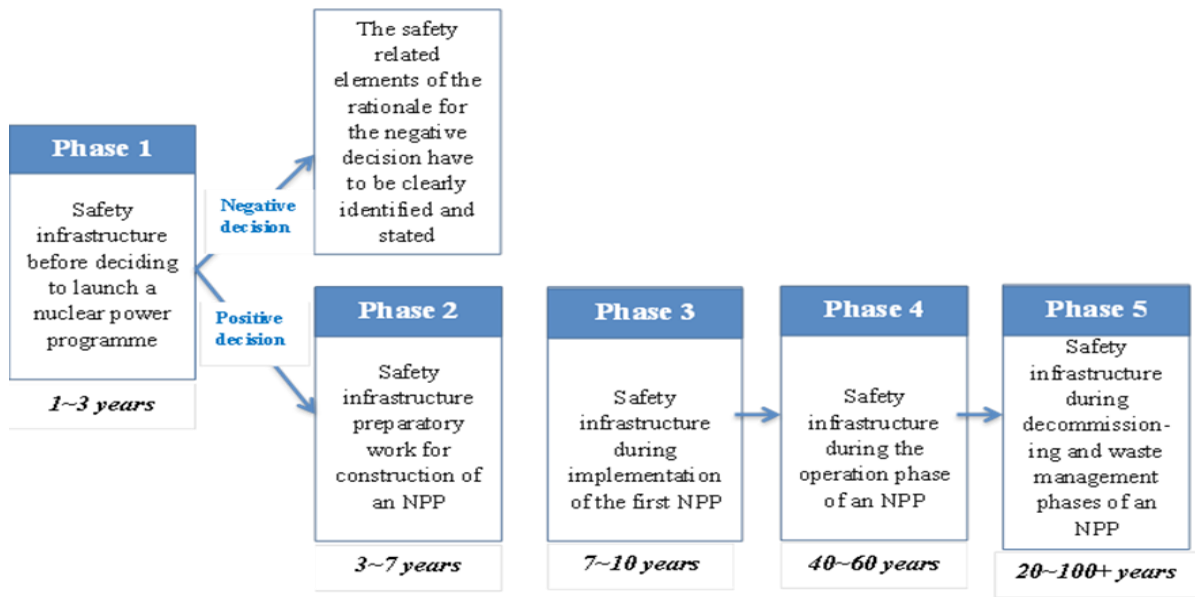
Nuclear Safety

Notwithstanding the Chernobyl and Fukushima accidents (both discussed in Section 4.2.2), nuclear power plants still remains a safe means of generating electricity. Nuclear reactors are designed with appropriate thermal and radiological shields to ensure that the operating personnel, the general public and the environment are not exposed to unsafe levels of nuclear radiation from operation of nuclear power plant. Safety improvements at nuclear power plants have over the years been made by identifying and

applying lessons learned from nuclear accidents, improving the effectiveness of defence-in-depth, strengthening emergency preparedness and response capabilities, enhancing capacity building through thorough and comprehensive training of operators and staff, and protecting people and the environment from ionising radiation.

Developing the necessary nuclear safety infrastructure is the key to ensuring safety in the lifetime of a nuclear power plant. Nuclear safety infrastructure is a set of institutional, organisational and technical elements and conditions that a country establishes to provide a sound basis and foundation for ensuring a sustainable high level nuclear safety throughout the stages of nuclear programme development. From a nuclear safety standpoint, the lifetime of a nuclear power plant is divided into five phases based on INSAG-22 with indicative average durations for each phase as presented in Figure 3.7. Ghana is in Phase 1 of the nuclear power programme and development of safety infrastructure has been central to all the activities in this Phase.

Figure 3.7: Main phases of safety infrastructure development over the lifetime of a nuclear power plant



Source: GAEC

Radioactive Waste Management and Decommissioning

Nuclear wastes are a significant part of the nuclear power picture, and need to be managed and disposed of properly. Nuclear wastes are not difficult to manage. Safe methods for the management and final disposal of high-level radioactive waste are technically proven. The amount of radioactive wastes is very small relative to wastes produced by fossil fuel electricity generation. It should be mentioned that in more than 5 decades of civil nuclear power experience, nuclear waste has not caused any serious health or environmental problems, nor posed any real risks to people.

Several power reactors have been completely decommissioned and dismantled, with the sites released for unconditional use. The options for decommissioning nuclear power plants range from returning the site outright to a greenfield state through to entombing the structures for a hundred years or more in order to allow substantial decay of radioactive materials. The option chosen will depend on regulatory requirements, public and political opinion, and safety and economic considerations.

Nuclear power is the only large-scale energy-producing technology which takes full responsibility for all its wastes including decommissioning and fully costs this into the product. The cost of managing and disposing of nuclear power plant wastes represents about 5 percent of the total cost of the electricity generated. Most nuclear utilities are required by governments to put aside a levy (e.g. 0.1 cents per kilowatt hour in the USA, 0.14 cent per kilowatt hour in France) to provide for management and disposal of the wastes. The actual arrangements for paying for waste management and decommissioning also vary. The key objective is however always the same: to ensure that sufficient funds are available when they are needed.

Furthermore, the nuclear and radioactive waste management industries work to well-established safety standards for the management of radioactive waste. International and regional organisations such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), the European Commission (EC) and the International Commission on Radiological Protection (ICRP) develop standards, guidelines and recommendations under a framework of co-operation to assist countries in establishing and maintaining national standards.

National policies, legislation and regulations are all developed from these internationally agreed standards, guidelines and recommendations. Amongst others, these standards aim to ensure the protection of the public and the environment, both now and into the future.

Human Resource Capacity

Human Resource development and technology support will be needed to sustain the introduction and development of nuclear power plant in Ghana. The sustainability of the programme requires developing local technical capabilities. This can be achieved over a period, with contractual arrangements for education and training programmes with the vendor country. This has been the practice worldwide where vendor countries through contractual arrangements establish on-site integrated training centre(s) in the recipient country and offer both on the job and specific training support both locally and in the vendor country. The establishment of the training centre(s) is essential for performing tasks.

Public Perception/Acceptance

Nuclear safety and issues of management of radioactive waste – both related to environmental values – shape public perception and concerns about nuclear power plant operation. The way to allay the fears of the general public is to focus more on relationship building, engaging in organised dialogue with stakeholders and concerned citizens at the local level, framing messages that speak to the background and social identity of key audience segments, using respected third parties and opinion leaders to build trust, and using websites and other social media tools that enhance transparency and two way dialogue with audiences. It is worth noting that the NPI, the main technical body championing the development of the necessary nuclear infrastructure has two centres dedicated to public communication, sensitisation, education and information on the nuclear power programme. Together, the centres have prepared a communication strategy document, developed a website and other social media platforms, organised series of stakeholder engagement meetings (this will continue throughout the programme lifetime), prepared questionnaires aimed at collecting data on public perception and receptiveness of nuclear power (this is yet to be administered due to lack of funds), publish a monthly newsletter aimed at educating, providing information and status updates of the nuclear infrastructure development.

3.3 The Milestone Approach and Ghana Nuclear Power Roadmap

3.3.1 The Milestone Approach

A successful nuclear power programme requires a national commitment of at least 100 years. Creating the infrastructure and building the first nuclear power plant will take at least 10–15 years<sup>18</sup>. This requires strong national leadership to ensure coordination and broad political and popular support. Nuclear safety, nuclear security and non-proliferation have to be ensured and seen to be ensured. Thus, the highest standards of safety, security and safeguards must be applied. It should be emphasised that a country pursuing a nuclear power programme remains responsible for the safe, secure, peaceful and efficient use of nuclear power. This requires the country to have an owner/operator with prime responsibility for safety, and a competent independent regulatory body to oversee the programme. A nuclear power programme cannot simply be bought.

Nuclear power plants have long lifetimes, relatively low running costs but high capital cost resulting in financing characteristics that are different from other major projects. Developing successful financing and contracting is a major challenge and requires significant government involvement. Decommissioning and the management of radioactive waste will require resources after the power plant has been retired. Therefore arrangements need to be in place to accumulate adequate funds.

The milestone approach<sup>21</sup> for a nuclear power programme is holistic and considers the development of 19 specific infrastructure issues. The framework is divided into three phases and milestones, with the duration of each phase dependent on the degree of commitment and resources applied to the programme. These different phases are:

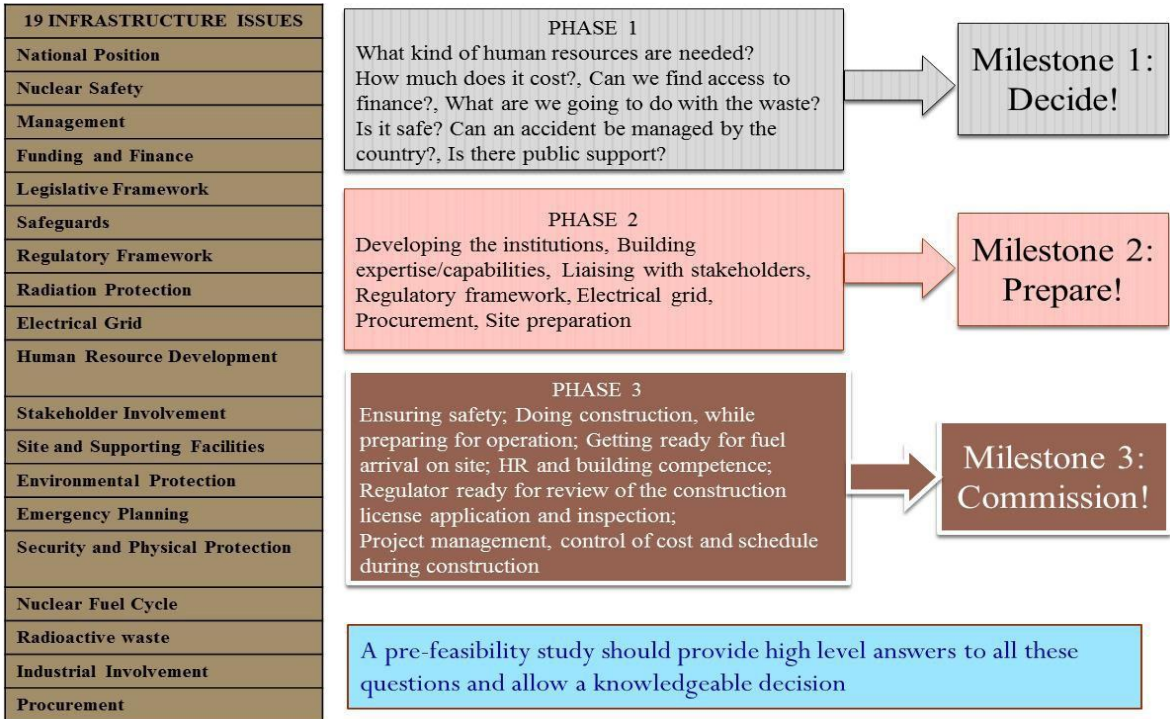
- i. Phase 1: Considerations before a decision to launch a nuclear power programme is taken.
- ii. Phase 2: Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken.
- iii. Phase 3: Activities to implement a first nuclear power plant.

The completion of each Phase is marked by a specific Milestone at which the progress of the development effort can be assessed and a decision made to move on to the next Phase. These milestones are:

- i. Milestone 1 (at the end of Phase 1): Ready to make a knowledgeable commitment/ decision to a nuclear power programme.
- ii. Milestone 2 (at the end of Phase 2): Ready to invite bids for the first nuclear power plant.
- iii. Milestone 3 (at the end of Phase 3): Ready to commission and operate the first nuclear power plant.

Key considerations and challenges faced by newcomer countries such as Ghana in developing the 19 infrastructure issues have been summarised in Figure 3.8 for each of the phases.

Figure 3.8: Newcomer Challenges in developing nuclear infrastructure for introduction of nuclear energy



Source: GAEC

3.3.2 Ghana Nuclear Power Roadmap

The draft roadmap<sup>19</sup> (Figure 3.9) for Ghana’s nuclear power programme identifies actions for each of the 19 infrastructure issues spanning across the three Phases. Appropriate Structures/Agencies have been identified to be responsible for the various infrastructure actions in the roadmap. An overall time frame of 14 years has been proposed from programme initiation to plant commissioning. This is strongly predicated on strong government commitment and dedicated funding for activities. Phase 1 and 2, which sum up the developmental phase are scheduled for eight years, whereas Phase 3, the construction phase, is scheduled for six years.

Figure 3.9: Roadmap for Ghana’s Nuclear Power Programme



Source: GAEC-NPP, 2015

18 IAEA NG-G-3.1, Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series Publication, Vienna, 2007

19 The roadmap for Ghana nuclear power programme, NPID-120000-STG-001, January 2016

### 3.3.3 Key Organisations

#### Key Assumptions to Achieve Targets

- i. Strong evidence of Government supports by providing sufficient oversight, logistics and fund commitment.
- ii. Active participation of all key stakeholders.
- iii. Functional role appointment (and competence development programme) of the regulatory authority.
- iv. Consistent following of roadmap and effective demanding and reporting of progress at top governmental level.
- v. Strong GNPPO with regarded authority and needed flexibility to effectively manage and coordinate the programme development.
- vi. Strategic Inter-Governmental Agreements and Consultancy engagement.
- vii. One unit envisaged to be constructed under the programme.
- viii. Turnkey (EPC) type of contract for the construction of the NPP.
- ix. A 1 – 3 years transition period for transfer of operation of NPP from EPC contractor to Ghanaian operator.
- x. Full scope of Ghanaian operating personnel to be ready at least a year before commencement of commissioning of NPP.

Three key organisations are involved in developing the national nuclear infrastructure with each having a specific role to play and with responsibilities changing as the programme advances. These are the Ghana Nuclear Power Programme Organisation, Nuclear Power Institute and the Nuclear Regulatory Authority

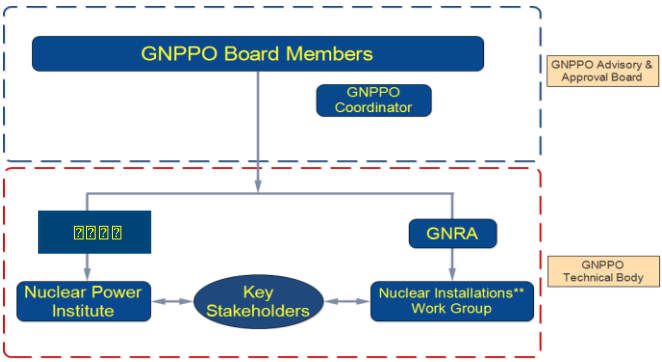
#### Ghana Nuclear Power Programme Organisation (GNPPO)

Following the presidential commission report, cabinet took a decision to include nuclear energy into the energy mix in 2008 and subsequently nuclear energy was included in the national energy policy and strategy in 2010. The government of Ghana declared its intention to pursue a nuclear power programme for peaceful purposes through a letter submitted to the International Atomic Energy Agency in 2012. The Ghana Nuclear Power Programme Organisation (GNPPO) was established to see to the implementation of the programme and the development of the necessary nuclear infrastructure for successful introduction of nuclear energy into the energy mix. Currently, the GNPPO is under the Ministry of Energy and is to be custodian of the national nuclear energy programme.

In order to accelerate the development of the necessary nuclear infrastructure, the Ghana

Atomic Energy Commission acting on behalf of the government of Ghana and the GNPPO, established the Nuclear Power Institute (NPI) to provide technical support to the GNPPO. The NPI has been working to promote the cause of the development of the required nuclear infrastructure for Ghana's Nuclear Power Programme. The GNPPO has advisory and technical bodies as presented below (Figure 3.10).

Figure 3.10: Involvement of Key Organisations



Source: GAEC-NPP, 2015

#### Legislative Framework and Independent Nuclear Regulatory Authority

Developing a nuclear power programme requires Ghana to have a comprehensive nuclear law and to ratify international treaties and conventions. Ghana has so far ratified most of the international treaties and conventions necessary for a nuclear power programme, with the exception of three outstanding conventions. The Office of Legal Affairs, GAEC (OLA-GAEC) is working to ensure that Ghana ratifies the remaining conventions. In addition, the OLA-GAEC with support from other stakeholder institutions is conducting legal gap analysis to determine laws and legislations that need amendment or enactment to meet the requirements of the nuclear power programme.

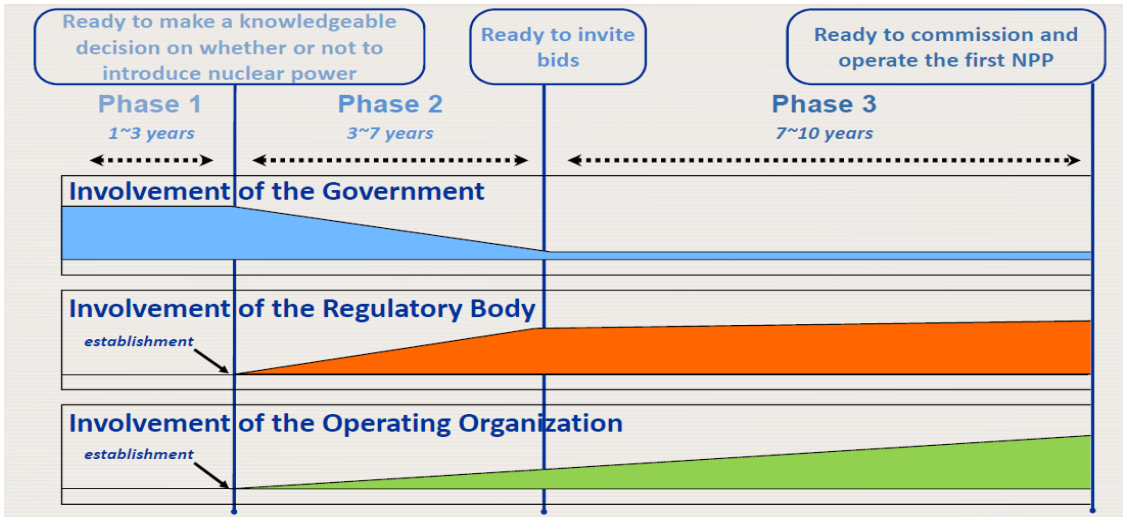
In August 2015, Parliament of Ghana passed a comprehensive nuclear law, NRA Act, 2015 (Act

895) that establishes an independent Nuclear Regulatory Authority (NRA) to ensure an effective regulatory regime with respect to nuclear safety, security and safeguards. The NRA is mandated to facilitate the development of national policies and the regulation and management of activities associated with the handling and utilisation of all radioactive and ionising radiation sources in Ghana.

#### Owner/Operator

The owner/operator is the outstanding organisation yet to be established. Discussions have been ongoing as to how to settle on the owner/operator organisation. This is being supported by the development of owner/operator document that will address the function, role, and structure of the organisation. It is expected that decision on the establishment of the owner/ operator would be finalised by the end of 2017. The involvement of these three key organisations changes depending on the Phase as illustrated in Figure 3.11.

Figure 3.11: Involvement of Key Organisations



Source: GAEC-NPP, 2015

### 3.3.4 Nuclear Energy Policy

A Nuclear energy policy document is to be prepared within the framework of the national energy policy. The document seeks to place nuclear energy within the right national context in regards to developing a sustainable energy mix for the country. The basis of the nuclear energy policy is to:

- Prepare for the development of manpower and promote plans for the introduction of nuclear power for electricity in the country;
- Attain energy independence and security of electricity supply;
- Enhance strategies for the realisation of aspirations envisaged in Ghana's national objective of attaining a middle income status and beyond.

## 3.4 Some Critical Areas Requiring Attention

### 4.4.1 Industrial Involvement

Developing local or national industrial involvement/participation<sup>20</sup> for a nuclear power programme involves the arrangement or rearrangement of a number of industries in the country for services, materials supply, fabrication and construction, as part of the integrated supply chain that should be established for the programme. Though for the first nuclear power plant, the most common scheme is a turnkey EPC contract for both the nuclear island and the balance of plant (BOP), the EPC contractor will engage subcontractors and suppliers to engineer, design, construct and commission the nuclear power plant units which typically is a mix of local industrial organisations and international suppliers. Again, the owner/ operator organisation will take on projects that are related to the turnkey project with the EPC contractor (e.g. grid upgrades, roads, training centres and administrative facilities) and will enter into contracts with local industrial organisations to support these projects. Therefore, there is the need to do the following:

- Develop/prepare/conduct national/local industries' capacity surveys;
- Establish policies and identify target areas;
- Establish industrial standards and quality assurance mechanisms;
- Build capacity and provide incentives for national R&D programme, establishing partnership with experienced companies, providing official long-term and low- interest loan for capital investment.

During Phase 1 of the programme, the management body of the programme (GNPPO) should assess national and local industrial capabilities, interest of business/industrial leaders in participating in the NPP project considering the special requirements necessary, necessary investment for intended upgrading of industrial facilities and develop short and long term policies on the level of local participation that is practical and desired.

During Phase 3 of the programme, the GNPPO should continuously coordinate and implement industrial involvement policy (capacity building,

incentives) and reassessment of the sources of supply to support operation.

<sup>20</sup> IAEA NE series No. NG-T-3.4: Industrial involvement to support a national nuclear power programme, Vienna, 2016

Figure 3.12: Construction of a nuclear Plant



Source: Google Images

### 3.4.2 National Position

The national position<sup>21</sup> is the outcome of a deliberative process and study that establishes the governmental strategy and commitment to develop, implement and maintain a safe, secure and sustainable nuclear power programme known as *knowledgeable decision*. It should be noted that an intention to develop a nuclear power programme is not a decision to embark on a nuclear power programme. According to the current roadmap for nuclear power development, a comprehensive report which will present an assessment of the 19 infrastructure issues including a complete prefeasibility for an implementation of a nuclear program will be prepared at the end of Phase 1 (expected date, December 2017). This report will be the technical basis for a national decision to be taken by government that would clearly communicate Ghana's readiness and commitment to proceed with the programme or otherwise according to the international (and national) norms, standards and obligations of the Country. The comprehensive report would consider among others<sup>22</sup>:

- Thorough analysis and development of scenarios of the country's energy demand and supply alternatives;
- Macro-economic study on the impact of introducing a nuclear power programme;
- Considerations of nuclear safety, including the recognition of the non-zero possibility of a severe accident;

<sup>21</sup> IAEA NE series No. NG-T-3.14: Building a national position for a new nuclear power programme, Vienna, 2016.

<sup>22</sup> Requirements for an effective national position on nuclear energy, NPID- 305100-STG-001, July 2014

- iv. Initial analysis of the domestic and international legal requirements and agreements required to proceed;
- v. Preliminary evaluation of the potential sites capable of hosting a nuclear power plant;
- vi. Analysis of the government funding necessary to support the development of the appropriate infrastructure, especially the regulatory oversight;
- vii. Strategy for the development of the necessary human resources;
- viii. Strategy and funding approach to provide for decommissioning, management of spent fuel, nuclear waste and environmental remediation;
- ix. Plan for effectively engaging stakeholders and the public throughout the process.

### 3.4.3 Human Resource Development

One of central challenges in undertaking a nuclear power programme and deploying a first nuclear power plant (NPP) for newcomer countries is to attain and maintain the competence and qualification of NPP personnel, which includes management staff, operations, maintenance personnel, engineering and technical support personnel and training staff as well as the regulatory body. Staffing of a first NPP is a comprehensive and long-term project and the success of it requires the successful completion of a number of sub-projects, including the development of certain elements of nuclear power programme infrastructure; the development of national and NPP training systems; and attracting, selection, training, qualification and authorisation of NPP personnel.

### 3.4.4 Funding and Finance

The nuclear power programme so far has not been given the necessary funding support to develop the needed nuclear power infrastructure required for the introduction of nuclear energy into Ghana's energy mix. It must be noted that the development of the needed nuclear infrastructure is a national requirement that cannot be owned by any third- party. Thus, strong government commitment, ownership and dedicated funding for the program is critical. It is considered that strong funding support from government would also encourage stronger international developmental support for the country's nuclear power infrastructure development.

A first-run estimated cost of the fourteen-year roadmap for developing the required nuclear infrastructure is US\$ 125 million. These estimates account for only the investments needed to develop the necessary infrastructure, and do not include the costs associated with the construction of the nuclear power plant itself.

#### Urgent Actions Requiring Government's Attention

The roadmap requires all these studies to be completed by the end of 2017 to enable the government make a knowledgeable commitment to the nuclear power programme. It is therefore imperative that government gives critical attention to ownership of the nuclear power programme by government, the establishment of owner/operator organisation, and setting aside dedicated funds for all other work tasks of the Ghana Nuclear Power Programme Organisation (GNPPO).

# Chapter 4 Petroleum

## 4.1 Introduction

The infrastructure plans for crude oil and its derivatives as well as for natural gas and its derivatives are presented separately in this report. While the oil value chain is described in two broad activities, i.e. upstream and downstream, the gas value chain is presented in three broad activities, namely upstream, midstream and down stream. Upstream activities, (exploration and production) are however considered as the same for both the oil and gas value chain. Also, supply and demand projections are presented for both oil and gas.

### 4.1.1 Goals and Objectives

The petroleum sector policy defines certain processes for regulating the petroleum industry, with respect to the licensing and operation of the oil and gas companies; improving the institutional and human resource capacity; enhancing local content and fiscal incentives that will ensure the maximum benefits to the people of Ghana.

The goals of the sector are to:

- i. Ensure the effective management of the oil and gas resources of the country and accelerate the exploitation and development of new hydrocarbon resources for the overall benefit and welfare of all Ghanaians.
- ii. Increase local value added investments in the oil and gas sector and the indigenisation of knowledge, expertise and technology.

The objectives of the sector have been defined based on upstream and down stream activities.

#### Objectives for Upstream Activities

The general objectives of the upstream sub- sector, however, are as follows:

- i. Manage oil and gas revenues transparently and ensure equity for the benefit of the present and future generation of Ghanaians.
- ii. Encourage investments along the oil and gas industry value chain through fiscal incentives and “even-handed” regulation.

- iii. Maximise the benefits of oil and gas wealth generation through the use of local goods and services, people, businesses and financing in all aspects of the oil and gas industry value chain and retaining the benefit within Ghana.
- iv. Develop dedicated institutions and legislations to govern the oil and gas industry installations and operations and to ensure security and enforce safety requirements.
- v. Develop a viable domestic petrochemical industry based on natural gas.
- vi. Support capacity building at all levels in the country's technical, vocational and tertiary institutions.

#### Objectives for Downstream Activities

The objectives of the petroleum downstream sub – sector are as follows:

- i. Rehabilitate and expand petroleum refining, storage, distribution and marketing infrastructure.
- ii. Ensure fair distribution of petroleum products to all parts of the country.
- iii. Reduce heavy burden of oil imports on the country's economy by accelerating the exploitation of indigenous hydrocarbon resources.

## 4.2 Overview of the Oil Infrastructure Plan

### 4.2.1 Upstream Activities

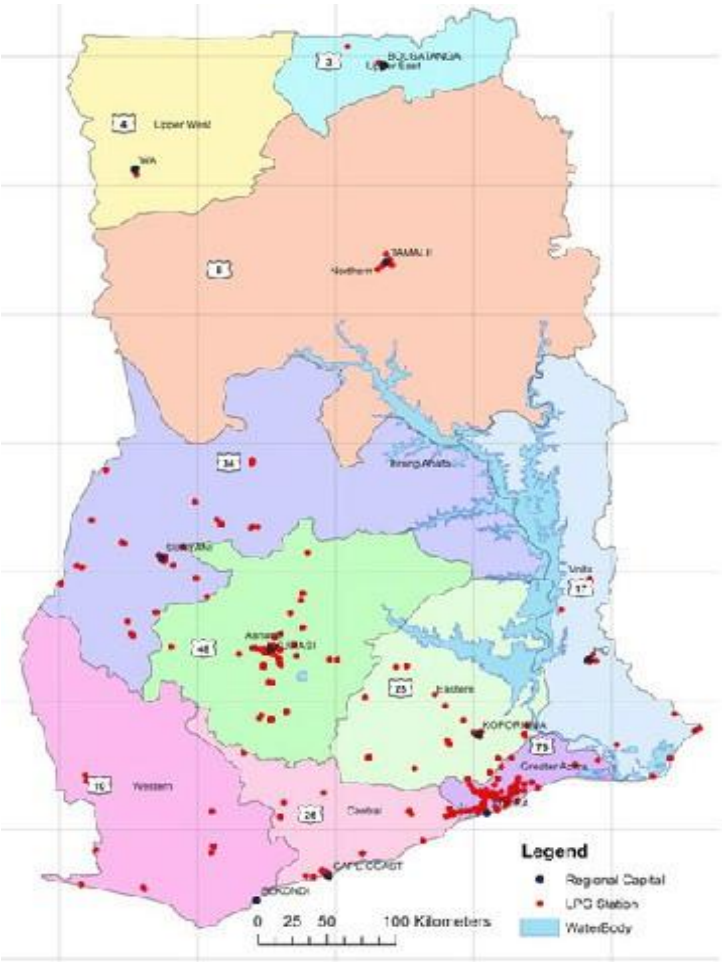
The upstream sub-sector of the oil and gas value chain involves six key stages: licensing, exploration, appraisal, development, production and de-commissioning. These activities are mostly capital intensive, and local participation is very minimal.

### 4.2.2 Downstream Activities

The downstream sub-sector, on the other hand, has significant local participation. It currently consists of activities such as importation, refining, storage, transportation, distribution and utilisation.

Petroleum products are distributed round the country through about 3,000 retail outlets. The Greater Accra Region, with the highest level of consumption of petroleum products in the country, has the highest number of retail outlets, with the least number in the Upper West Region, as depicted in Figure 4.1.

Figure 4.1: Locations of LPG retail outlets across the country



Source: TEC/EUEI-PDF Study, 2011

### 4.3 Oil Demand Plan

The various utilisation options for oil and its derivatives as well as the associated demand profiles for both power and non-power applications for the next 30-year period, are considered in the following sub-sections.

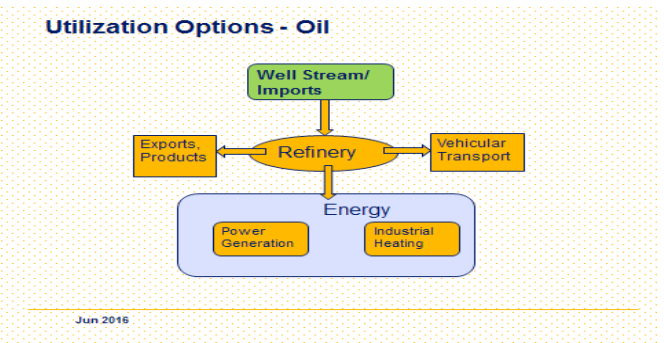
#### 4.3.1 Oil Utilisation Plan

Refining crude oil results in the production of gasoline, fuel oil, LPGs, diesel and kerosene/jet fuel, the utilisation options of which, include the following:

- i. Power Generation
- ii. Industrial Heating
- iii. Vehicular Transport

These are summarised in figure 4.2.

Figure 4.2: Oil Utilisation Options



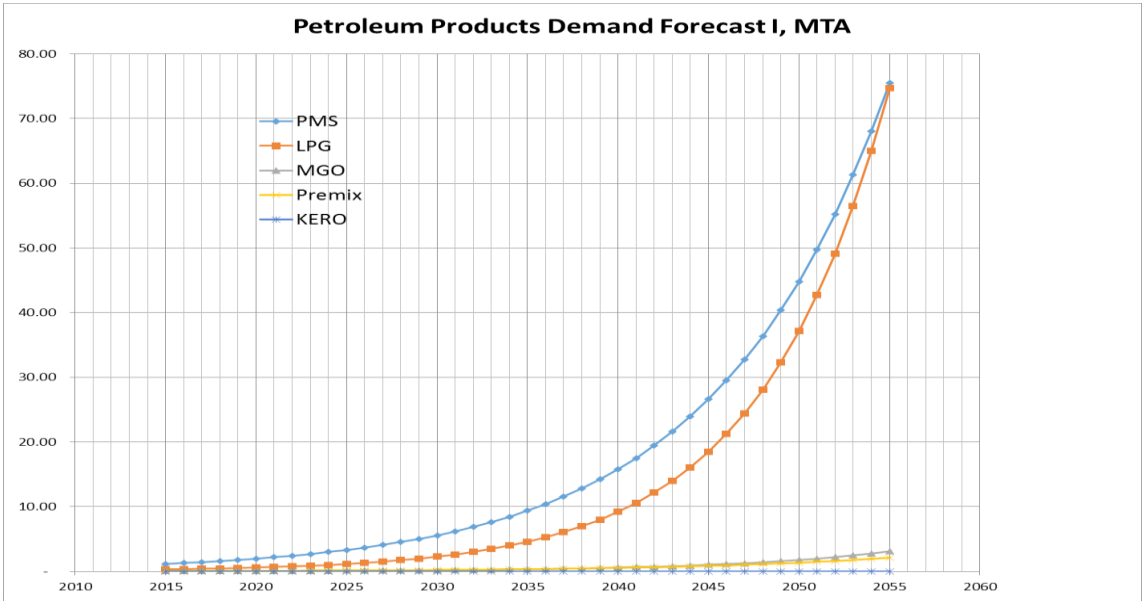
Source: Author's Construct, 2017

The power sector constitutes the largest share of demand at an average of 88 percent of total demand over the period 2015 to 2040.

#### 4.3.2 DemandForecastforCrude Oil and Petroleum Products

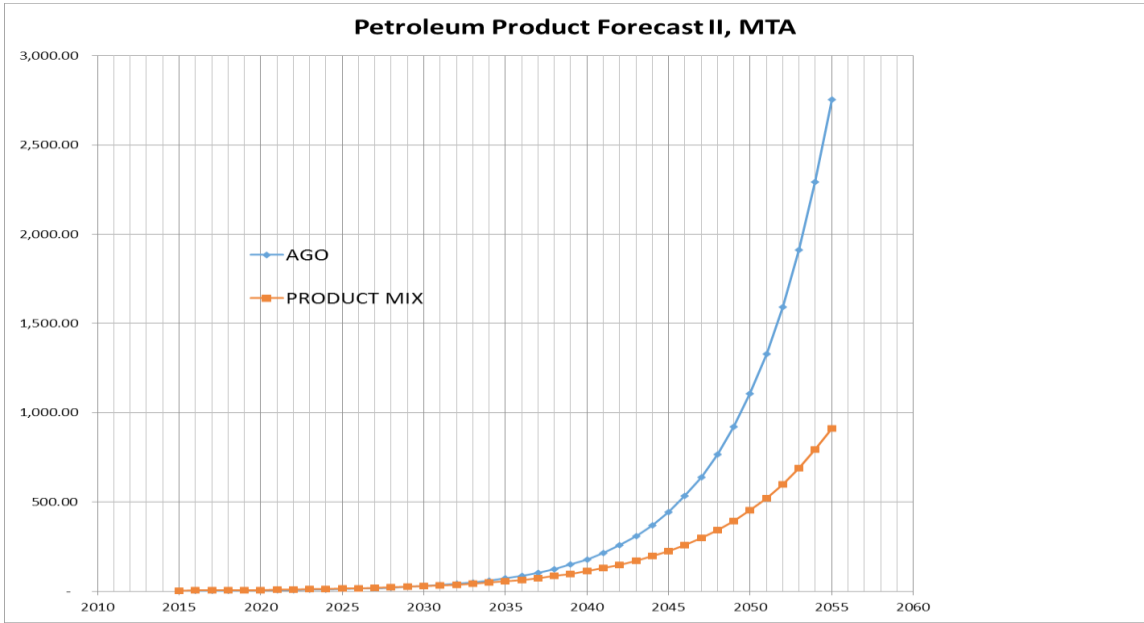
The demand profile for crude and the various petroleum products are presented in Figures 4.3 and 4.4 respectively.

Figure 4.3: Annual Petroleum Product Demand Forecast, Million-Tonnes/Year



Source: Author's Construct, 2017

Figure 4.4: Annual Petroleum Product Demand Forecast, Million-Tonnes/Year



Source: Author's Construct, 2017

### 4.4 Oil Supply Plan

The oil supply plan explores and makes forecasts for two broad categories of oil supply sources namely:

- i. Imported Oil
- ii. Domestic (indigenous) oil production based on internal gas reserves and resources.

Figure 4.5: Tank Farm



Source: Google Images

#### 4.4.1 Supply Forecast for Imported Oil

Ghana is spending more money importing crude oil than it is earning from its export of the product. The section covers two broad categories of oil supply sources:

- Domestic production based on domestic gas reserves and resources
- Oil imports

##### Domestic Oil

Domestic oil supply are based on the reserves from the Jubilee, the TEN, the MTA (Mahogany, Teak and Akasa); and the Sankofa fields. Furthermore, the Paradise field discovered by Hess is an oil and gas condensate discovery while the Hickory field also by Hess, is a gas condensate discovery. There are also likely to be more resources (both non- associated gas and associated) from undrilled structures. Three scenarios have been prepared based on the above summary of reserves and resources:

- Base supply scenario
- Low supply scenario
- High supply scenario

The following sections discuss each resource based on current information about the status and development of the fields and prospects.

### Imported Oil

The crude oil processed by the Tema Oil Refinery (TOR) and some petroleum products are imported. There is an offshore facility (Single Point Mooring) used for offloading crude oil tanker vessels and a network of pipelines that connect the facility to the refinery. Similarly, petroleum products imported are also offloaded through discharge facilities such as oil jetty and All Berth Bouy (ABB). It is expected that in the future indigenous crude oil would be gathered and transported to the refinery for processing. This would be part of the medium-to-long term infrastructure plan.

TOR is the only refinery in the country and has a capacity of approximately 45,000 barrels per day, which is about 60 percent of the nation's current demand (of 75,000 barrels per day). Crude oil used by the refinery is currently sourced from Nigeria and other African countries including, Equatorial Guinea, Cameroon, Gabon and Angola. The refinery is linked to an oil jetty and the Single Point Mooring (SPM) and Conventional Buoy Mooring (CBM) at the Port of Tema by pipelines of various diameters for the transfer of crude oil and refined petroleum products. The main refinery products are gasoline, fuel oil, LPGs, diesel, and kerosene/jet fuel. The infrastructure plan reviews the existing and planned refinery capacity and make recommendations for appropriate expansion.

The overall domestic storage capacity for crude oil and refined petroleum products is estimated at 1,057,700 MT of liquid products, 17,200 MT of LPG and 300,000MT of crude oil. The Bulk Oil Storage and Transportation (BOST) Company and TOR collectively own about 80 percent of the total storage capacity and the remaining 20 percent are owned by private depot operators. Currently, BOST owns storage facilities at six locations within the country namely, Accra Plains, Akosombo, Mami Water, Kumasi, Buipe and Bolgatanga.

### 4.4.2 Domestic (indigenous) Oil Production Forecast

Domestic oil supplies are drawn from the Jubilee, TEN, MTA (Mahogany, Teak and Akasa) and the Sankofa oil fields. Furthermore, the Paradise and Hickory fields discovered by Hess are oil and gas condensates (the latter being a gas condensate only). There is the high possibility of the existence of more resources (both non-associated gas and associated) from undrilled blocks.

Based on available information, the following sections discuss the status, development and prospects of each of the fields.

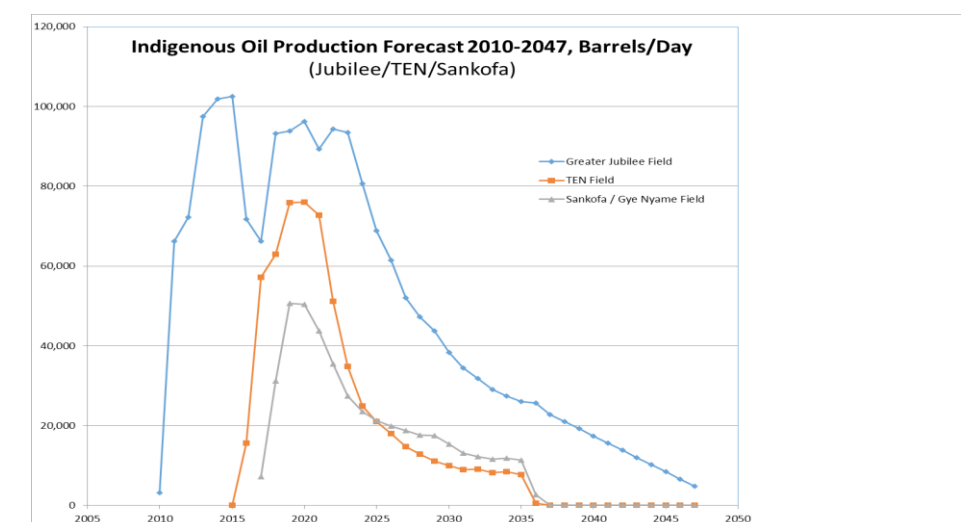
#### Jubilee Production Potential

There are significant quantities of gas associated with the Jubilee field's oil reserves, which came into production at the end of 2010. The Jubilee oil is light crude with Gas to Oil Ratio (GOR) in excess of 1,000 standard cubic feet per barrel.

The field is being developed in phases; hence, there are more wells to be drilled. This would increase the oil and gas production and extend the plateau of production profiles.

Figure 4.6 reflects the expected indigenous production forecast.

Figure 4.6: Indigenous Oil Production Forecast, 2010 – 2047, Barrels/Day

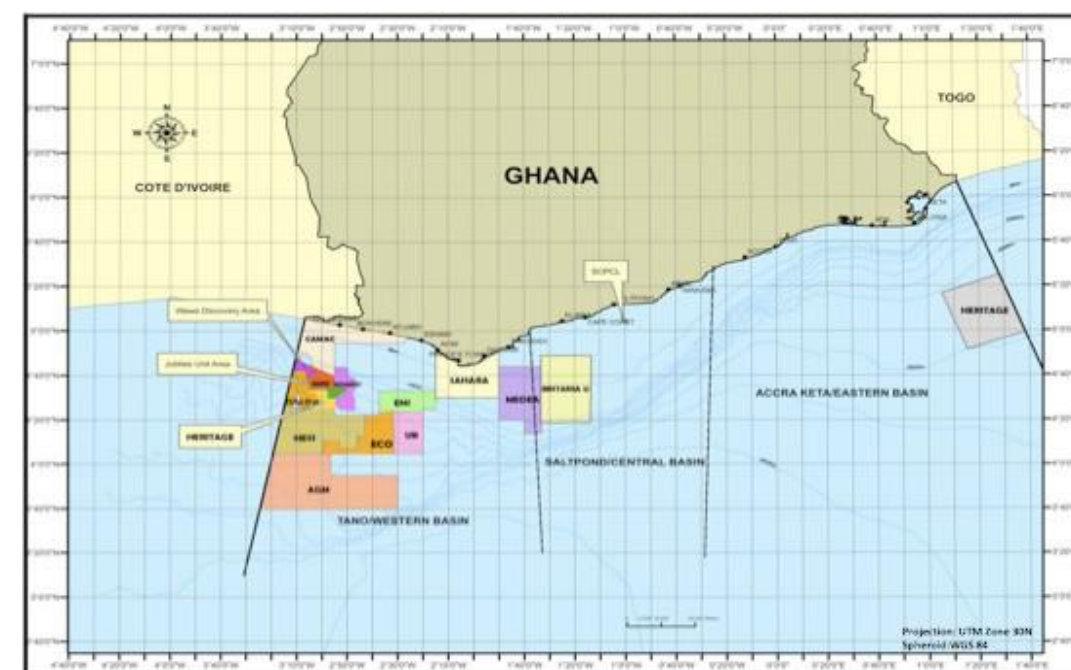


Source: Author's Construct, 2017

### 4.4.3 Reserves Potential for Indigenous Oil Resources

The Jubilee oil field is currently in production, as portrayed in the offshore activity map in figure 4.7. The Tullow block, which covers the TEN fields is also shown to the west of the Jubilee oil field adjacent to the Cote d'Ivoire border.

Figure 4.7: Ghana's Offshore Activity Map



Source: Gas Master Plan, 2015

The KOSMOS block, which contains the MTA fields, is to the east of the Jubilee fields. These fields will be developed and produced using the Jubilee Floating Production Storage and Offloading (FPSO) vessel. The Greater Jubilee Full Field Development Plan sets out the integrated development of the Jubilee field, as well as the Mahogany and Teak discoveries (together known as the “Greater Jubilee”). The Mahogany and Teak discoveries will be tied back to, and produced through the existing Jubilee FPSO vessel. To the south of the Jubilee field is the Hess Block, which contains seven separate discoveries. The ENI Block is to the east of the Jubilee field.

Table 4.1: Supply Plan – Reserves Potential for Indigenous Oil

| Reserves Statement (As at 30 <sup>th</sup> June 2016) |                   |                      |                                |                      |
|-------------------------------------------------------|-------------------|----------------------|--------------------------------|----------------------|
|                                                       | Ultimate Reserves | Recoverable Reserves |                                |                      |
|                                                       |                   | Gross                | Net Participating (GNPC/State) | Carried and Interest |
| Crude Oil & Condensates (MMBO)                        |                   |                      |                                |                      |
| Saltpond*                                             | 5.6               | 0.35                 | 0.15                           |                      |
| Jubilee                                               | 628               | 455                  | 58.7                           |                      |
| Mahogany                                              | 31                | 31                   | 3.7                            |                      |
| Teak                                                  | 0                 | 0                    | 0                              |                      |
| TEN                                                   | 239               | 239                  | 34.1                           |                      |
| Sankofa & Gye Nyame (OCTP)                            | 204               | 204                  | 37.7                           |                      |
| Total Oil and Condensates (MMBO)                      | 1108              | 929                  | 134                            |                      |

Source: Gas Master Plan, 2015, \*Saltpond field has been shut in since December, 2015

The offshore area is generally prospective and has attracted the attention of numerous international oil companies. There are also potentially significant resources onshore in the Voltaian basin, though the exploration and development of these is a long-term proposition.

4.5 Infrastructure Plan – Refinery, Products Storage, Pipelines

4.5.1 Refinery

The current capacity of the Tema Oil Refinery is 45,000bpd. This will be increased to a capacity of 60,000bpd by 2025. Additionally, a new oil refinery in the Western Region, with a capacity of 60,000bpd is proposed, to handle the processing of the domestic oil finds in the offshore basins.

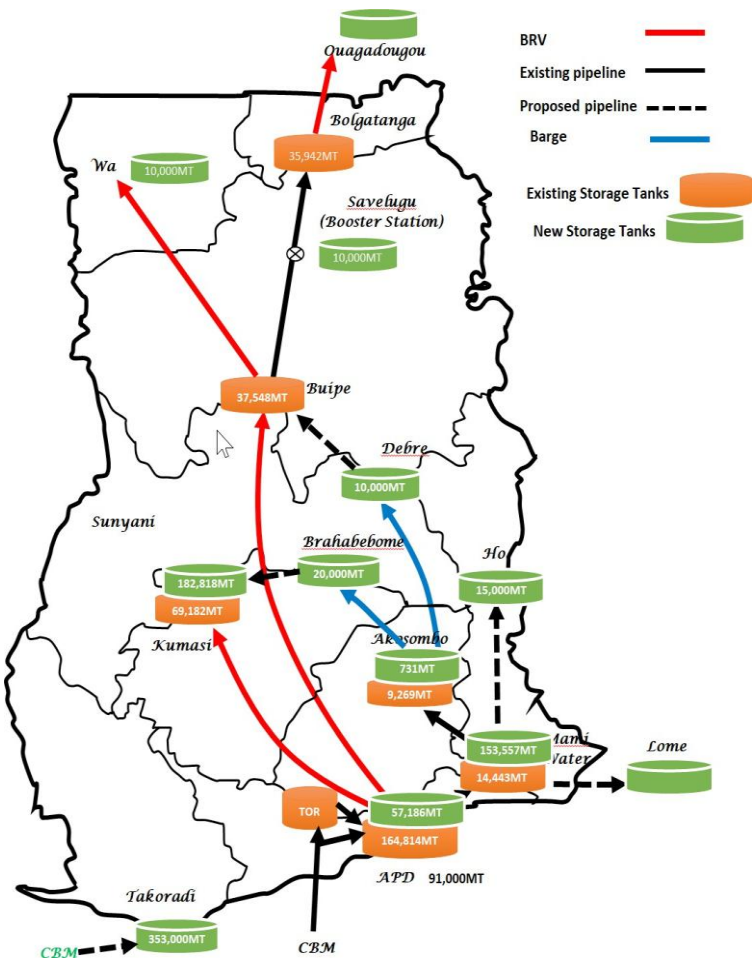
4.5.2 Transportation

The means for transporting crude oil and its finished products between the supply source and the market will remain via pipelines, road or marine vessels. The pipelines (and/or vessels) will also be used to transport oil produced domestically (indigenously), for processing at the Tema Oil Refinery and the proposed refinery.

Figure 4.8 shows the existing and proposed

storage and pipeline infrastructure for petroleum products.

Figure 4.8: Existing and Proposed Petroleum Products Infrastructure



Source: Author's Construct, 2017

4.6 The Gas Infrastructure Plan

The West Africa Gas Pipeline (WAGP) was created as a means for transporting natural gas from Nigeria into the country, for the generation of power. Over the years, however, the supplies from the WAGP have been unreliable: subject to major interruptions and supply shortfalls.

With significant domestic (associated and non-associated) gas reserves discovered, the gas supply dynamics in Ghana have changed. Likely near-term productions from the most advanced reserves are concentrated in three large offshore gas fields namely:

- i. the Jubilee field with associated gas reserves estimated at 335 billion cubic feet (bcf).
- ii. the TEN fields with associated gas reserve of 353 bcf.
- iii. the Sankofa field with non-associated gas reserves of 1,168 bcf.

A comprehensive Ghana Gas Master Plan Model (GMPPM) has been developed to examine alternative scenarios, covering the following main aspects:

- i. Estimates of the demand for gas in Ghana up to 2040 on the basis of a power dispatch model and netback prices for the most likely non-power off-takers.
- ii. Calculations of the national annual gas supply and demand balance in Ghana, as well as the regional balances.
- iii. The weighted average cost of gas resulting from the supply mix.
- iv. Determination of the location, capacity, costs and timing of new infrastructure: transmission pipelines and LNG terminals.
- v. The economic value of different gas utilisation scenarios.

The GMPM model enables different scenarios to be examined and compared. A training course has been provided for stakeholders so that future scenarios can be examined after the GMP study.

#### 4.6.1 Overview of the Gas Sector

Unlike it is in the oil sector, the gas value chain follows three main stages or activities: upstream, midstream and downstream. The upstream activities cover exploration and production while midstream activities cover gathering, processing and transmission. The downstream activities are limited to distribution and utilisation.

The requisite infrastructure plan along the value chain would cover each of these stages of activities. The current Gas Master Plan (GMP) presents a road map for most of the activities along the chain.

### 4.7 Gas Demand Plan

The following sub-sections discuss the various utilisation options for natural gas as well as the associated demand profiles for both power and non-power applications for the next thirty (30) years.

The transport of natural gas between the supply source and the market is typically by pipeline or by storage tanks or cylinders (on marine vessels or trucks or rail) as LNG or CNG.

Figure 4.9: Pip



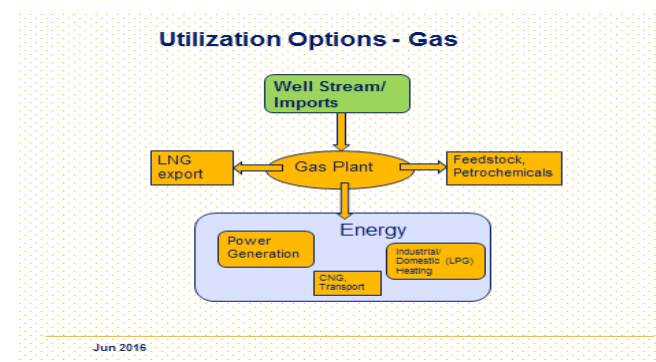
Source: Google Images

#### 4.7.1 Gas Utilisation

Gas is used mainly as an energy source or as feedstock for various industrial applications. Usually the utilisation option drives the type of processing and mode of transportation.

The main products from processing of raw or wet gas are Lean Gas and Natural Gas Liquids (NGLs) (which includes liquefied petroleum gas/LPG and condensates). The NGLs are removed from the gas stream and marketed separately. The lean or dry gas is utilised primarily as fuel for power generation, but could also be used as a fuel source for industrial applications, or as a feedstock for certain petrochemicals. The utilisation options are summarised in Figure 4.10.

Figure 4.10: Gas Utilisation Options



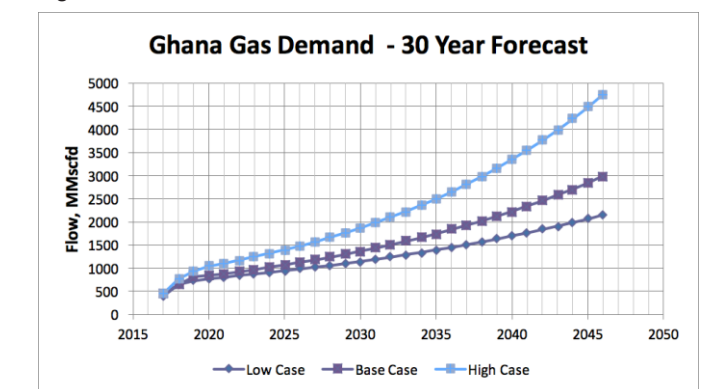
Source: Author's Construct, 2017

#### 4.7.2 Gas Demand Forecast for Power and Non-Power Loads

Given the uncertainties over future gas supplies, the development of new power and gas infrastructure and the demand for power, three alternative scenarios for gas demand projection have been considered:

- Low case – assumes gas requirement for existing thermal plants with a growth of 4% annually.
- Base case – assumes gas requirement for existing thermal plants with a growth of 5% annually.
- High case – assumes gas requirement for existing thermal plants with a growth of 6% annually.

Figure 4.11: Gas Demand Profile



Source: Author's Construct

### 4.8 Gas Supply Plan

Three broad categories of gas supply sources are covered, namely:

- Domestic gas reserves and production
- Regional gas imports
- LNG imports

#### 4.8.1 Domestic Gas Reserves and Supply

Domestic gas reserves are based on the supply of associated gas from the Jubilee field, the TEN field, the MTA field (Mahogany, Teak and Akasa); and the non-associated gas discovery, the Sankofa field. Furthermore, the Paradise field discovered by Hess is an oil and gas condensate discovery while the Hickory field, also owned by Hess, is a gas condensate discovery. More resources (both non-associated gas and associated) are also likely to be discovered from concessions that are yet to be drilled.

Apart from gas supplied from Ghana’s indigenous fields, additional gas can be sourced from Nigeria through the WAGP besides the potential for LNG imports.

Three scenarios have been prepared based on the above summary of reserves and resources:

- i. Base case supply scenario
- ii. Low case supply scenario
- iii. High case supply scenario

Table 4.2: Scenarios for Gas Reserves and Resource, Bcf

| Field                    | Low Case Supply | Base Case Supply | High Case Supply |
|--------------------------|-----------------|------------------|------------------|
| Jubilee*                 | 256             | 490              | 591              |
| TEN                      | 209             | 363              | 402              |
| Sankofa and GyeNyame     | 929             | 1,107            | 1,191            |
| MTA*                     | 3               | 128              | 173              |
| Hess                     |                 | 177              | 177              |
| Shallow Tano             |                 |                  | 193              |
| Other Non-associated gas |                 |                  | 1,000            |
| Other Associated gas     |                 |                  | 1,000            |
| Total                    | 1,397           | 2,265            | 4,730            |

Source: Gas Master Plan, 2015

\* NB: Estimates from Greater Jubilee Full Field Development Plan, 2015

To obtain a realistic picture of future production volumes, yet-to-find oil and gas fields are included in the analysis. Exploration in Ghana is continuing at a rapid pace and further discoveries are likely to be made. However, these possible further discoveries have only been taken into account in the high supply scenario forecast. The timetable for the start of supply for the yet-to-find fields is only indicative.

Table 4.3: Summary Data for Gas Exports and Pricing Scenarios

| Field                    | Production Year (earliest) | Daily Sales peak (mmscfd) | Indicative cost (US\$/mmbtu) |
|--------------------------|----------------------------|---------------------------|------------------------------|
| Jubilee                  | 2015                       | 60-120                    | 2.98-4.20                    |
| TEN                      | 2017                       | 30-50                     | 2.98-4.20                    |
| Sankofa*                 | 2018                       | 150-180                   | 9.8                          |
| MTA                      | 2019                       | 50-120                    | 4.20                         |
| Hess                     | 2021                       | 50                        | 2.98-4.20                    |
| Shallow Tano             | 2025                       | 50                        | 2.98-4.20                    |
| Other Non-associated gas | 2020                       | 140                       | 4.20                         |
| Other Associated gas     | 2019                       | 140                       | 2.98                         |

Source: Gas Master Plan, 2015    \*This negotiated price of US\$9.8 /mmbtu, by prevailing global gas prices, is excessive

4.8.2 Regional Gas Imports (Nigerian Gas via WAGP)

The WAGP<sup>1</sup> currently has a capacity of 170 mmscfd without additional compression. With additional compression, however, the capacity can be increased to 470 mmscfd at a maximum operating pressure of 150 bar. The Volta River Authority (VRA) has contracted a capacity of 123 mmscfd.

4.9 Processing Infrastructure Plan

This section reflects on the infrastructure required to transform the raw gas from its “crude” state to a saleable or consumable state. While refineries are used to process crude oil, gas plants are used to process raw gas.

Sweetening Plant (Sour Gas Removal)

The process of removal of the sour (and acidic) components of raw gas (H<sub>2</sub>S and CO<sub>2</sub>) is called sweetening. These components of the gas stream maybe removed with an amine column, using, for example, monoethanol amine (MEA) or diethanol amine (DEA) or monodiethyl amine (MDEA).

Dehydration and Dew-point Control (Water & Hydrocarbon)

Gas from the sweetening plant may still contain some water and heavy hydrocarbons. These must be reduced so that the gas product stays above both the dew-points of water and the hydrocarbons. This can be accomplished in several ways including:

- i. Chilling the gas (refrigeration) below the dew-point of the HC (and water); glycol may be required to prevent hydrate formation
- ii. Dehydration of the gas and absorption of heavy hydrocarbons in a column.

Hydrocarbon (HC) Liquids Recovery

The liquid HC from both the separators and the dew- point controller are sent to a fractionating column for separation of the individual components. This is essentially by distillation, utilising the different boiling points of the components. Hydrocarbon liquids recovery from raw natural gas can range from the use of a simple dew point controller to deep extraction processes.

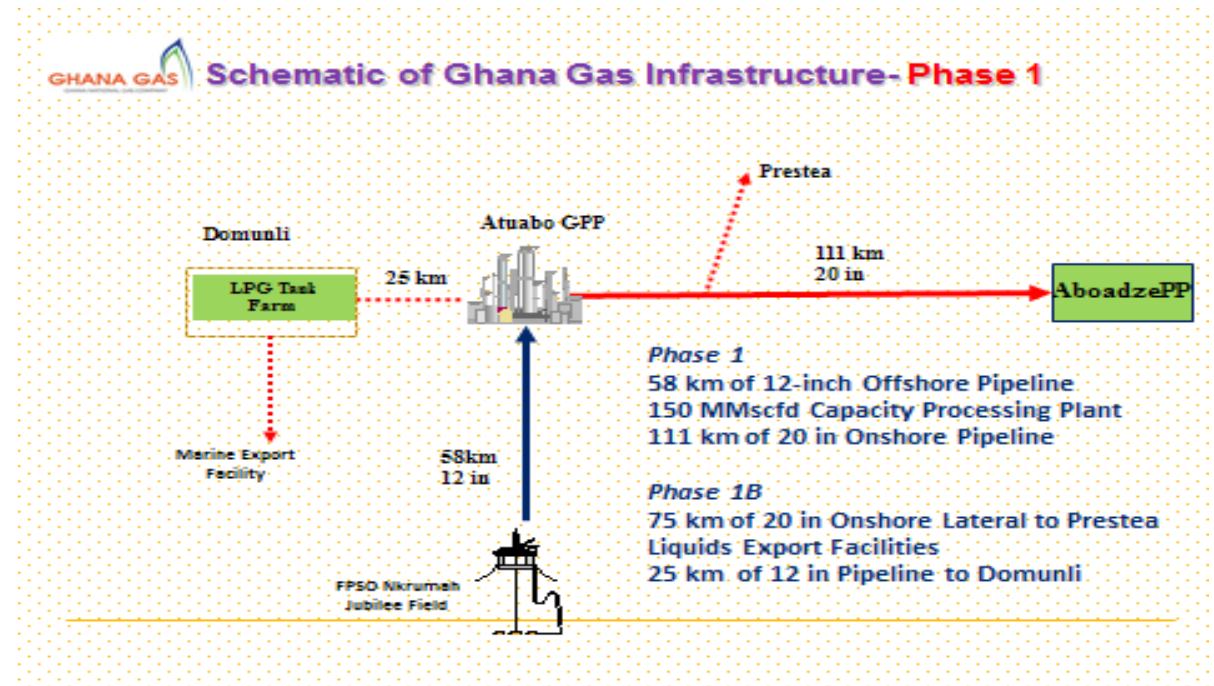
Sulphur Recovery

The acid gases (H<sub>2</sub>S and CO<sub>2</sub>) from the sweetening plant could be sent to a sulphur recovery plant where the H<sub>2</sub>S is reacted with O<sub>2</sub> to produce elemental sulphur. The residual SO<sub>2</sub> and CO<sub>2</sub> are rejected to the atmosphere depending on environmental regulations.

Figures 4.12 and 4.13 represent the current and proposed infrastructure plan for the gas system.

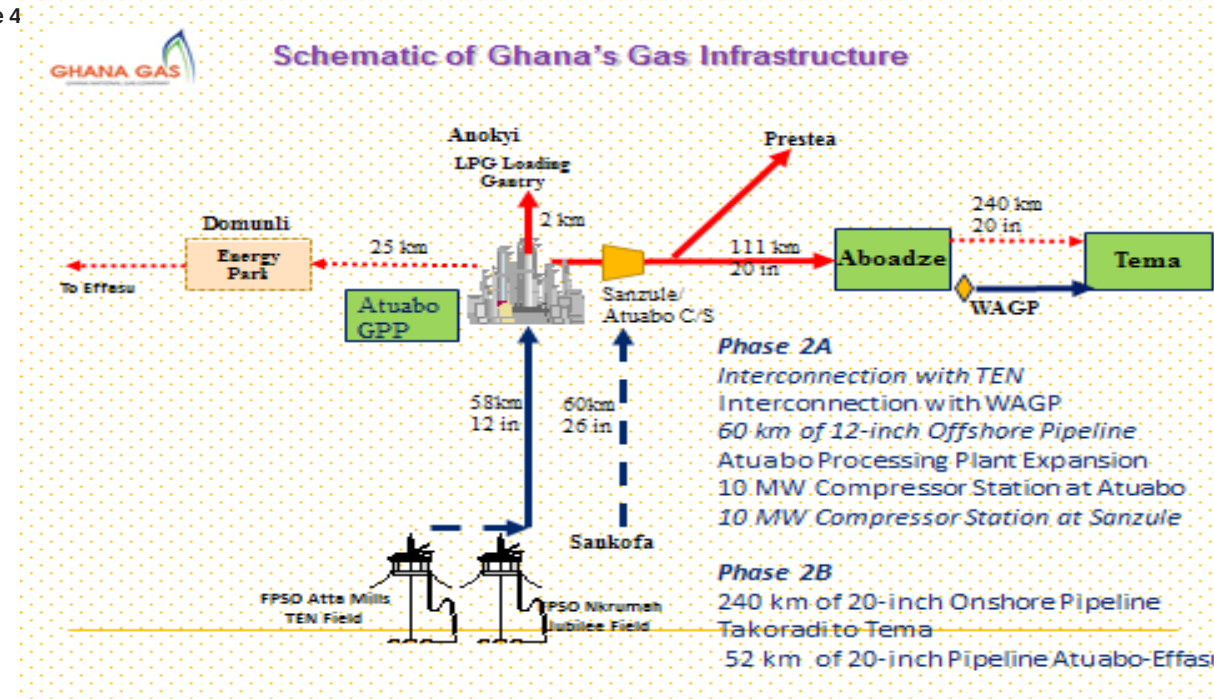
<sup>1</sup> NOTE: The WAGP has failed to deliver the contracted quantity consistently due to a coincidence of factors.

Figure 4.12: Ghana Gas Infrastructure Phase 1



Source: Author's Construct, 2017

Figure 4

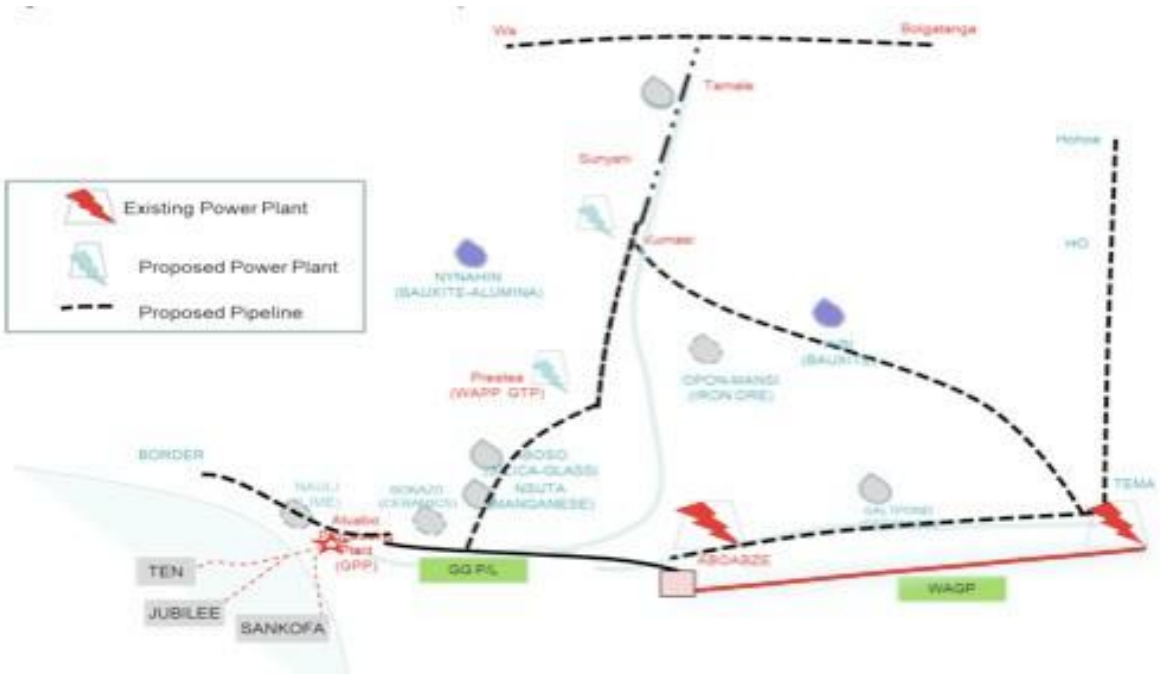


Source: Author's Construct, 2017

## 4.10 Transmission Facilities Plan

Based on technical parameters adopted, the following national transmission pipeline network will be developed.

Figure 4.14: Ghana Gas Transmission System



Source: Gas Master Plan, 2015

### 4.10.1 Western Corridor Gas Pipeline System

The proposed Western Corridor pipeline covers the Takoradi-Elubo border along the western coastline and takes off inland via the Essiama- Prestea lateral to Kumasi and ends at Sunyani at a cost of US\$563 million.

### 4.10.2 Eastern Corridor Gas Pipeline System

The proposed Eastern Corridor pipeline starts from Takoradi to Tema and has a dual path: one towards the Volta Region and the other to the Eastern Region terminating in Kumasi in the Ashanti Region at a total cost of US\$675 million.

### 4.10.3 Northern System

Connections from Kumasi via Sunyani, Tamale, Bolgatanga and Wa are proposed. The northern pipeline section is costly and the viability of the system is questionable. These are in effect three pipeline segments with a length of 300 km (Sunyani-Tamale) and 150 km (Tamale-Upper Junction, the approximate midpoint between Wa and Bolgatanga) with extensions to Wa and Bolgatanga totalling about 600 km at a cost of US\$468 million. Very low throughput volume and high capital cost means that the postage stamp transmission tariff would be high.

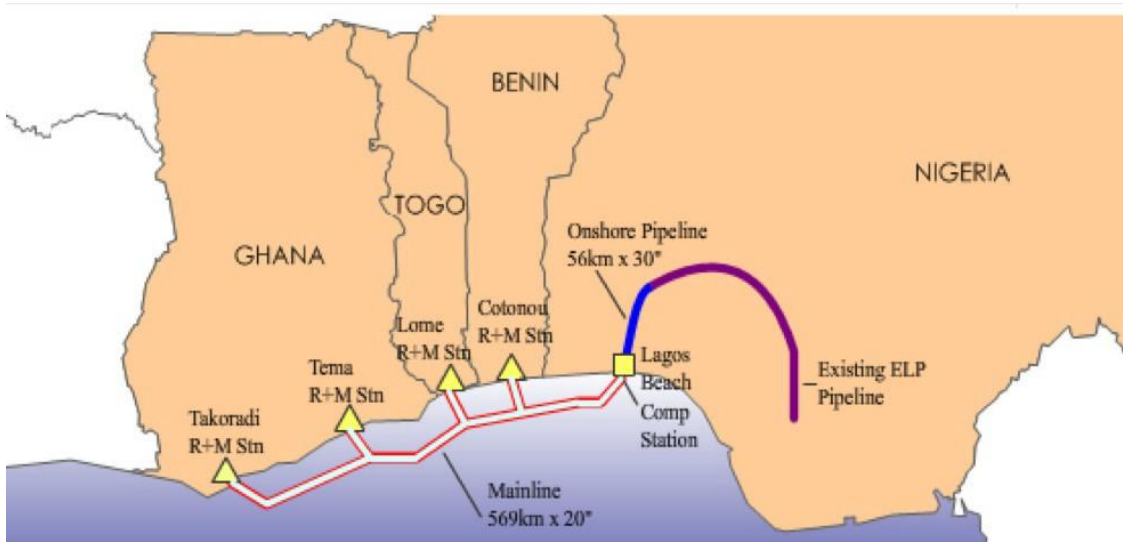
4.11 West African Gas Pipeline (WAGP)

The WAGP is a 691 km long offshore pipeline starting from Nigeria and ending in Ghana, with landing points in Cotonou (Benin), Lome (Togo), Tema and Takoradi. At full capacity and without compression, the pipeline can deliver 170 mmscfd. The maximum deliverability, requiring additional compression, is 474 mmscfd. While the contracted capacity for Ghana is 123 mmscfd, it should be noted that to date the WAGP has failed to deliver the contracted quantity consistently.

The flow of Nigerian gas has practically been restricted to Tema, with the Tema-Takoradi section of the WAGP remaining largely unutilised. This has opened the possibility of using this section of the WAGP to reverse flow surplus gas in the Western Corridor to feed the Eastern Corridor demand centres.

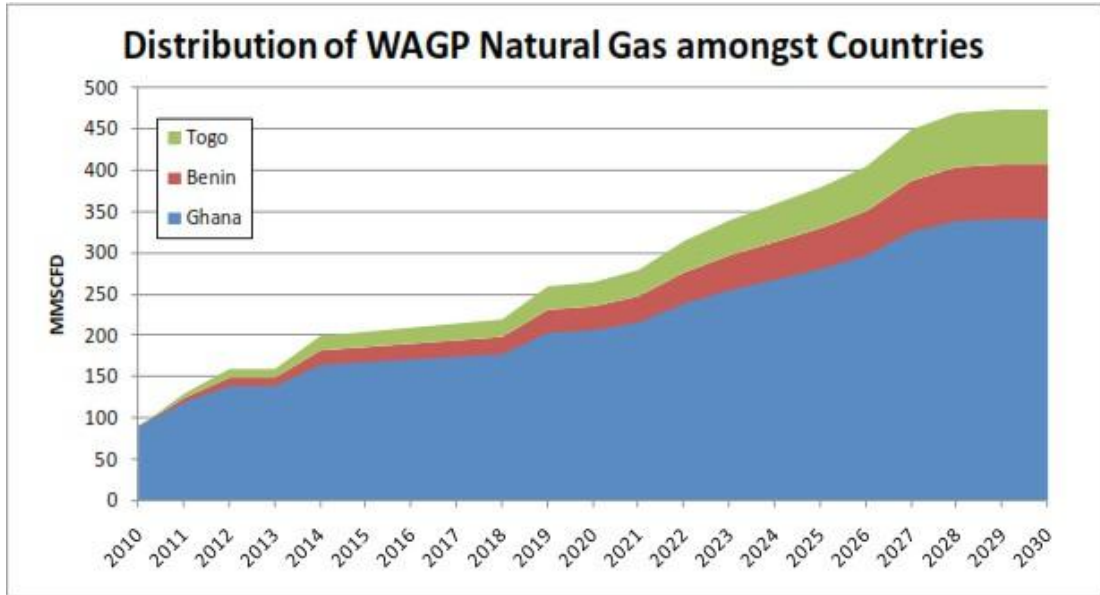
The distribution of natural gas from the pipeline to Benin, Ghana and Togo is shown in Figures 4.15 and 4.16.

Figure 4.15: The West Africa Gas Pipeline connecting Nigeria, Benin, Togo and Ghana



Source: Gas Master Plan, 2015

Figure 4.16: Distribution of Natural Gas from WAGP amongst Countries



Source: Ghana National Petroleum Corporation, 2011

4.12 Enablers for Implementation of Oil and Gas Infrastructure Plans

The petroleum infrastructure plan considers all the elements that influence the long-term life-cycle of the facility including design, construction, operation and maintenance. The enabling environment that drives the plans is critically important, with structures such as institutional and regulatory frameworks (both technical and financial), capacity building, community relations and corporate social responsibility in project affected areas, with local and private entity participation as well as access to finance. The institutional framework will reflect a clear and unambiguous delineation of sector agency roles to ensure sustainable growth of the industry.

4.12.1 Local Content

The promotion of “local content” in the petroleum industry in Ghana will necessarily be under the umbrella of the private sector. Local content would have to be unambiguously defined both in the context of individuals and corporations. Appropriate safeguards need to be in place to ensure that the implementation of any local content policy does not prove counter-productive. In selected cases, the government can also assist in providing access to capital to qualified “local entities”.

5.12.2 Capacity Building

Building the necessary local human capacity to meet the challenges of a relatively new petroleum industry in any country will require dedicated government and private investment. Both the academic institutions and the local industry have to be key stakeholders in this venture. Training in the principles and application of the relevant technologies need to be offered at home and abroad to both students and industry personnel. Cross-functional training should also be encouraged to sustain the intellectual capacity and versatility of the work force.

4.12.3 No Gas Flaring Policy

Ghana has a “No Gas Flaring” policy meaning that any produced gas will have to be:

- α. Re-injected back into the reservoir, or
- β. Developed for utilisation.

Option (a) enhances oil production rates particularly in the later years of the reservoir’s life. Option (b) is a more costly option in terms of facility requirements, but the development option will result in tremendous revenue potential as well as significant job creation.

Either of the two options will mean less atmospheric emission and a good basis for application for emission credits.

## 4.13 Gas Pricing Policy

The Natural Gas Pricing Policy (NGPP) was published by the then Ministry of Energy (MoE) in May 2012 and sets out the gas pricing principles. The 2012 document envisaged import parity pricing for gas, resulting in expected surplus revenue being accumulated in a Gas Rent Fund. This will, among others, be used to resolve investment deficits in the power sector, and, when resources permit, cross-subsidise the fertiliser industry and other strategic sectors.

## 4.14 Recommended Actions

### Policy and Regulations

To promote sustainable growth in the oil and gas industry, the government will develop enabling policies across the petroleum value chain. These policies will achieve the following benefits:

- i. Reflect fair returns to all stakeholders, including government, investors and end- users.
- ii. Be transparent, predictable, clearly defined and open to all investors that meet specified criteria.
- iii. Be simple to administer and not impose unnecessary bureaucratic ‘red-tape’ on private investors.

An enabling Act, in addition to the Petroleum Act 919 (2016), should be developed specifically for the gas sector.

### Institutional and Regulatory framework

The institutional and regulatory frameworks will reflect a clear and unambiguous delineation of sector agency roles. A responsibility matrix for the various sector agencies needs to be developed to spell out and establish roles clearly.

### Industry Development

The government will actively seek and encourage private sector involvement, with investment promotion and local content participation; and facilitate access to capital. There is a critical need to build local human capacity to meet the challenges of a relatively new petroleum industry including the areas of design, material specification, construction and operation and maintenance. Active promotion of community relations and corporate social responsibility in project affected areas is also recommended.

### Oil Demand and Utilisation Plan

The government will develop an oil utilisation plan that clearly spells out an allocation scheme for the various industries including power generation, vehicular transport and industrial heating. Demand for oil and oil products for the uses mentioned above will be considered alongside other sources of fuel or energy forms.

### Oil Supply Plan

The development of indigenous oil supply sources (both offshore and onshore) would be strongly encouraged to reduce cost and enhance supply security. The national oil company, GNPC, will initiate its own exploration and production business within the next 5-10 years.

### Oil Infrastructure Plan

A dedicated infrastructure plan that links the supply points to the market will be developed and regularly updated. Ghana needs another refinery to augment or replace the existing one at Tema. This should have sufficient capacity to handle both indigenous and imported crude. For petroleum products storage, periodic assessment of available capacity will be conducted. Pipeline infrastructure that transports petroleum products will be expanded to gradually replace road transportation (BRVs).

### Gas Demand and Utilisation Plan

The Gas Master Plan, which is the roadmap for the growth of the nascent gas industry, will be updated periodically and reflect the changing industrial needs into the future. Petrochemical and agrochemical industries should be given priority after power generation. Demand for gas and gas derivatives for the uses mentioned above will be considered alongside other sources of fuel or energy forms. A predictable gas pricing methodology (for both commodity and tariffs) will be developed and adhered to.

### Gas Supply Plan

The development of indigenous gas supply sources (both offshore and onshore) will be strongly encouraged to reduce cost and enhance supply security. Planned or unplanned disruptions to gas supply can be addressed either by linepack or an LNG source, depending on the duration of the outage or imbalance. Pipelines will be constructed linking offshore oil supply points to new refineries.

### Gas Infrastructure Plan

An appropriate gas infrastructure plan with adequate available capacity will be determined and revised periodically to handle any incremental flows coming onto the system. The requirement for an additional train for gas processing should be assessed based on projected production of raw gas from the fields.

