International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

Affordable, Sustainable and Clean Energy Option for Bangladesh Industrial Sector: A Case Study

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***Abstract*— In context of prevailing depletion of prime energy resource (Natural Gas), Bangladesh is facing acute energy crisis. Although global energy resources seem to be abundant, the environmental Pollution and climate change, in particular, pose additional limitations. Clean technologies require adequate financing and consumers should be prepared to pay higher prices. This paper deals with sustainable, affordable and clean energy option, applicable for industrial sector of a developing country with limited energy resources like Bangladesh.**

***Index Terms*—Sustainable and Affordable Energy, Clean Coal Utilization – Coal Water Slurry / Producer Gas and Onsite Steam and Electricity Production.HFO, LNG, LPG, BTU, Ktoe, CSW.**

I. INTRODUCTION

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as a new development target up to 2030 [1]. SDGs are based on Millennium Development Goals (MDGs). Out of 17 goals of SDGs, the following three have strong connection with the energy and power sector development:

- Goal 7: Affordable and clean energy. Ensure access to affordable, reliable, sustainable and modern energy for all.
- Goal 9: Industry, innovation, infrastructure. Build resilient infrastructure, promote sustainable industrialization and foster innovation.
- Goal 13: Climate action. Take urgent action to combat climate change and its impacts.

In December 2015, COP21 was held in Paris, and Paris Agreement was adopted as a new framework for the countermeasures of the global warming and replace Kyoto Protocol adopted in 1997. This Agreement will have a legal binding force effective to all the 196 participating member states and areas to the Agreement (Paris Agreement). Global energy demands have not yet been fully realized due to the lack of sophisticated technologies and sufficient energy resources as a result world is facing severe energy crisis especially in developing country and it is expected to increase in the forthcoming years. In order to reduce the gap between demand and supply clean coal technology would be one solution. The main focus of this case study is to provide electricity in industry by developing clean coal technology. Followings are the rationale for development of clean technology [2].

- Abundance and relative low cost per BTU for coal.
- Reduce dependence on consumption of Natural Gas and the much higher priced Oil/LNG.
- Add coal to the generation fuel mix in an economic and environmental friendly manner.
- Potential lower life cycle cost by retrofitting uneconomical heavy-fuel oil Natural Gas boilers.
- Diversity of fuel can improve fuel availability and pricing security.
- Fuel options for energy are limited and tendency of the commercial fuel close to depletion.

II. OVERVIEW OF BANGLADESH POWER SECTOR

A. Social Economic Scenario

The area of the country is 147,570 km2, population is 156,594,962, and density is 1,033 persons per km2. This is a high population density. The Bangladesh economy maintained a high growth rate of 6.2% on average for 10 years until fiscal 2012. Supporting economic growth is the Ready-Made Garment (RMG) industry, which is increasing exports and expanding demand due to the influx of overseas workers' remittances [3]. On the other hand, the economy has been cited as structurally vulnerable because of its dependence on external demand.

TABLE I
NOMINAL GDP PROJECT (CURRENT PRICE)

	2015	2020	2025	2030	2035	2041
GDP (Billion USD)	194.30	340.58	585.62	943.45	1,423.64	2,175.52
Growth rate (USD)	11,9% p.a.	11,4% p.a.	10.0% p.a.	8.6% p.a.	7.3% p.a.	-
Exchange rate	77,9	83.2	88.0	92.5	96.3	100.1
GDP deflator	5.8%	5.3%	4.8%	4.3%	3.8%	3.2%
Per Capita (USD)	1,207	1,998	3,270	5,060	7.396	10,993

The above table summarizes the basic index of GDP Growth which are as follows [3]:

- This projection of GDP (nominal) up to 2041
- In projecting nominal GDP, inflation rate is expected to become gradually moderate, to 3.2% in 2041.
- The study team considers that the 7.4% p.a. growth from 2016 to 2020 might be overstretching and that the growth rate between 6.5 and 7.0%, as projected by international organizations, may be more realistic.

- However, considering the consistency with the economic development plan officially made public by GoB, this study follows the GoB's economic growth target, i.e. 7.4% p.a. from 2016 to 2020, assuming that all the necessary policy measures to achieve this target will be optimally in place.
- Real GDP (constant at 2005 price) as of 2041 is estimated to reach 38 trillion BDT, about 4.6 times of the current level (8.2 trillion BDT). The average growth rate from 2016 to 2041 is 6.1% p.a.
- Nominal GDP (current price) is estimated to become about 220 trillion BDT in 2041.

B. Population Projection [3]

- Population projection refers to United Nations' "World Population Prospects 2015". In the "Medium variant" scenario (adopted for GDP projection), the population as of 2041 is expected to reach 198 million, i.e. 0.8% p.a. growth from 2014.
- The growth rate is expected to decline from 1.2% to 0.4%.
- In the "Low Variant" scenario, the total population starts decreasing from 2039.

C. Economic Development Scenario [3]

- Bangladesh's GDP per capita as of 2014 (747 USD) was almost equivalent to that of Thailand around 1976.
- Bangladesh saw a 4.2% p.a. growth of GDP per capita from 1998 to 2014 (16 years). This can be compared with Thailand's growth rate (4.4% p.a.) from 1960 to 1976 (16 years)
- Assuming that Bangladesh follows the track of Thailand's economic growth in the past, the accelerated growth is expected to continue
- In addition, considering the follower advantage for Bangladesh (4.9% p.a. growth for the past 10 years), the growth rate of GDP per capita can be still higher than the past track of Thailand.
- Bangladesh GDP capital started increasing rapidly when the industrial sector's share exceeded 20%.

Recently the trend curve has been taking a similar track to what Thailand experience before.

D. Future Image of Industrial Structure

- Until 2021, Bangladesh Industry will depend on natural resources, imported materials and imported parts & machines and will diversify gradually including Light Engineering and Pharmaceutical.
- After 2021 towards 2041, Bangladesh industry will be above to provide row materials and machines for itself and will be a high value added industry by introducing FDIs and taking advanced technologies and knowledge's.
- Agro industry is always important because it can absorb huge labor force and can secure food supply.
- Furthermore Agro industry can be high value added industry by agro processing.
- Jute and Jute goods were main export products in the past century in Bangladesh.
- Until 2021, although the Bangladesh economy will remain to depend much on traditional industries RMG Jute and Leather etc., the new industries will expand gradually and the export products will the diversified during the same period and from 2021 the tendency will be accelerated.

TABLE II
GROWTH RATE OF MANUFACTURING AND TOTAL GDP [4]

	2010	2011	2012	2013	2014
Manufacturing	6.65%	10.01%	9.96%	10.31%	8.68%
Total GDP	5.57%	6.46%	6.52%	6.01%	6.12%

Table 2.Shows the growth rate of manufacturing sector for the past five years which has outperformed that of total GDP, which indicates that manufacturing in Bangladesh has been growing rapidly.

E. Projection of Industrial Sector Energy Consumption

- The main reason why the ratio of industrial sector's energy consumption to GDP is creeping up (GDP elasticity higher than 1) in Bangladesh is that the economic development is still at an early stage and that a shift from labor-intensive industries to energy –consuming industries is still in process.
- The energy consumption of the industrial sector will be about 54,500 k toe, about nine times increase from 2013, in 2040

TABLE III
PROJECTED ENERGY CONSUMPTION IN INDUSTRIAL SECTOR

Year	2015	2020	2025	2030	2035	2040
Energy Consumption (Ktoe)	8000	11000	18000	28000	40000	54000

Table 3 indicates the projected energy consumption in 2040 will be 54000 (Ktoe) which is about 7 times of 2015 consumption.

F. Energy utilization in Industry, Power and Fertilizer (Major Sectors)

1) Industrial Sector Efficiency

Bangladesh Industrial Sector consumes both Electrical and Thermal Energy. For electrical energy industries basically depend on Grid supply as well as gas based captive generation. Both electricity supply from grid and Gas supply are too erratic and industries often opt for standby Diesel generation. For thermal energy industries primarily depend on Gas which is also erratic in supply from low pressure to no supply. To supplement industries opt to use Diesel/HFO for boiler operation.

The Boiler efficiency is around 80% but the captive electricity generation efficiency is 30% to 35% only.

2) Urea Fertilizer Production Efficiency

Natural Gas Consumption is 44mcf/ton Urea average which is 1.7 times (25 mcf/ton) more than world standard. It indicates the potential in efficient utilization of Natural Gas in Fertilizer Industries in Bangladesh.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

3) Power Generation Efficiency

Gas Consumption for Power Sector (under BPDB) is 337.4 BCF in 2014 FY while Power Generation Capacity was 8,340 MW and Generated Power was 42,200 GWh. From these figures, it is assumed that current power generation efficiency is around 38%. Provided that efficiency can be raised to 45%, which is considered as a international benchmark as a gas based power plant, Energy gas consumption will be reduced to 285 BCF, and differential of 52 BCF is wasted. This is equivalent of 1,300 MW power plants.

TABLE IV
BANGLADESH DAILY GAS PRODUCTION FORECAST (MMCFD) FOR 2015-2019

Petrobangla	2015	2016	2017	2018	2019
Grand Total	5315	5551	5469	5309	5122

Table IV provide data of recent past and future Daily Gas Production which indicates the followings:

- Gas Supply from current domestic gas field will peaking out in 2017- 2018, and decline.
- Recoverable Proven reserve of natural gas in 20.8TCF.12.1 TCF has been produced and consumed by 2014. Remaining gas reserve will be 8.7 TCF (Reserve to Production ratio in 9.5 years).
- Current Gas development performance is not satisfactory.
- New gas fields need to be explored and developed

G. Gas price and cost structure [5]

Gas pricing system is prepared and decided by the Bangladesh Energy Regulatory Commission (BERC). There are eight market sectors and each has its own pricing structure. These price figures are revised from time to time under the circumstances to suit.

TABLE V
BANGLADESH INDIGENOUS GAS PRICE BY SECTOR (FROM 1 JUNE 2017) [5]

Sl. No.	Sector	BDT/M³	USD/MMBTU
1	Power	3.16	1.1429
2	Captive Power	9.62	3.486
3	Fertilizer	2.71	0.987
4	Industry	7.76	2.809
5	Tea Garden	7.42	2.692
6	Commercial	17.04	6.180
7	CNG	40.0	14.500
8	Domestic	11.20	4.064

It is to be noted that some calculation are done with local currency, where 1 USD is equal to BDT 80. Cost component consists of Government Tax 55% and Natural Gas Extraction & Distribution Charge 45%.

Table V Demonstrate, although natural Gas Price is not beyond International level-government raised gas price once in September 2015 and twice in 2017 about 23% on both occasions, which lead the investors to a great anxiety and future fuel price and profitability.

In circumstance above to sustain continuous production and development the loan option for sustainable affordable and reliable power and energy source is Coal (Indigenous and Imported) which is potentially lower cost against imported HFO, LNG and LPG.

The present market price of the above mentioned fuels are as below:

- CNG (Indigenous) – Tk. 40.0 / M³ (Heat content 35.0MJ/M³)
- LPG (Imported) – Tk. 69.0/ Kg (Heat content 50.0 MJ/Kg)
- HFO/ Diesel (Imported) – Tk. 42.0/ Tk. 62.81 per Litter (Heat content 40 MJ/Litter)
- Imported Coal – Tk. 10.0 / Kg (Heat content 25.0MJ/Kg).

It is worth noting that the price of LNG has not yet been formulated but apprehension is that it will be anywhere around CNG (Indigenous) price.

H. Bangladesh Coal Background [6]

U.S. Geological Survey states that the Bangladesh has "small reserves of coal, natural gas, and petroleum. As of 2011, coal supplied only 2.5% of the electricity generated with gas accounting for almost 80%. In May 2011, the country's overall coal production was around 3,000 tons a day, from the lone operational state-owned coal mine.

Rapid economic growth stimulating a rapid increase in electricity demand and shortages of gas for power generation, the Bangladesh government is looking to domestic and imported coal to fuel a significant proportion of its ambitious power generation expansion plans. In its 2010-2011 annual report the Bangladesh Power Development Board flagged that the government wanted an additional 12,000 MW in capacity installed by the end of 2016, 24,000 MW by 2021 and 39,000 MW by 2030.

I. National Coal mining policy

As of 2011, the government has a plan to generate over 10,000 mw of electricity from coal-based power plants by 2021 and 20,000mw by 2030 under its proposed coal sector master plan. The plan calls for over 50,000 tons of coal a day for generation of electricity by 2015, which would double by 2021. Of the targeted electricity, 11,250 MW would come from plants burning coal from domestic mines, while the rest would be generated at the plants run by imported coal [6].

According to the state-run oil, gas and mineral resources corporation Petrobangla, there are five deposits of about 2,500 million tons of high-quality coal in the three northern districts.

III. CLEAN COAL TECHNOLOGY

Coal is an extremely important fuel and will remain so. Some 23% of primary energy needs are met by coal and 39% of electricity is generated from coal. About 70% of world steel production depends on coal feedstock. Coal is the world's most abundant and widely distributed fossil fuel source [7].

Development of new 'clean coal' technologies is addressing this problem so that the world's enormous resources of coal can be utilized for future generations without contributing to global warming. Much of the challenge is in commercializing the technology.

International Journal of Engineering Research & Technology (IJERT)
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Bangladesh is a Developing Country with very limited Energy Resources and taking note of its present socio - economic condition affordable and alternative to coal utilization is not foreseeable. To meet industrial requirement in electrical and thermal energy (heat and power) Bangladesh might have to opt for clean coal utilization technologies in at site generation to minimize the Health Hazards and Environmental Pollution and for continuing the pace of development as conceived by Government.

The followings are the available prudent technologies for clean coal utilization:

- Use of coal in Solid (Pulverized) state
- Use of coal in Liquid (CWS) state
- Use of coal in Gaseous (Producer Gas) state

The first option is basically for grid power generation. A few power plants with potential capacities (650 MW, 1300 MW) have been under planning and construction phases in costal belt of the country to facilitated the import and handling the huge quantity of coal. These power plants are of Ultra Super Critical mode of operation to minimize the Health Hazards and Environmental pollution, with Net thermal efficiency 39% to 44% [7].

The industrial sector factories of Bangladesh mainly Textile and Garments and others like pulp and paper, steel – making and Re-rolling, cement, Glass, Sanitary and Tiles, Chemical, Chemical Fertilizer, Pulp & Paper, Sugar and Jute Mills, Brick, Food Products (Frozen Foods) are located in a scattered manner throughout the country. The basic requirement of these industries is in the range of up to 20 MW (electricity) and 30 / 40 ton per hour (thermal) per factory [7].

Till today these industries run on Natural Gas from grid – which has been utilized for captive power generation and onsite steam production. Presently supply of natural gas is totally erratic with very low / zero pressure. The situation compelled the shutdown of the factory production leading to enormous financial losses. To overcome the hurdles factory owners opt for sourcing of other primary fuels: like CNG (from Transport fueling station) LPG (private imported), HFO and Diesel (Government controlled).

This Fuel Switching from Indigenous natural gas to alternative primary Fuel lead to the drastic fall of profit margin and in many cases to incur losses. In circumstances above to survive and stay and develop the only option remain open is utilization of coal (Indigenous and Imported).

For sustainable development of industrial sector and remain operational coal utilization for onsite distributed power and energy production conforming clean and environment friendly prudent technologies are:

A. Coal combustion as CWS (Coal Water Slurry)/CWM (Coal Water Mixture) / CWF (Coal Water Fuel)/Coal Water Syntheses) / LC (Liquid Coal), which was developed in the Soviet Union [8]

CWS/CWM/CWF/CWS/LC can be effectively produced from virtually any grades of black bituminous coal or brown coals, as well as from dry and moist wastes of coal enrichment factories. The adoption of CWS as fuel permits to radically reduce the “footprint” and volume of coal preparation facilities; therefore construction costs become lower; other costly components of the traditional coal dust aspiration and under washing systems; the degree of fire and explosion danger at the power plant facilities is minimized to zero; CWS production facilities cause no environmental pollution and provide safe sanitary and hygienic condition for its operating personnel.

There is a minimization of other losses and dangers associated with coal long-term store (oxidation, coal dust loses caused by wind, autogenously ignition or explosions), as well as its transportation and extended feed system [8].

Any regular (dust / pulverized) coal-burning thermal power technology is cumbersome, archaic and environmentally unfriendly featuring the following five principal aspects associated with fuel processing:

- A coal warehouse into which coal is unloaded and where it is stored;
- A coal feed system (the bunker, the feeder, and the magnetic separator. etc.).
- A coal dust production facilities including coal crushers, mills, etc.
- Storage bunkers, coal dust feed and dehydration units.
- A coal dust furnace' feed system and the devices used for removing and filtering smoke gases.

A comparison of different combustion methods reveals the following advantages of the two-stage CWS -burning furnace:

- The solid constituent of the water - coal slurry does not need to be reduced to a fine grained substance (the CWS optimal sizes being 71-µ (60-70%) and 71-250 µ (the rest).
- The temperature in the reaction zone will always be maintained below 1000°c.
- Heat increase is distributed radically to the furnace screens;
- CWS can be effectively produced from a broad spectrum of base coals as well as from residue (sludge) of coal enrichment factories.
- The proposed fluidizes-bed furnaces have as extensive adjustment range. Use of CWS as fuel in furnaces excludes the hazards of coal under burning (99.5% coal burn-up rate), drastically reduces the quantity of or completely eliminates all harmful substances, including sulphur, in the gases, that are otherwise emitted into the atmosphere, provides better working conditions of the personnel responsible for fuel preparation and power plant /boiler operation.

The ashes collected as a result of CWS combustion are very finely drained and contain no harmful substances whatsoever. They can be utilized as building materials, as cement fillers as well as for land reclamation, etc, etc. The ashes obtained from the combustion of CWS produced from brown coals may also be effectively processed into mineral fertilizers.

B. CWS Process and Benefit

CWS is a unique patented process, developed in Russia / China over the last 20 years. It has been perfected to use the coal (of any grade any specification) in a thermal power stations. This process ensures:

- Full combustion of carbon
- Minimum production of harmful substances and gases including C02
- Long-time storage (24 months) of the cavitatated plasticized slurry without losing coal's original properties

All this results into multipoint pollution in a coal fired power station. Considerable pollution savings are achieved on following points [8]:

- This process can utilize any grade of coal.
- At coal, milling coal is mixed with water, resulting no coal dust or any other air bound particles. The process itself create less wear and tear on milling equipment (reducing by 75%).
- Putting the slurry into combustion areas is efficient and less pollutant the coal dust.
- Energy requirement is reduced by 30% to produce the slurry creating less Pollution
- Pre-furnace ensure that no Nox is produced and minimum sox is produced.
- Effecting burning in chamber furnace endures no Bottom Ash or Slag IS produced. This also leads to super cost reduction in maintenance.
- The only reaming ash. which represents inherent component of ash contents in the original coal become the only ash, which has no carbon left, and no harmful residue left. The Ash is disposed directly into a block making unit (optional).

Cost of the plant Fuel Switching is not more than 13-15% of the total cost of power station. Time taken to install is approximately 8-10 months. Investment pay-off of retrofitting is about 5 months. Investment cost to build new CWS boiler is about the same with new oil fired boiler, but the operating cost is significantly lower on the CWS boiler. This process provides multipoint pollution & cost saving at minimum cost.

TABLE VI
STANDARD SPECIFICATION OF CWS / CWM/CWF/CWS/LC

Parameters	Density	Viscosity	Size	Ash	Sulphur
Values	65-70%	1000CP	d<50µ	A<7%	S<0.5%

Table VI contains the basic specification of CWS

1) Favorable Economic Effects

It is difficult to compare the relative costs of using a CWS against traditional coal or oil firing, because the price of the CWS itself varies according to the coal price, the location of the plant, and/or the plant capacity etc. The economic advantage compared to pulverized coal is however indicated by significant reduction in handling cost by simplifying facilities required for loading and unloading activity in general.

- 2 tons of coal water slurry (costs ± US$ 300) can replace 1 ton of heavy oil (costs US$ 500), a significant saving of production cost.
- Users can save ± 70% fuel cost for per ton of fuel oil (heavy oil)
- Coal water slurry can replace heavy oil fuel and brings tremendous economic benefits as an oil substitute fuel.

2) Current end Users of the Product and its Market Potential

- At present 10000 MW capacity Cws Power Plants are in operation in China.
- At present, there are more than 20 processing plants in China. Production of coal water slurry with the total production capacity of more than 4 million tons (colorific valued of oil to Cws is 2 to 1).
- HFO and dust coal burning boilers are most likely to be switched in Cws.
- It is also feasible to burn in boilers with Natural Gas where it is in deficit.

Ukraine in 2012 Guarantee for US$ 3-5 billion for Reconstruction and Modification of Power Plants from Natural Gas for CWS Burning.

C. Coal Gasification - Producer Gas [9]

An alternative form of coal combustion is conversion of solid fuel into a Gaseous fuel known as Producer Gas which is a mixture of gases: hydrogen, carbon monoxide, methane, carbon dioxide, water vapor, nitrogen, tar and suspended particulate matter which has been develop and utilized throughout the world as primary fuel and feed for Chemical, Pharmaceutical and Chemical Industries.

Gasification is sub-stoichiometric combustion; it involves a thermo-chemical conversion process involving high temperature oxidation and reduction operations of Coal with air/oxidant under sub-stoichiometric conditions. The resultant gas is known as producer gas. Raw and hot producer gas could be used for meeting thermal needs or could be cooled and cleaned, and used in reciprocating engines & gas turbines for power generation.

1) Process

The essence of gasification process is the conversion of solid carbon fuels into carbon monoxide by thermo chemical process. The gasification of solid fuel is accomplished in air sealed, closed chamber, under slight suction or pressure relative to ambient pressure. Gasification process occurring in general explained in this section.

In gasification, the combustion is carried out at sub-stoichiometric conditions with air to fuel ratio being 1.5:1 to 1.8:1. The product gas thus generated during the gasification process is combustible. This process is made possible in a device called gasifier with a limited supply of air which is shown below in figure 1.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 10, October - 2017

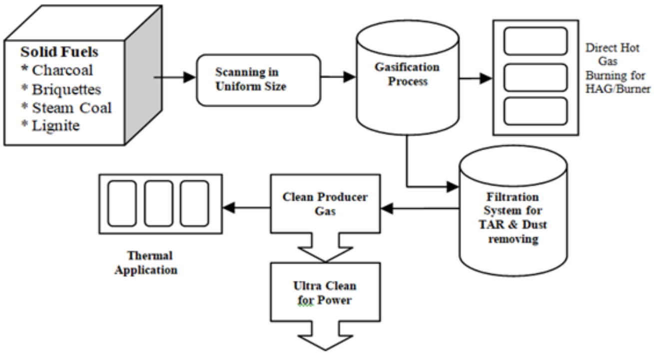

Fig. 1. Gassification process diagram.

The yield of Gasification is a combustible gas having a calorific value of 4.5-5.0 MJ/Kg with an average composition of CO: 20 +/- 1%, CH_4: 3 +/- 1%, H_2: 20 +/- 1%, CO_2: 12 +/- 1% and rest N_2.

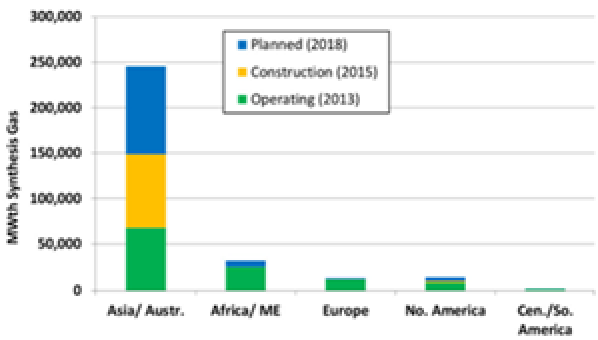

Fig. 2. Gassification capacity by geographic region [9].

Fig. 2 Demonstrates that Gasification plants had been fairly evenly distributed between Asia /Australia, Africa/Middle East and North America. The gasification capacity (both operational and under construction) in the Asia/Australia region now exceeds the rest of the world put together. The prime movers behind this current and expected growth are the chemical, fertilizer, and coal-to-liquids industries in Asia.

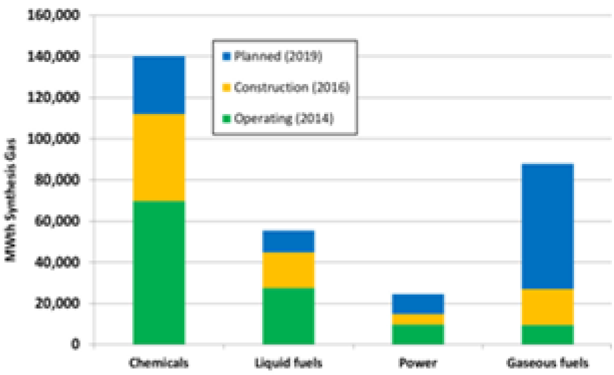

Fig. 3. Gasification by application [9].

Fig. 3 Shows that Gasification for substitute natural gas has also shifted to Asia. In contrast, the natural gas (in the form of Liquefied Natural Gas - LNG) is extremely expensive in Asia and Africa. The high cost of importing LNG and the concerns about energy security haves prompted potential number of operative and under construction plants in Asia.

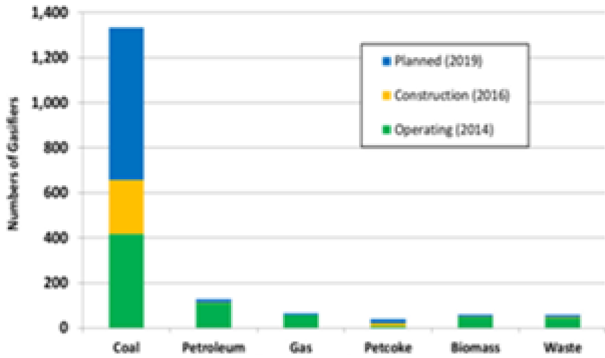

Fig. 4.Number of gasifiers by primary feedstock [9].

Fig. 4 The bar chart demonstrates the dominance of coal in feedstock. The 948 billion short tons of recoverable coal reserves estimated by the Energy Information Administration. The amount of coal burned during 2007 was estimated at 7.075 billion short tons. In terms of heat content, this is about 57,000,000 barrels (9,100,000 m3) of oil equivalent per day. In comparison (2007) natural gas provided C51,000,000 barrels (8,100,000 m^3) of oil equivalent while oil provided 85,800,000 barrels (13,640,000 m3) per day- Coal is now the dominant feedstock and will continue to be so.

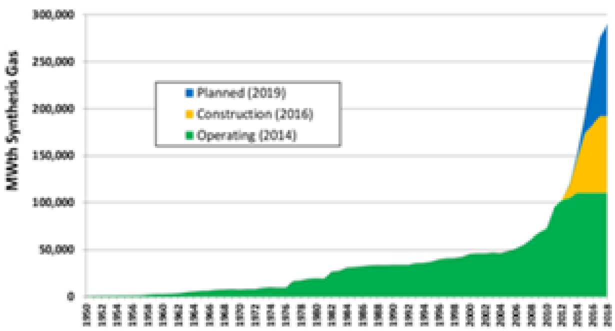

Fig.5. Cumulative worldwide capacity and growth [9].

Fig.4 Demonstrates Gasification Market. Trends of Gasification projects are becoming both larger and smaller. Demand for smaller, modular gasifiers for Coal, biomass and waste gasification is increasing. Worldwide gasification capacity is expected to grow significantly by 2018, with the primary growth occurring in Asia.

D. Benefits: Coal Gasification and Utilization

1) Applicable Coal

Coal of all kinds in size 0~10mm could be taken. Lignite, high Sulfur Coal, high ash coal, Bituminous coal, Hard Coal (to be pulverized) could be gasified well.

2) Less Water Cost

Less water is cost in gasification process. Gasification agent could be air, air plus steam, air rich with O2 plus steam, or O2 plus steam. The moisture in coal could serve as gasification agent too.

3) High Safety

Easy to run and control, no danger as there is no pressure parts in the gasifier station. Control room is separate from gasifier station. Nobody will be exposed to any risk. To suspend or restart is simple.

4) Work under No Pressure

Management is easy as its process is simple with no tar and phenol water auxiliary system.

5) High Utilization of Coal

The utilization percent of carbon is over 95% generally. The extra heat from coal gas and discharged ash are collected and reused by waste heat boiler and in heat exchanger. The heat is to produce steam to generate electricity and air conditioning.

6) No pollutants

It produces no tar and no phenol water. There is no offensive smell. The discharged water contains no phenol contents, so it is processed simply to recycle in the gasification station. There is no Benzene and phenol in coal gas, thus De-nitrification and Desulphurization is of lower cost. Coal gas is processed by Bag dust filter to remove off dust, so no dust will harm the burning system of ceramics, steel and others.

IV. COST ANALYSIS

In Coal Gasification System and Coal Gas Boiler through a simple Filtration and Desulfurization the level of particulate materials and SO2 can be reduce to 20mg/m3 and 50mg/m3 respectively. These are far below international acceptable level. The trunkey investment for plant and mechinary of a 2t/houor capacity Gasifier,20t capacitydemy-water plant,15 t/hour Coal Gas Boiler with Filtration and Desulfurization including civil construction and mechanical erection is about USD 1.O million only [10-15].

TABLE VII
COST COMPARISON FOR ONSITE STEAM PRODUCTION FOR INDUSTRY

	Fuel Type						
Parameters	Pulv. Coal	CWS	Coal Gas	HFO	Dies-el	LPG	Gas (Local)
Burn - off Rate	80%	90%	99%	90%	90%	99%	99%
Boiler Thermal Efficiency	70%	84%	90%	84%	88%	90%	90%
Ultimate Efficiency	65%	70%	80%	80%	85%	90%	90%
Net calorific value KJ	25 MJ/ Kg	18 MJ/ Kg	6 MJ/M³	41.80 MJ/L	41.80 MJ/L	50.0 MJ/ Kg	35.0 KJ/M³
Present Banglades-h Market price Tk.	Tk. 10/Kg (Imp.)	Tk.10 Kg	Tk. 3.33/ Kg	Tk. 42.0/ L	Tk. 60.0/ L	Tk. 68.0/ Kg	Tk.7.5/ M³ (Ind. Use)
Consumpti-on to produce 1T saturated steam	150 Kg	166Kg	450 M³	72 Kg	68 Kg	55 Kg	80 M³
Fuel cost per T Steam (Tk.)	Tk. 1500	Tk. 1660	Tk. 1485	Tk. 3024	Tk. 4080	Tk. 3740	Tk. 600
Utility & Manpower cost	High	Mod.	Low	High	Mod.	Low	Low
Dust emission mg/m³	300	300	300	300	80	50	50
SO2 emission mg/m³	900	900	600	900	500	100	100

If we depreciate the total investment for switching to coal gas from present natural gas operation by 10 years (plant life time), the cost for steam production will increase only by USD 0.7/t (7000 hours operation in a year). The total cost for steam production (coal gas operation) will cost less than half in comparison with available alternative fuels like HFO, Disel and LPG operation.

In circumstances industries will be able to absorb such increase cost by uninterrupted and time bound production and supply in and will continue to survive and develop paving the industrial development and sustain GDP growth of the country.

In coal gas operated gas engines through cooling and simple Filltration Desulfurization the level of particulate materials and SO2 emission can be reduced to 20mg/m3 and 50mg/m3 repectively which is per bleow interantion acceptable level. The turnkey investment for plant and machinery of a 1.5t/hour capacity gasifier, 4 Nos.1000kW capacity natural gas engine conversion to coal gas operation (2 MW output) with cooling Filtration and Desulfurization and coal gas storage including civil construction and mechanical erection is about USD 0.6 million only [10-15].

TABLE VIII
COST COMPARISON FOR ONSITE ELECTRICITY GENERATION FOR INDUSTRIAL APPLICATION

Parameters	Available Fuel Type			
	Natural Gas (Indigenous)	Compressed Natural Gas (Indigenous)	LPG (Imported)	Coal (Imported)
Genset Capacity (Kw)	1000	1000	1000	-
Derated Capacity (Kw)	700	700	700	-
Converted Capacity (Kw)	-	-	-	500
Heat Rate Kj/kwh	11000	11000	11000	12000
Ultimate Fuel Consumption (Kj/kwh)	11000	11000	11000	15000 (Gasification)
Present Bangladesh Market price (Tk./Kj)	10/35000	40/35000	68/50000	10/24000
Fuel Cost per kwh electricity production	Tk. 2.82	Tk. 12.50	Tk. 14.96	Tk. 6.25
Utility & Manpower cost	Low	High	Moderate	Moderate
Particulate Material emission mg/m^3	50	50	50	300
SO2 emission mg/m^3	100	100	100	600

If we depreciate the total investment for Fuel Switching to coal gas from present natural gas operation by 10 years (plant and machinery life time), the cost for 1kWh production will increase only by US cents 0.43(7000 hours operation in a year). Ultimate cost of onsite electricity generation stands at Tk.9.69/kWh. This almost same to present peak hour electricity tariff(Tk.9.50 /kWh) from Grid but the Grid electricity tariff is subjected to frequent enhancement and disruptions in supply.

In this context on site electricity production and utilization ensures uninterrupted supply to sustain continuous production and meet supply dead line. The industries may avoid production loss and sustain time bound shipment and thus will continue to survive and develop paving the industrial development and sustain GDP growth of the country.

V. CONCLUSION

Prevailing depletion of natural gas and limitations in transmission and distribution facilities compelled Bangladesh industrial sector to sustain reduction in production & incur profit losses which impede a lot its development initiatives.

To supply uninterrupted electricity and steam at affordable cost & to minimize profit loss and sustain development – only option remains is to adopt distributed generation schemes based on coal as primary fuel. The latest developed clean coal utilization technologies can facilitate onsite electricity and steam generation conforming to all environmental emission and health hazard norms and standards.

The thermal efficiencies in onsite cogeneration schemes are much higher than that of ultra super critical (43% to 45% LHV basis) and IGCC (39% to 42% HHV basis) scheme which cater extreme concentration of air pollution and effluent hazards.

Presently due to electricity and natural gas supply interruptions, manufacturing costs of industries be it steel, cement, ceramics or pharmaceuticals have increased significantly in this year, eating into businesses' profit margin. A survey on 10 companies listed on Dhaka stock exchange found that eight saw a significant increase in their manufacturing expenses from a year earlier (July 09, 2017). If the trend continues, it will hamper investment and much-needed job creation in the country.

Bangladesh is trying hard to overcome present Primary Fuel shortfall through various options but these infrastructures are of very long term and of potential investment and will take a few years to come in operation. Coal (both indigenous and imported) in abundance reserve worldwide, with relative low and stable market price, can sustain and develop Bangladesh industrial sector and GDP.

The cost comparison (Annexure-1 & Annexure-2) for onsite steam production and electricity generation utilizing coal shows its economic viability and affordability in clean coal technologies, conforming all climate action and environmental pollution in comparison with alternative fuels.

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