GREEN ENERGY INTERNATIONAL LIMITED

GREEN & BROWN FIELD DEVELOPMENT:

A Case For Associated Gas Utilisation In Nigeria

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Presented by

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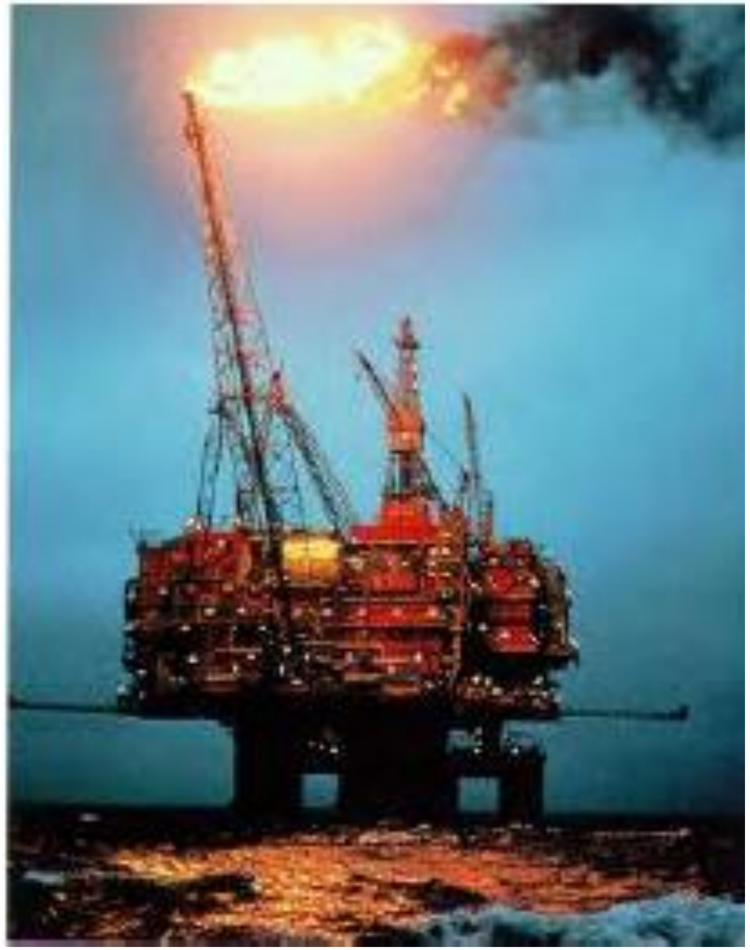
Content

Historical Perspective

- Natural gas harnessing has been a challenge for the 50+ years of oil & gas exploration in Nigeria
- Reason for this include:

1. ***Inadequate infrastructure*** to harness AG produced & ***limited gas market*** at the time
2. ***'Weak' legislature*** to restrict flaring & 'weak' sanctions when companies flare gas
3. ***Lack of willingness of early explorer***/producer (Shell/BP)

- World bank (2007) noted that the Nigerian Govt. loses $2.5 Billion annually due to gas flaring
- ~150 BCM of gas (worth $30.6 Billion) flared annually (World bank)



Historical Perspective

- *'There might be wastage of energy and resources going on which, one day, those giving advice to the Nigerians (i.e. the British) could be reproached…Until there is this worthwhile market and until there are facilities (e.g. pipelines & storage tanks) to use the gas, it is normal practice to burn off this by-product from the oil wells'*

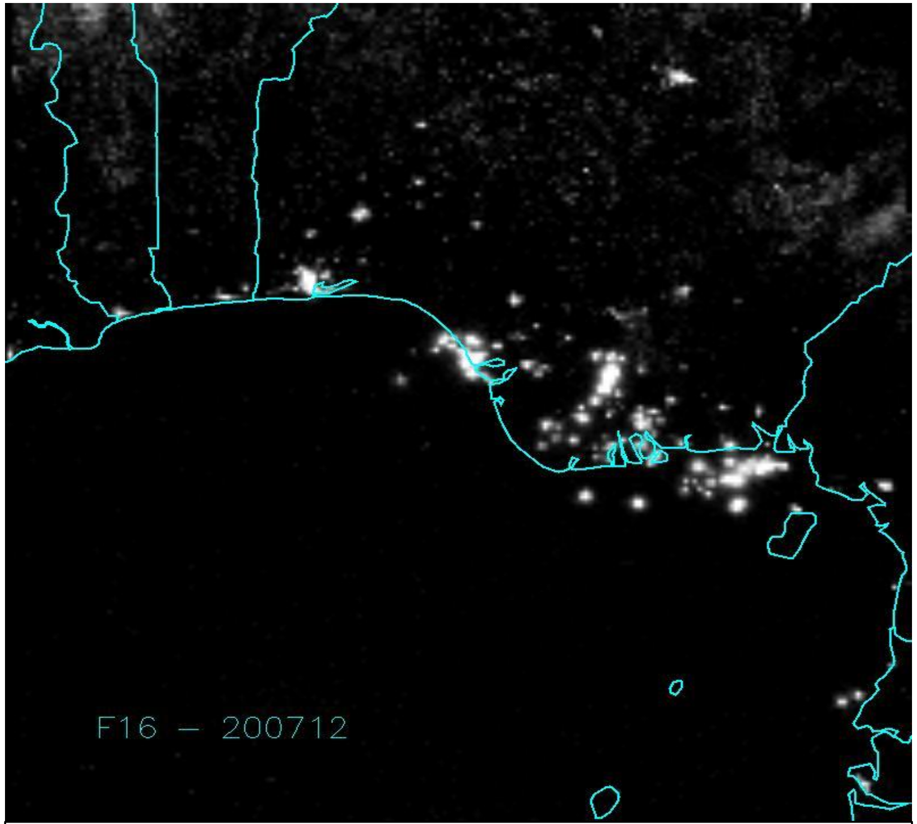
  - Lord Home

  Secretary of State to Nigerian Colony (Pre-Independence)

  Source: Nigeria Oil & Natural Gas Industry File D0/77/33 National Archives

- *"Shell/BP's need to continue, probably indefinitely, to flare off a vey large portion of the associated gas they produce will no doubt give rise to a certain amount of difficulty with Nigerian politicians, who will probably be among the last people in the world to realise that it is sometimes desirable not to exploit a country's natural resources and who, being unable to avoid seeing the many gas flares around the oilfields, will tend to accuse Shell/BP of conspicuous waste of Nigeria's 'wealth'. It will be interesting to see the extent to which the oil companies feel it necessary to meet these criticism by spending money on uneconomic methods of using gas"*

  - British Commissioner to UK Foreign Office, 1963



Nigeria Satellite Image of Flaring
(National Oceanic & Atmospheric Admin (NOAA)

- ***North sea flaring has reduced from >90% in the 70's 2% in 2015***
- ***Onshore flaring at btw 6 – 14% since 1991***

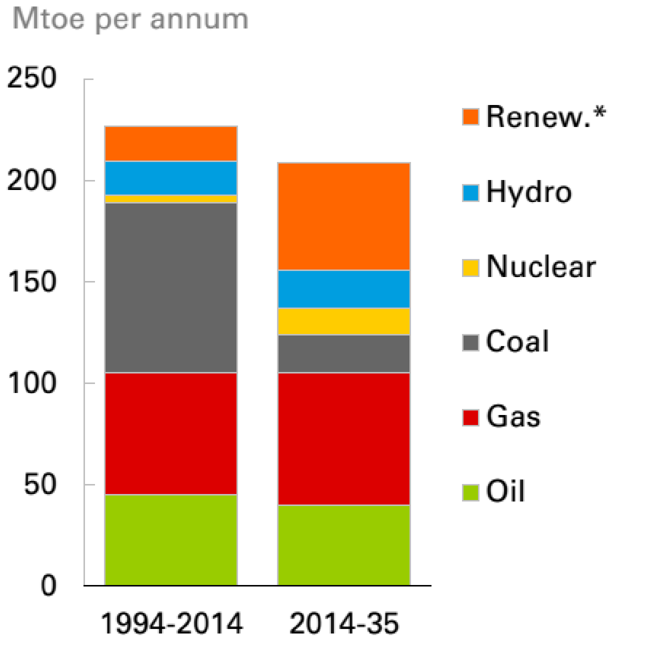
Background: Global Energy Outlook

- In '50 & '60s there was little demand or market for Gas. Natural gas has gained significant popularity in the past 30yrs providing ***24% of the world's total energy***
- *Gas is the fastest growing fossil fuel (1.8% p.a.) in the world, supported by strong supply growth, particularly of US shale gas & LNG & by environmental policies (BP Statistical 2016)*
- *Nigerian Domestic gas demand has tripled btw 2001 & 2014, growing from ~4.1 BCM/yr to 12 BCM/yr*

	Growth 2014-35 (p.a.)	Growth 2014-35 (cumulative)	2014 (share)	2035 (share)
Primary energy	1.4%	34%	100%	100%
Oil	0.9%	20%	32%	29%
Gas	1.8%	44%	24%	26%
Coal	0.5%	10%	30%	25%
Nuclear	1.9%	50%	4%	5%
Hydro	1.8%	45%	7%	7%
Renewables*	6.6%	285%	3%	9%
Population	0.9%	21%		
GDP ($2010 PPP)	3.5%	107%		
Energy Intensity	-2.1%	-35%		
CO_2 emissions	0.9%	20%		

* Includes biofuels

Annual demand growth by fuel



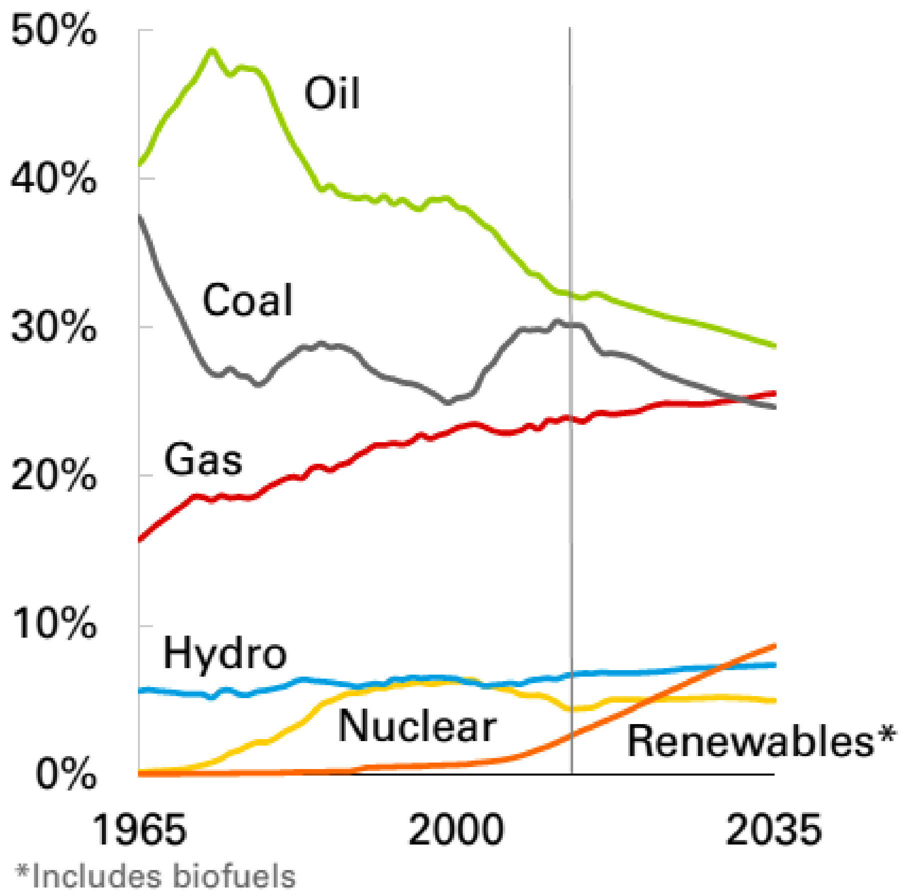
Much of the growth in energy is used for power generation… BP Statistical

Background: Global Energy Outlook

- ***Power generation*** plays a ***major role in evolution of the global fuel mix*** with m***ost demand*** expected to be in ***that area***
- ***Demand for power*** will ***grow at a rate*** >***2% per year in*** next 20 yrs
- A ***3rd of the growth*** in power generation will be in ***regions that lack adequate access to electricity*** – developing Asia & Africa
- Gas is expected to capture ***24% of power generation*** in ***industrialised nations*** & ***21% in developing countries*** by 2020

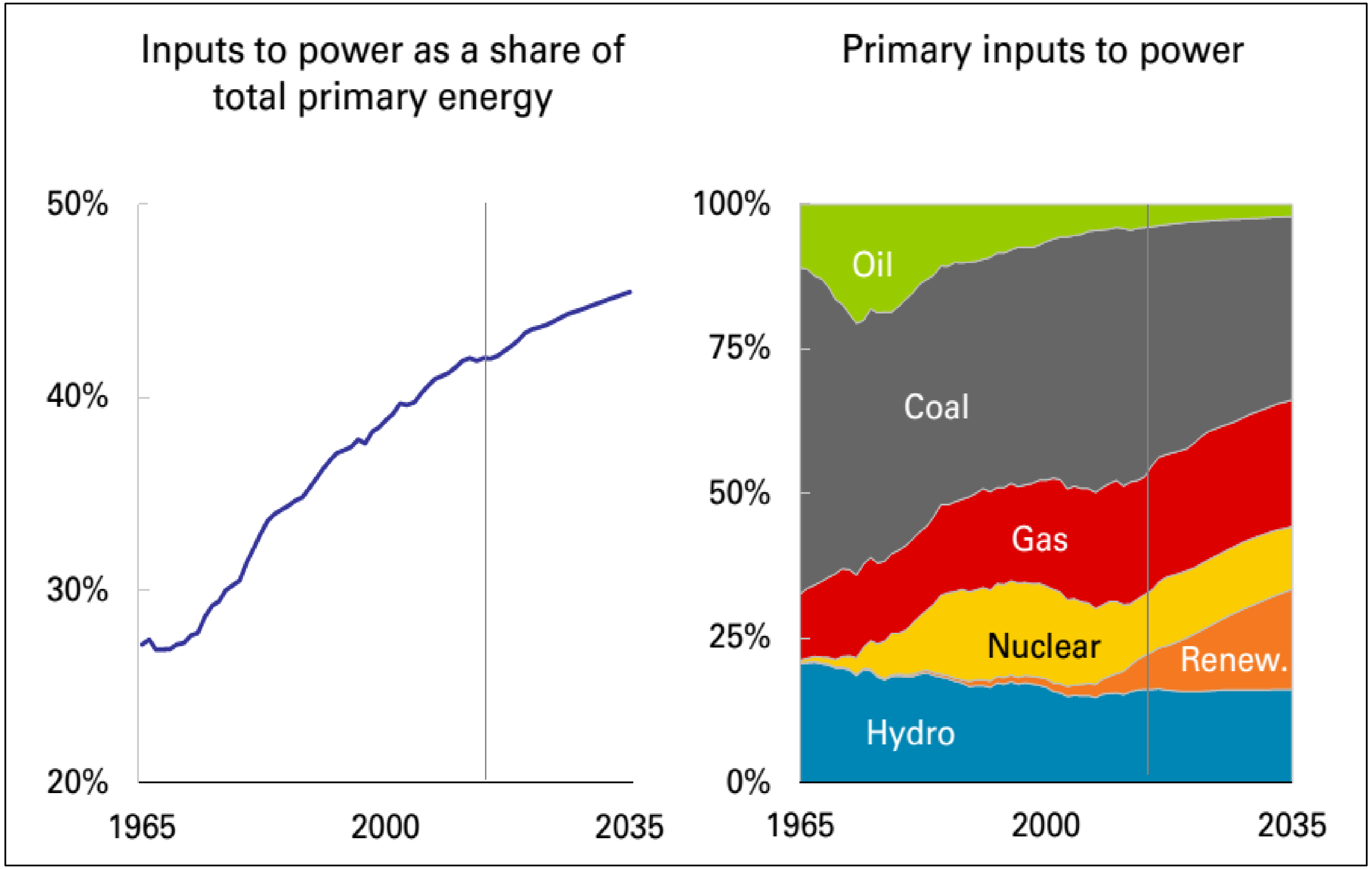
Reason for Increasing Importance of Natural gas

- *It's **environmentally friendly** - burns more efficiently: CO_2 production per unit of electricity generated ; **1.0 for coal, 0.7 fuel oil**, & **0.5 natural gas***
- *It's **cheaper than other fuels** - 6MScf of Gas = 1bbl of Oil, 6MScf of gas @ \$3.00 ≈ 1 bbl @ \$40.00*
- *It's better for power generation than other fuels (higher thermal efficiency, lower operating cost, lower emissions, lower capital investment, etc.)*
- *There is **better predictability** about gas price as price is controlled by **regional factors***



Share of Primary Energy: (BP Statistical, 2016)
The Fuel Mix is set to change significantly…

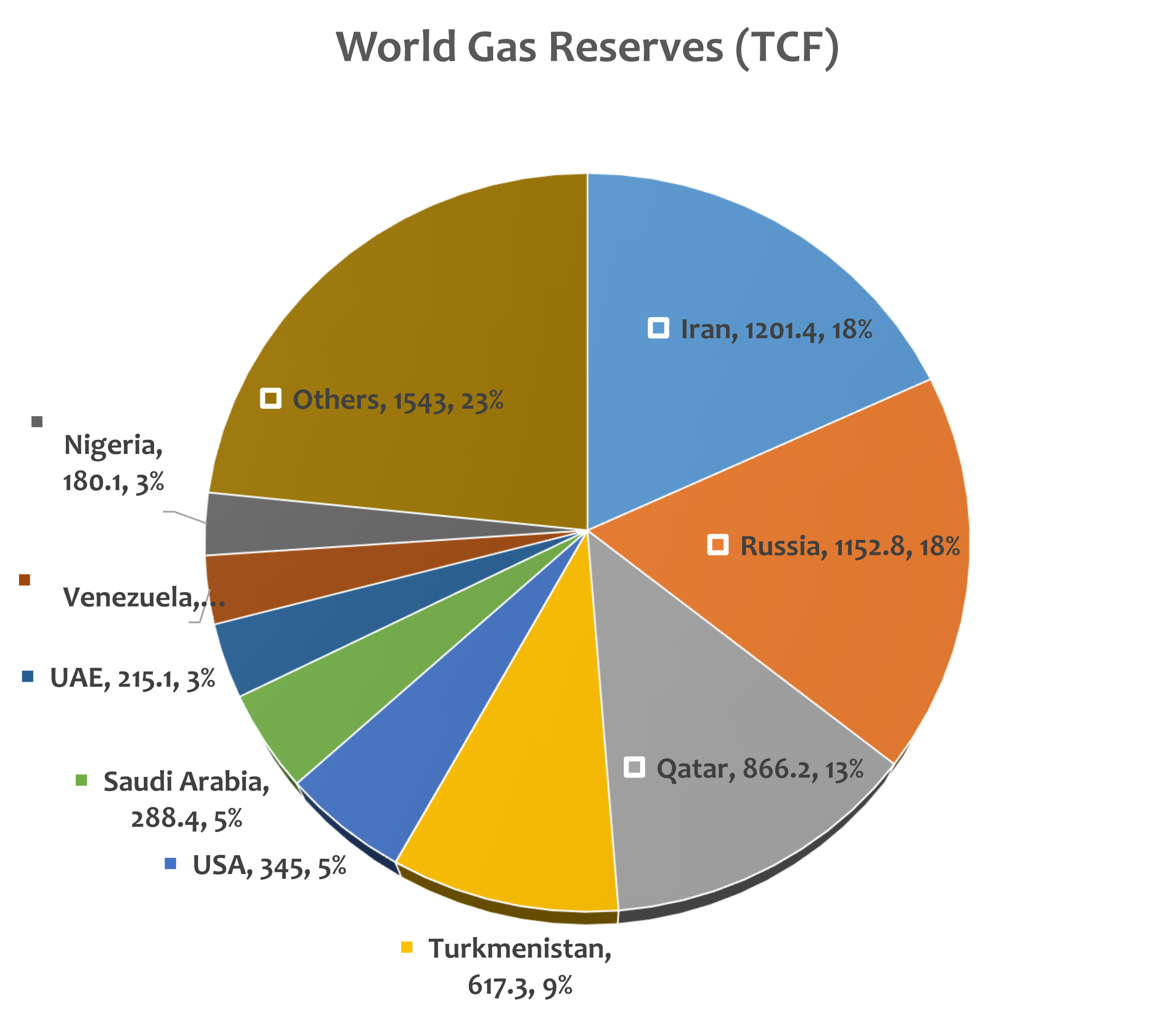
Background: Global Energy Outlook



Africa's Energy Mix - BP Statistical, 2015

Energy	Share of consumption in Africa (%)
Gas	26.0
Oil	43.0
Coal	23.0
Hydro	7.0
Nuclear	1.0
Renewable	1.0

Background: Global Outlook



- *World Yet-to-be-discovered gas = 5,200 TCF*
- *50% in Russia, Middle East & North Africa*
- *1,170 TCF in North, Central & South America (23%)*
- *Nigeria: 400 – 600 TCF (Yet-to-be-discovered) 7.7% - 11.5% of total global*

Nigeria Proved Reserves (TCF)

Yr 2005 Gas Reserves (TCF)	AG	NAG	Total
Ultimate Recovery	144	89	234
Produced	46	4	50
Remaining Reserves	98	85	184

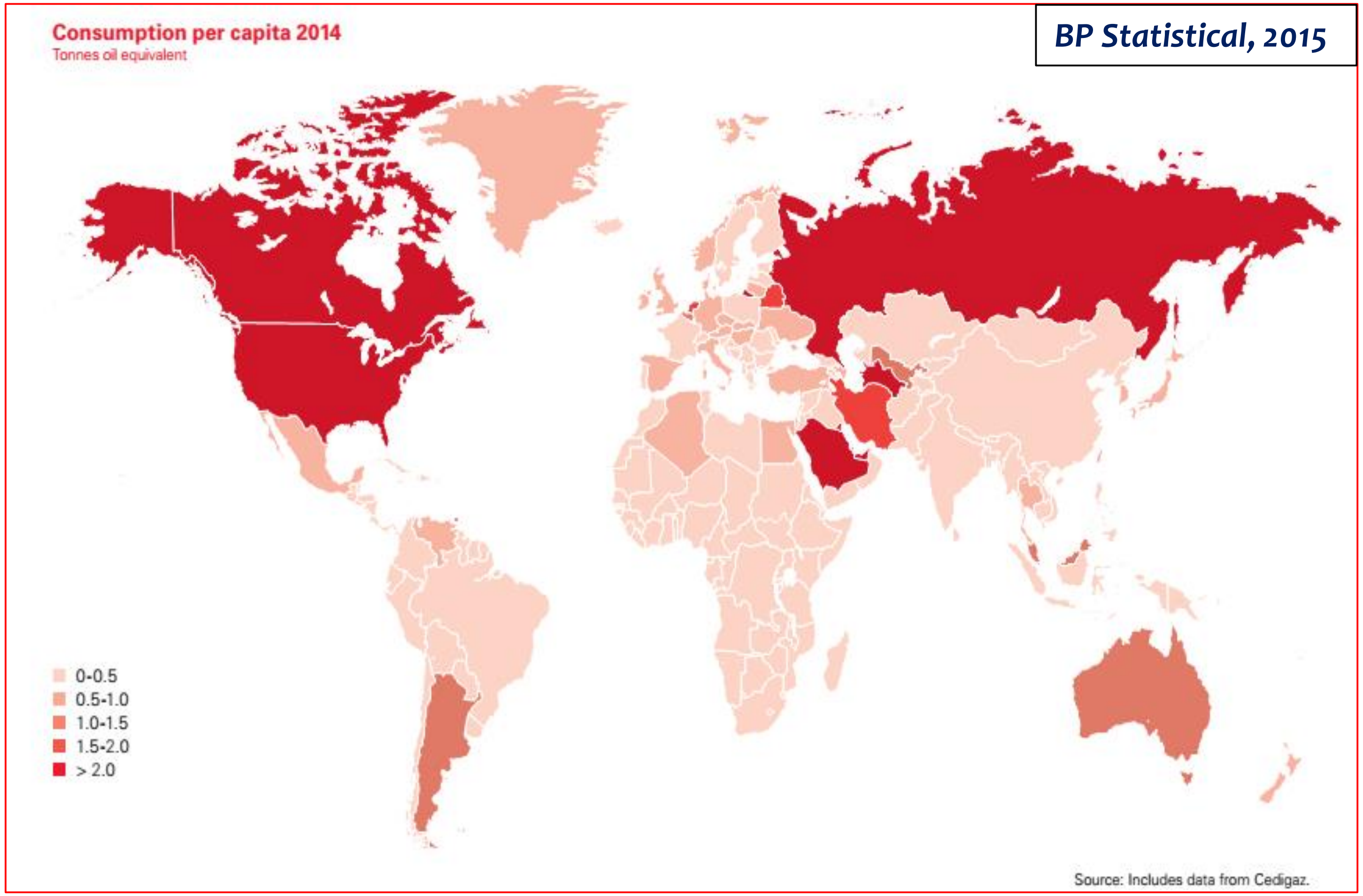
Background: Global Outlook

2015 Ranking	Country	Gas Production (BCF/d)	% Share of Total Production
1	USA	70.5	21.4%
2	Russian Federation	56.0	16.7%
3	Qatar	17.1	5.1%
4	Iran	16.7	5.0%
5	Canada	15.7	4.7%
6	China	13.0	3.9%
7	Saudi Arabia Norway	10.5	3.1%
8	Algeria	8.1	2.4%
9	Indonesia	7.1	2.1%
10	Turkmenistan	6.7	2.0%
11	Malaysia	6.4	1.9%
12	Mexico UAE	5.6	1.7%
13	Netherland	5.4	1.6%
14	Australia	5.3	1.6%
15	Egypt	4.7	1.4%
16	Pakistan Thailand Trinidad & Tobago	4.1	1.2%
17	Nigeria	3.7	1.1%
World Total		334.8	

BP Statistical, 2015

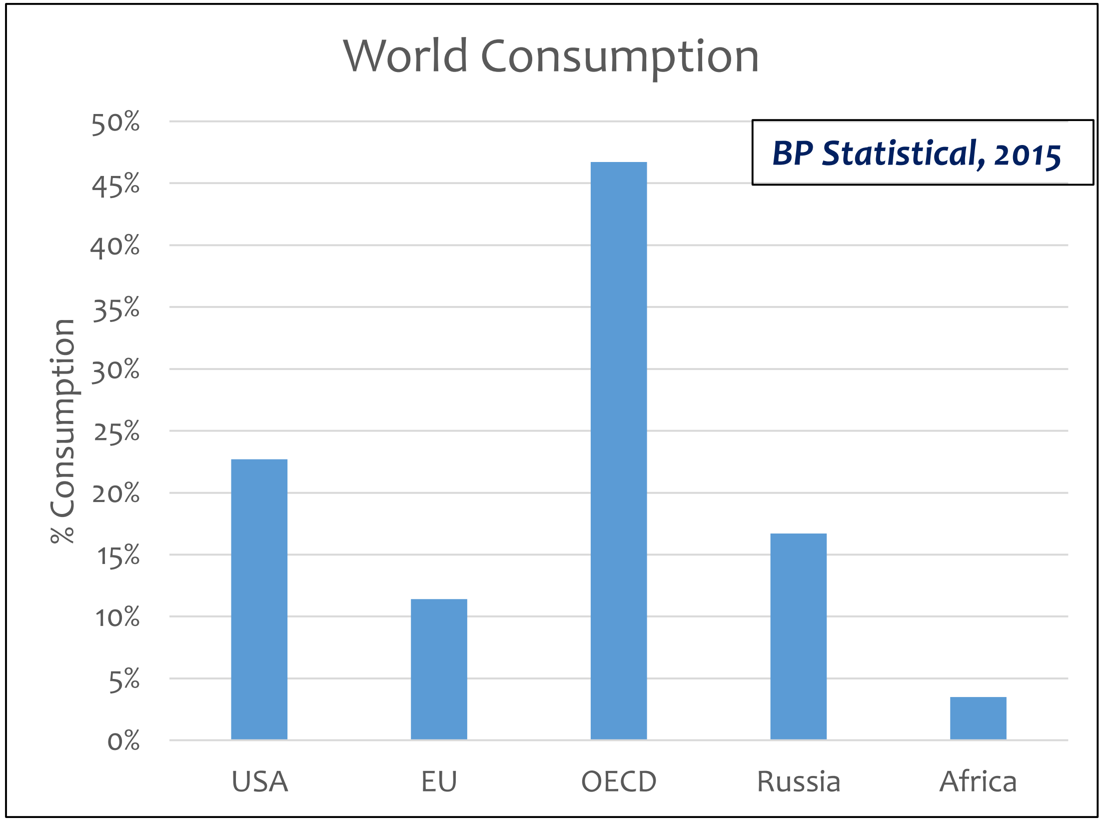
Biggest share of production comes from Associated Gas

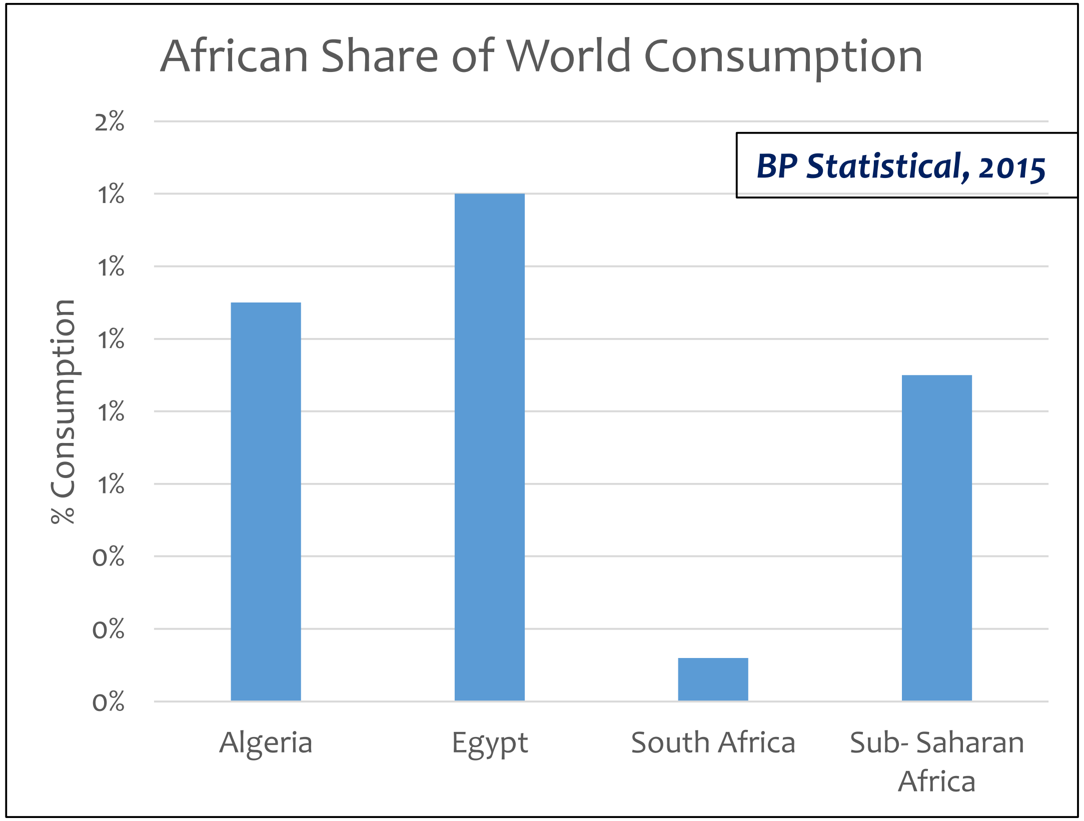
Background: Gas Consumption & Power



Africa's gas production remains low ***(19.6 BCF/d in 2015) 5.8% of global production but*** *remains a* ***significant net gas exporter - 86.4 BCM/yr (8.36 BCF/d) at the expense of domestic consumption***

Background: Global Consumption





USA	EU	OECD	Russia	Africa	Total world
73.5 Bcf/d	37.4 Bcf/d	152.7 Bcf/d	55 Bcf/d	11.6 Bcf/d	328.3 Bcf/d

Algeria	Egypt	South Africa	Sub Saharan Africa*
3.6 Bcf/d	4.6 Bcf/d	0.4 Bcf/d	2.9 Bcf/d

**** Nigeria's consumption is 40% of Sub Saharan Africa @ 1.26 Bcf/d***

Background: Sub-Saharan Africa & Power

- Acute power supply shortage in Sub-Saharan Africa is due to ***limited gas supply, transmission/distribution deficiencies*** & ***poor plant maintenance***
- ***Total installed power*** generation across the region = ***68,000 MW less than Spain's installed capacity***
- 40,000 MW in South Africa, ***rest has ~28,000 MW (Argentina's installed capacity)***
- < 1/3 of Sub-Saharan Africa have access to electricity ***(Rural area ~10%)***
- ***< 40% Nigerian population have access to electricity,*** the rest rely on diesel generators ***(with capacity of ~5,900 MW at a cost of ~$13Million/yr)***
- ***Nigeria has the world's highest conc. of small-scale generators***
- Only 55% of Nigeria's 7,000 MW installed capacity available (4,000MW) ~ ***Tokyo's Narita airport Area's Grid power***
- ***UK Gas Demand = 125 BCM/yr*** *with 64 Million population (Nigeria's 170 Million population use 12 BCM/yr)*
- ***South Africa*** *(52 Million population) consume* ***55 times more energy per head than a Nigerian*** & the ***Americans, 100 times more***

Nigeria Domestic Gas Market

2015 Total Gas Production (BCF)	Domestic Supply (BCF)	Export Supply (BCF)	Power Generation Demand	Amount of Gas flared
2,656	308.5	1,241	3.5 BCF/d*	1.4BCF/d**

**** NIPPs** Need **~1.3 BCF/d*** (NNPC Data); ***** 36% of production flared*** daily; ***~$4.9 Million,*** Nigeria - *2nd **largest flaring country in the world*** (11% of global flare at 16 BCM/yr)

NNPC, 2016

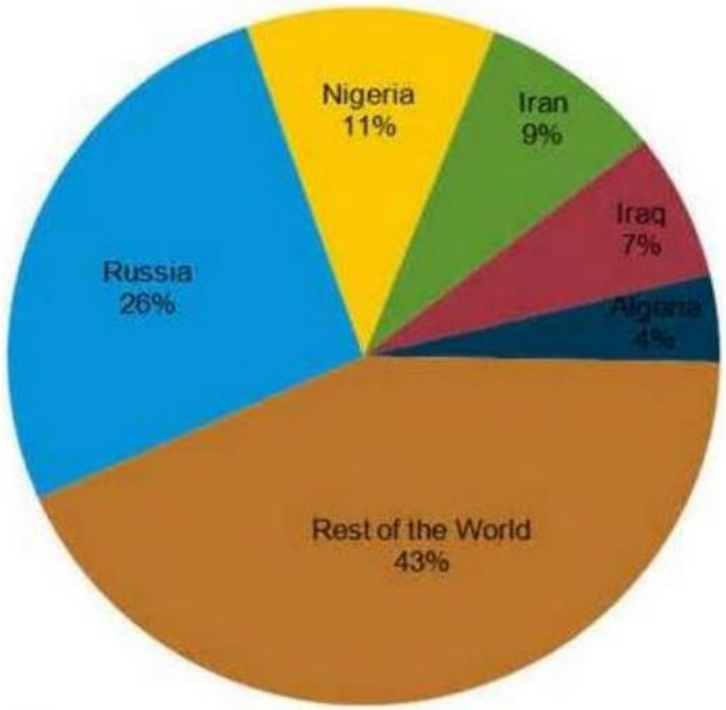
- ***Nigerian Domestic Gas Consumption ~12 BCM/yr (424 BCF/yr = 1.16 BCF/d)*** (Oxford Institute for Energy Study, 2013)
- ***Indigenous*** companies' ***share of oil production*** = 12% (~260k bopd at Aug. 2015)
- Insufficient Domestic supply, ***Manufacturing sector = 4% of nation's GDP***
- ***Deployment** of the flared gas* for ***fuel source*** for ***domestic use, fill the supply gap*** & achieve ***Vision 2020 of zero-flare-out policy***
- ***66% of Nigeria live below poverty line (US$1.00/day)**, ranked **among 30 poorest country***
- *Of the ~2,000-km gas pipelines, only 1/3rd is dedicated to domestic consumption, the rest is for LNG export*
- ***Need for ~15,000-km transmission lines** - experts believe Nigeria will remain infrastructure-constrained for another 10-15yrs*

Concession	Yr-2015 Gas Production (%)
JV	68.89
PSC	21.88
NPDC	8.22

Gas Flaring & Its Effects

Fast-Forward Present Day (2016)

- *'In many oil fields, gas is produced with crude oil when brought to the surface. When SPDC first built production facilities in the 1950's and 1960's, there was **little demand or market for this 'Associated' Gas**…*
- *The volume of flared gas **increased by 12% over the year & flaring intensity by 9%**…*
- *The increased **frequency of pipeline sabotage** over the last two years has resulted in numerous **unplanned production shutdowns**. These in turn have **impacted the performance of gas processing systems**, which operate more efficiently with uninterrupted production, and has **constrained our progress on reducing flaring** intensity**….(SPDC 2016)***
- Gas ***flaring*** causes ***wastage of valuable fuel source***, ***economic loss***, ***environmental degradation*** & ***health risk***
- Combustion processes with complete combustion create harmless gases like CO_2 & H_2O, ***Flaring in reality is rarely successful in the achievement of complete combustion*** (Leahey & Preston 2001).
- ***Flaring*** process ***with incomplete combustion*** emits pollutants that can have ***adverse health impacts*** - cancer, neurological, reproductive & development effect (Kindzierski 2000)



Top 5 Flaring Countries, 2010 - Source: (NOAA) (National Oceanic and Atmospheric Admin)

Impediment to AG Development

Gas utilization projects have been delayed or abandoned due to the following reasons;

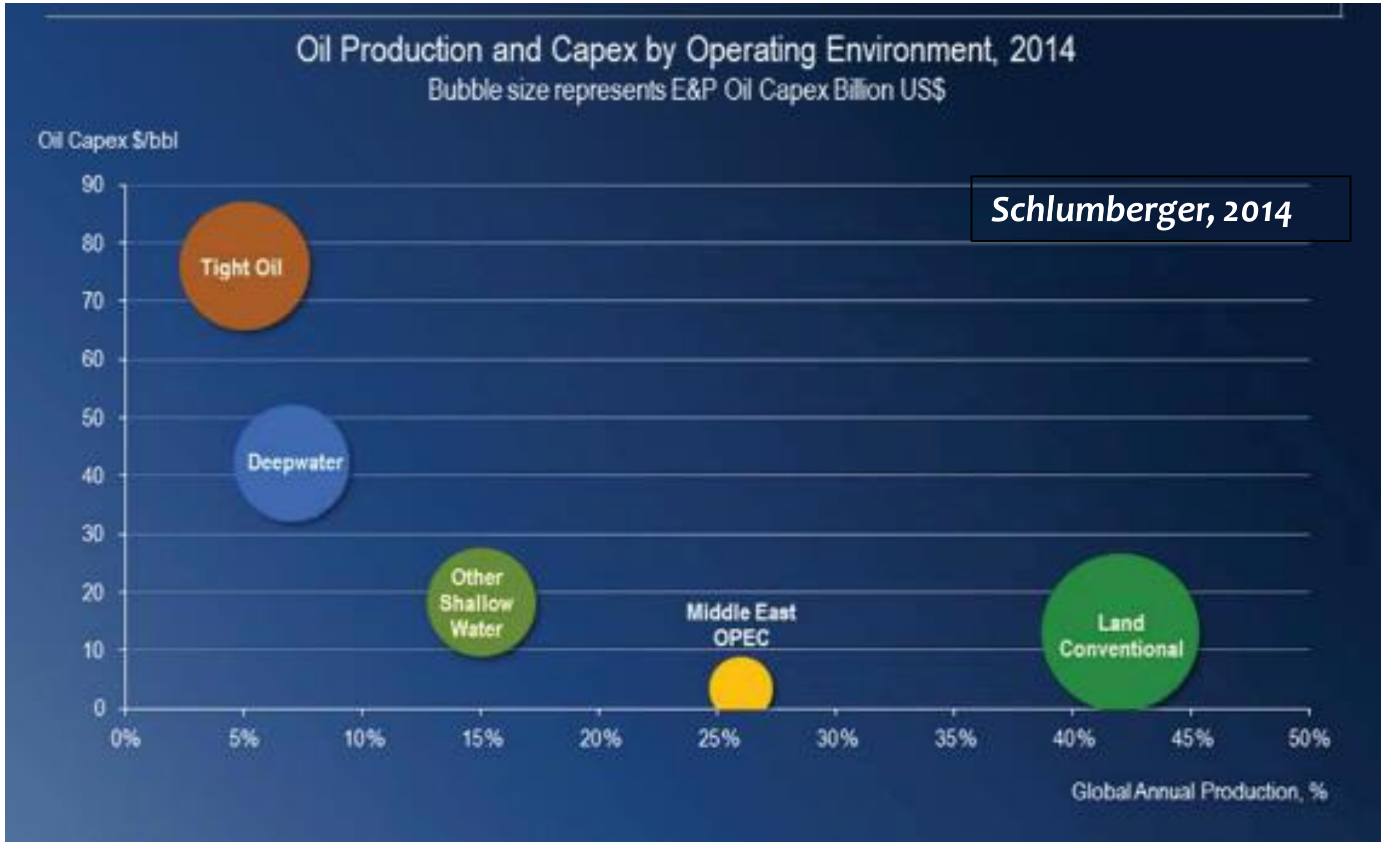
- ***Reluctance of Oil & gas companies to commit due to non passage of PIB*** e.g. Brass & Olokola LNG
  - Investors sceptical about signing ≈20years FID
  - Industry structure & parameters not clear
- ***Funding constraint/challenges***
  - *Sustained commitment from JV partners in terms of cash call not adequately met*
  - *Funding challenges have resulted in delays to 2 major associated gas gathering projects that were expected to deliver an additional 35% reduction in flared gas' - (Shell, 2016)*
- ***Increased security situation (frequency of pipeline sabotage)***
  - Numerous unplanned production shutdowns which affect performance of gas processing systems
- ***Limited Gas Infrastructure, remoteness of fields & Little incentives for investments***
  - Gas master plan which would address the issue is yet to be fully implemented
  - Enormous infrastructure cost to capture, process & transport stranded gas
  - Some fields are too small to justify investment

- ***Unwillingness to develop gas due to faster economic return on oil project***
  - Oil project payback period = 3yrs vs. gas project payback period =6-7 yrs
  - Oil projects gives companies more upfront money than gas investments with same funding
  - ***Ensuring oil flows at minimal cost***, hence gas flaring as a consequence of ***cost minimisation strategy***

Impedment to AG Development

- ***Declining Crude Oil Price which have led to capital discipline***

- Prioritising cash flows
- Monetising existing discoveries
- Divesting non-core assets



Impediment to AG Development

- ***Gas Pricing Reform***

- 3 most ***political economy logics under-pinning gas pricing policies*** in Nigeria:

1. Gas is (at least initially) produced in association with ***Oil & NGLs*** and thus ***regarded as a free by-product*** of ***more-valued hydrocarbons***, and at worst, a ***nuisance*** (price is fixed at very low level), at best, infrastructure cost of capturing/processing/delivery

2. Gas price perceived as a way of ***rent distribution*** by the state for poorer segments of the population

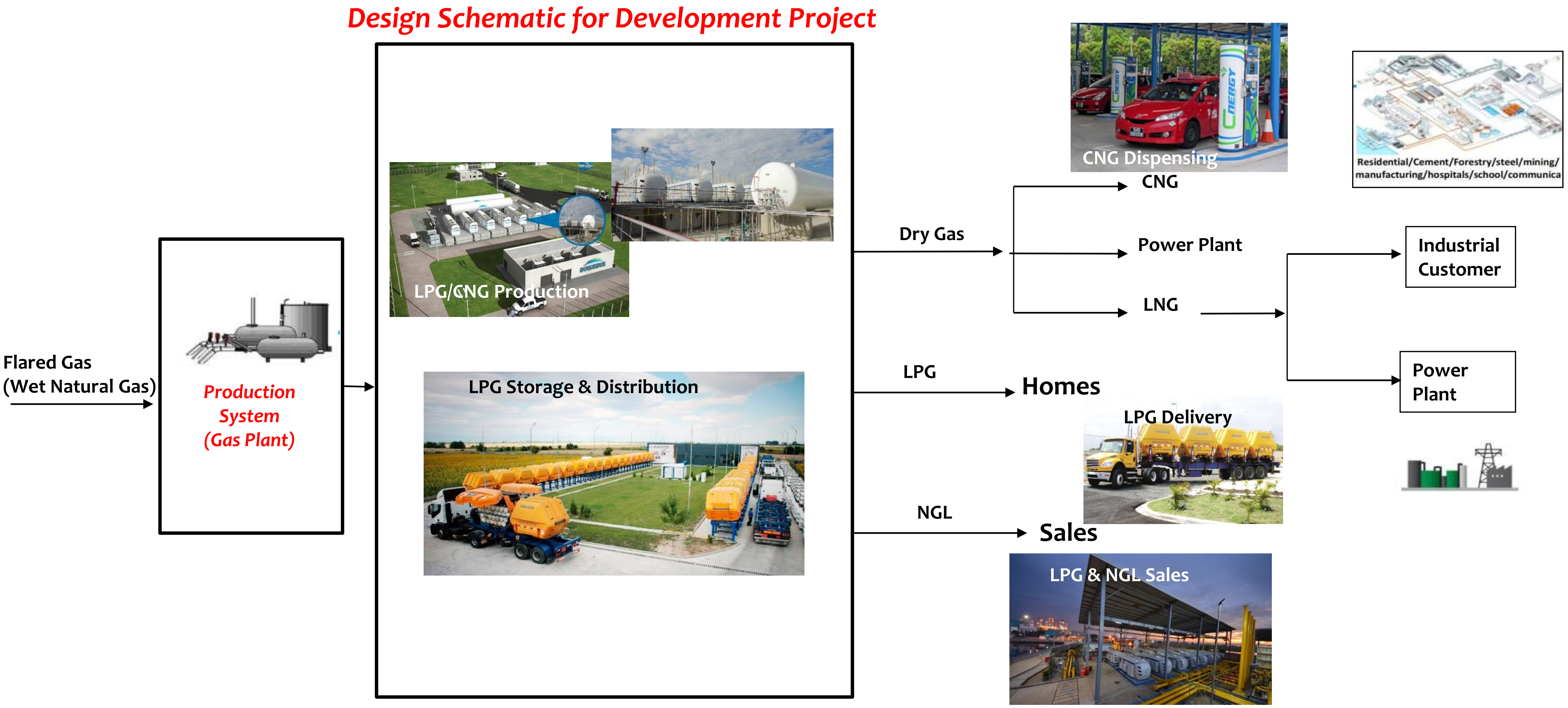
3. Low gas prices are seen as a source of ***comparative advantage*** for expansion into higher-value-added industries and economic diversification

- Especially as it constrains development of new production or diverting supplies which would otherwise have been exported

- Nigeria is in the process of introducing PIB & Gas Master Plan - aimed at revising gas price upwards & introducing more market oriented pricing mechanisms

- Delayed in implementation due to fierce opposition from industrial & political stakeholders

AG Gas Utilisation: Overview



AG Gas Utilisation: Tool Box

- *Basic characteristics of oil fields*
- *Requirements for gas treatment, LPG production, gas transmission, power generation & distribution, costing*
- *Applications & their technical/financial viability assessment*
- *Benefits of gas master plans: regulatory clarity & stability*
- *Intermittent/variable profile of AG gas production – key consideration when choosing technology option for devpt.*

Feasible End Use of AG Gas

1. ***Power production*** *at oilfield for* ***transmission to existing power grid*** *through power lines (medium scale)*
2. *Power production at the oil field for* ***electrification of non-electrified rural area*** *(small-scale)*
3. ***Supply of piped gas to larger consumers****, such as power plants & industries (medium-scale)*
4. ***LPG alone*** *or in* ***combination*** *with the other means of use*

Medium-scale: Gas substituted for alternative fuels at lower or equivalent price to power plants & industrial consumers ***replacing LPFO/diesel generated electrical power***

Case Study – Medium-scale

Ivory Coast Domestic Gas Market: 1.5 - 2.0 BCM/yr

1. Does not import or export any gas
2. All the gas supply comes from ***offshore*** field, some of which are AG gas. Used mainly for ***power generation***
3. Gas price indexed to oil products: $4.00 - $8.00/MMBTU

Equitorial Guinea Domestic Gas Market: 1.5 BCM/yr

1. All the gas supply comes from ***offshore*** fields (Alba & Zafiro), all are AG gas
2. Output ~7BCM/yr, bulk dedicated to ***LNG export***
3. ~1.5 BCM/yr ***consumed locally (Methanol & Power plant)***

South Africa Gas Market & GTL:

- *Gas chemically treated in a matter that converts it to liquid hydrocarbons at ambient temp. to facilitate conveyance*

1. SA ***import*** 3.0 - 3.5 BCM/yr via 865-km-***pipeline*** linking Mozambique's ***onshore*** Temane & Pande gas fields to ***Sasol's synthetic fuels & chemical plants*** at Secunda
2. Mossel Bay gas fields (~2 BCM/yr) feeds ***Petro SA's GTL plant***

AG Gas Utilisation: Oilfield Characteristics

SEPARATION TEST OF RESERVOIR FLUID

Molecular composition of separator gases

Northern Delta Data

1. CONDITIONS				
Pressure (psia)	565	365	215	15
Temperature (degF)	102.0	102.0	102.0	102.0
2. COMPOSITION (mole per cent)				
Non-hydrocarbons				
Nitrogen	9.57	9.15	8.72	8.28
Carbon Dioxide	2.18	2.22	2.18	2.17
Hydrogen Sulphide	0.00	0.00	0.00	0.00
Hydrocarbons				
Methane	72.05	70.75	69.48	65.70
Ethane	7.70	7.86	8.25	8.21
Propane	5.35	6.36	7.16	8.20
i_Butane	0.72	0.83	0.93	1.30
n_Butane	1.50	1.75	2.03	3.23
i_Pentane	0.35	0.38	0.42	0.99
n_Pentane	0.39	0.45	0.55	1.20
Hexanes	0.11	0.13	0.15	0.41
Heptanes +	0.08	0.13	0.13	0.31
TOTAL	100.00	100.00	100.00	100.00

MOLECULAR COMPOSITION OF RESERVOIR FLUID

Coastal Swamp II Data

Components	Mole percent
Nitrogen	0.00
Carbon dioxide	0.73
Hydrocarbons:	
Methane	52.51
Ethane	2.79
Propane	4.62
I - Butane	2.60
N - Butane	2.42
I - Pentane	1.61
N - Pentane	1.10
Hexanes	1.76
Heptanes plus	29.81
TOTAL	100.00

- *More % propane components (ave. 6 mole%) than % Butane (ave. 2.3 mole%) sampled data in Northern Depobelt than the one in Coastal swamp II Depobelt propane (ave. 4.5 mole%) & Butane (ave. 5.01 mole%)*
- ***Need for more studies to ascertain this theory***

AG Gas Utilisation: Oilfield Characteristics

- Oilfield fluid characteristics is source rock dependent
- *Niger Delta Source: Organic Matter - mixed maceral components (85-90% Vitrinites with some Liptinites (resin/waxes/spores) & Structureless Organic Matter (Bustin, 1988)*

2 categories of Oil in Niger Delta

1. ***Light Paraffin based***, waxy oils from ***deeper reservoirs*** (wax content up to 20%, *(Kulke, 1995)*, high n-paraffin/naphthalene of 0.86 *(Doust & Omatsola, 1990)*
2. ***Biodegraded Oils*** from ***shallow reservoirs***. Lower API gravity (ave. API of 26) *(Kulke, 1995)* & naphthenic non-waxy.

- Heavily biodegraded oil (8-20° API) in Pleistocene sands
- ***56%*** of Niger Delta Oils have ***30-40°API, 15% < 25°API*** *(Thomas, 1995)*
- C1 – C7 varies with different oilfields
- ***AG gas are rich gas with higher Mole % of C2 – C7***
- The ***higher the C3 & C4 content***, the higher the ***LPG extraction***
- *Higher C4 content, more LPG recovery,* ***Nigerian LPG (cooking) requirement : 70/30 or 80/20.*** *Impacts NPV*

Reservoir Fluid	Surface Appearance	GOR Range	API Gravity	Typical Composition, Mole %					
				C_1	C_2	C_3	C_4	C_5	C_{6+}
Dry gas	Colourless gas	Almost no liquids	-	100					
Wet gas	Colourless gas -	>100 Mscf/bbl some clear or straw-coloured liquid	60^o -70^o	96	2.7	0.3	0.5	0.1	0.4
Condensate	Colourless gas - significant amounts of light coloured liquid	3-100 Mscf/bbl (900-18000 m^3/m^3)	50^o-70^o	87	4.4	2.3	1.7	0.8	3.8
"Volatile" or high shrinkage oil	Brown liquid - various yellow, red, or green hues	"3000 scf/bbl (500 m^3/m^3)	40^o-50^o	64	7.5	4.7	4.1	3.0	16.7
"Black" or low shrinkage oil	Dark brown to black viscous liquid	100- 2500 scf/bbl (20 - 450 m^3/m^3)	30^o-40^o	49	2.8	1.9	1.6	1.2	43.5
Heavy oil	Black viscous liquid	Almost no gas in solution	10^o-25^o	20	3.0	2.0	2.0	12.0	71
Tar	Black substance	No gas viscosity > 10,000cp	< 10^o	-	-	-	-	-	90+

Mole Composition & Properties of Typical Single-Phase Reservoir Fluid
(Heriot Watt Res. Sim. Manual)

AG Gas Utilisation: Nigerian Gas Projects

- ***Domestic gas Utilisation (Industrial)***

1. *Steel Plant*
2. *Aluminium Plant (ALSCON)*
3. *Fertiliser Plant*
4. *Cement: Extension of Ajaokuta to Obajana cement factory*
5. *LPG Market*
6. *CNG for automobile: alternative to gasoline/diesel*
7. *Gas Distribution Zone: encouraging manufacturing outfit (food/beverage, glass etc) to switch from less efficient fuel (LPFO/diesel) to cheaper, more efficient natural gas*

- *Greater Lagos Area (Gaslink Nig. Ltd) – 9 neighbourhood & 30 industrial customers*
- *Ikorodu Industrial Area (Falcon Nig. Ltd)*
- *Epe – Lekki Area (Gasland Nig. Ltd)*

- ***Export***

1. *NLNG Trains 1 -5*
2. *NLNG Trains 6 & 7*
3. *Brass LNG*
4. *Olokola LNG*
5. *Oso NGL Project*
6. *WAGP (could expand to Takoradi reaching 580 MMScf/d)*
7. *TSGP (Trans Sahara Gas Pipeline) to connect Nigeria to Algeria*
8. *EGP **(Escravos Gas Project)***

- *EGP-1 (40,000 bbl of LPG & Cond.)*
- *EGP-2 285 MMScf/d*
- *EGP-3: to process 400 MMScf/d into 15,000 bopd NGLs feedstock & 300 MMScf/d*
- *EGP-3 NGL – to produce 40,000 bopd of synthetic crude (could increase to 120,000 bopd for export)*

AG Gas Utilisation: Nigerian Gas Projects

- **Power**

Power Reform Project (Fed. Govt.)	
Name of Plant	Capacity (MW)
2000	
Geregu	434
Ihovbor (Edo)	450
2005	
Alaoji (Rivers)	1074
Olorunsogo/ Paplanto	335
Omotosho (Ondo)	335
2015	
Omoku (Rivers)	225
Sapele (Delta)	500
Egbema (Imo)	250
Calabar (Cross River)	561
Ikot Abasi (Akwa Ibom)	230
Gbaran/Ubie (Bayelsa)	225

Plants supply power at less than installed capacity due to gas project yet to be completed

- ***Others: Egbin, Sapele & Ughelli,*** *Agip's* ***Okpai plant,*** *Shell's* ***Afam plant***

1. ***Oben/Sapele Gas Plant*** *feeds Geregu & ELPS* ***280 MMSCf/d***
2. ***Utorogu Gas Plant*** *feeds ELPS* ***300 MMSCf/d***
3. *Frontier's* ***Uquo Gas Plant – 90 MMScf/d***

- *Ibom Power, Ikot Abasi – 23.4 MMScf/d*
- *Unicem Calabar – 17.6 MMScf/d*
- *Notore Fertilizer, Ikot Abasi – 15.7 MMScf/d*
- *Alaoji, Rivers – 20 MMScf/d*
- *Calabar IPP – 13.3 MMScf/d*

- ***Re-Injection***

1. *Akri – Oguta field - began in late 70's*
2. *Obiafu – Obrikom*
3. *Kwale – Okpai*
4. *Asabo – Ekpe*
5. *Belema Gas Injection Project: 80 MMScf/d*

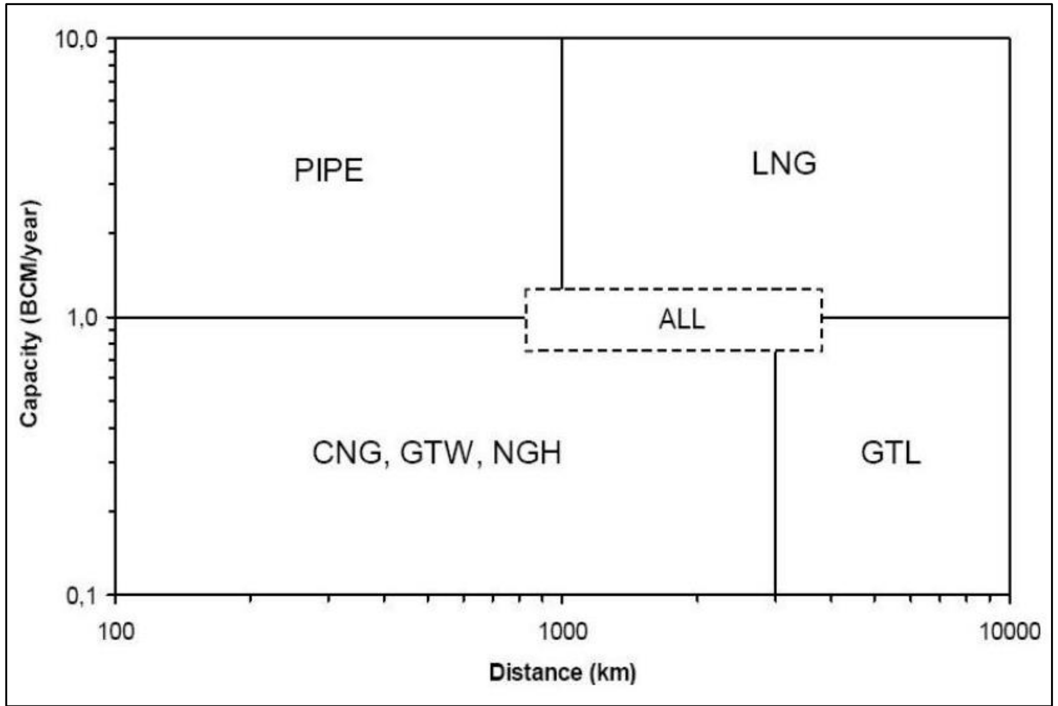
AG Gas Utilisation: Project Viability Assessment

Factors that influence the feasibility of Gas developments:

- Size of the resource
- Distance to the market
- Size of the market
- Technology used

Gas Transport

- Gas in its marketable form after processing for a specific energy content, sour & acid components & HC composition (~90% methane + 10% other light alkenes)
- Compressed to 10 - 150 bar & fed into a subsea pipeline
- For compensation of pressure drops along pipeline, ***intermediate compressor stations on the sea floor must be installed.***
- Onshore, the gas is expanded to the pipeline network pressure
- ***Economies of scale in gas transport:*** the higher the volume, the lower the cost per unit of energy transported

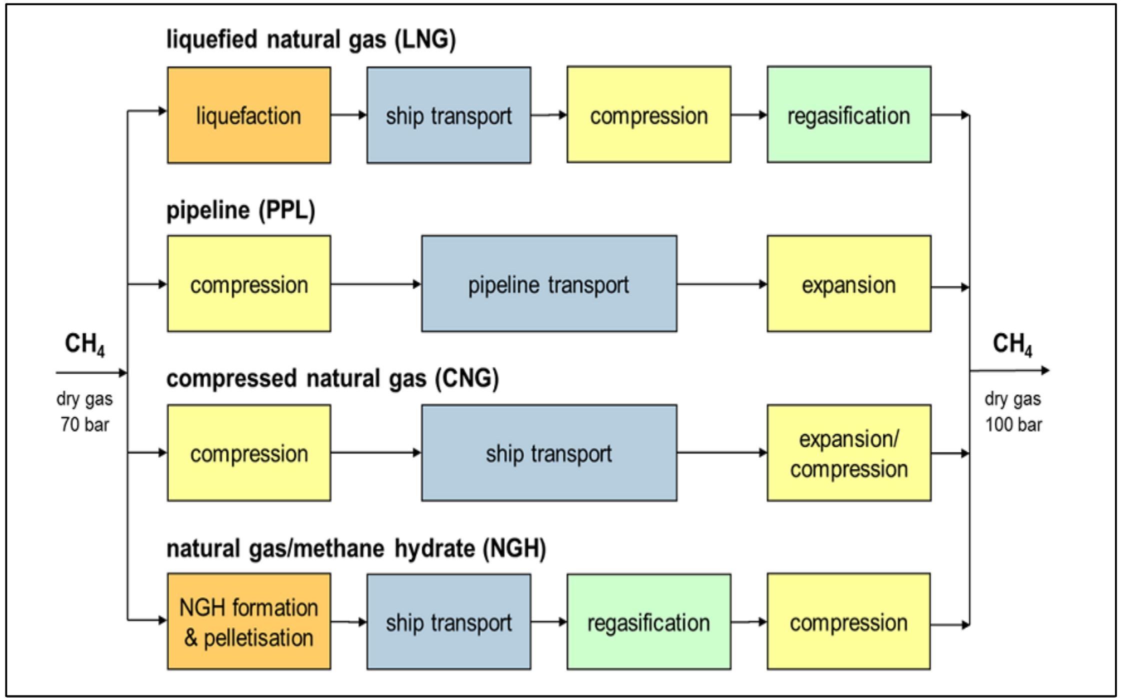


Capacity-Distance Diagram for Transport of Stranded Natural Gas (Gudmundsson and Graff, 2001)

- This influence what transport capacity & distance a particular pipeline will be feasible
- The shorter the distance & larger the capacity, the more feasible a particular natural gas pipeline, with increasing distance the feasibility of pipeline decreases.

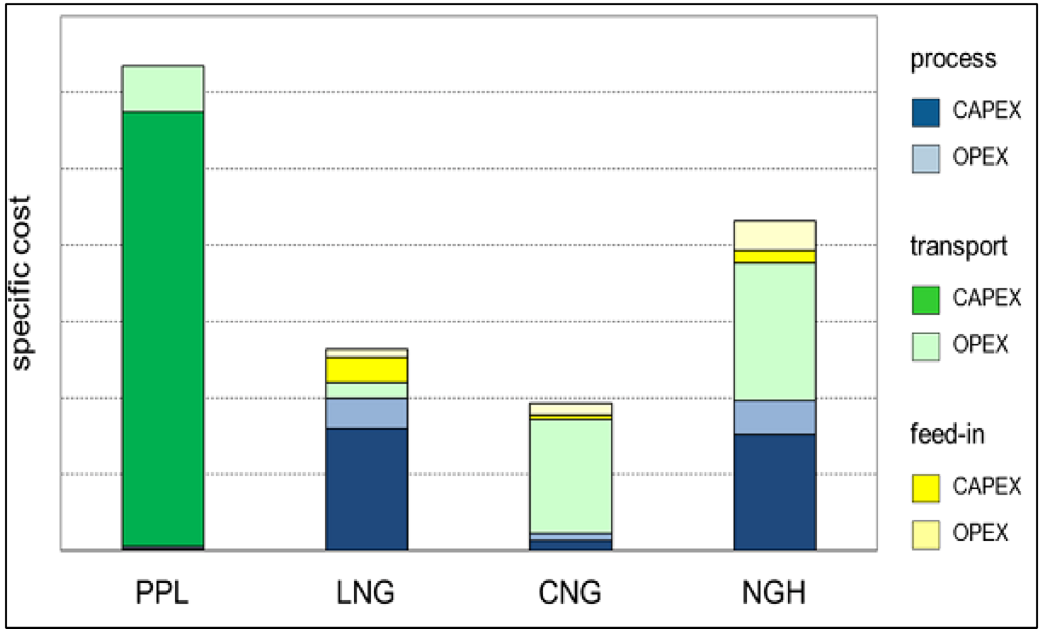
AG Gas Utilisation: Conveyance Methods

- ***Offshore pipelines*** (***less than 1000-km***) appropriate for ***large-volumes*** ***(above 1 BCM/yr)*** *i.e.* ~97.4 MMScf/d
- ***LNG*** appropriate for ***large-volumes*** (***~100 MMScf/d)*** for ***long-distances*** ***(above 1,000-km)***
- *~80% of the natural gas resources yet to be developed world-wide are too small for LNG technology & about half of these (40% of total) are stranded (~212BCF, sustained delivery of 34 MMScf/d), calling for non-pipeline technologies.*
- ***GTL***: ***medium-to-low volumes*** for ***long-distances***
- ***CNG, GTW & NGH: medium-to-low volumes*** and **medium-to-short** distances.
- Size of the market influences the transport capacity of a particular pipeline
- The distance the feasibility of a particular pipeline becomes marginal depends on many factors
- ***Diagram illustrates what stranded gas technologies are likely to be appropriated with respect to distance & capacity***
- ***When the feasible pipeline distance is exceeded, other natural gas transport technologies become appropriate***



Technologies & System Boundaries for an Comparative Assessment of Natural Gas Transport Options

AG Gas Utilisation: Conveyance Methods



Specific Total Costs of the Transport Options: Pipeline (PPL), LNG, CNG & Methane/Natural Gas Hydrate (NGH) (20,000** Nm^3.h^{-1}**/1000-km Scenario

CNG Transport:

- Gas compressed at 2.0 – 2.2 MPa to less than 1% of volume of atm. pressure & ***buffered on offshore production unit***
- Then stored under 220 bar pressure in spirally wound pipes inside the cargo hold of the carrier (ship).
- At the import terminal, gas is either expanded or pressurised to pipeline conditions.
- CNG used for lower capacity & medium distance transport.
- Methane for vehicle fuel is also stored as CNG.
- ***Energy to volume ratio is typically 25% of gasoline***

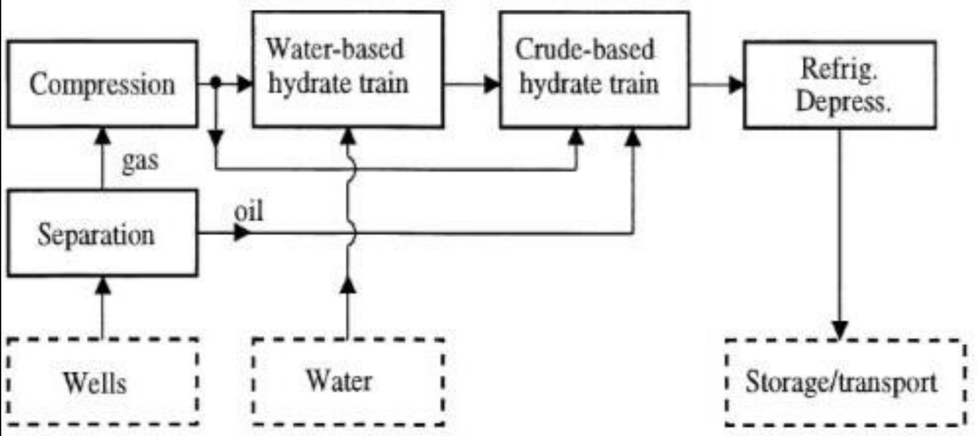
Liquefied Natural Gas (LNG):

- Gas ***refrigerated & liquefied below -162C,*** for storage & transport. Stored at close to atm. pressure, less than 125kPa
- As a liquid, LNG takes up 1/600 of the vol. of the gas at room temp.
- ***Energy to volume ratio is 66% of gasoline***
- After transport & storage, it is reheated/vaporised & compressed for pipeline transport.

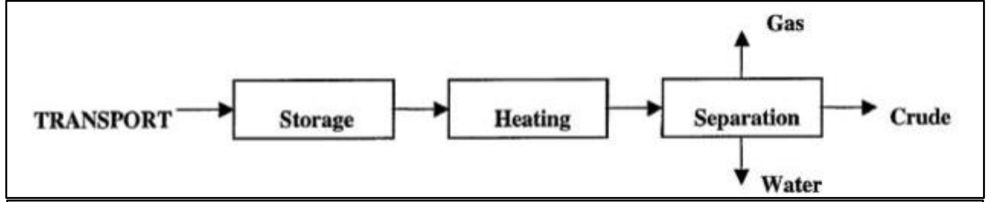
AG Gas Utilisation: Conveyance Methods

Methane Hydrate Transport:

- The process involves reacting gas & water in the presence of crude oil, under the hydrate forming conditions of at 2°- 10 °C and 60 - 90 bar
- The resulting hydrate slurry produced remain practically stable at atm. pressure when refrigerated to about –15 °C & stored in air
- It can be pumped through pipelines or transported by tankers.
- Methane hydrate pellets are produced & transported by a specialised carrier ship (in case of offshore)
- Boil-off gas from hydrate dissociation is used in the ship propulsion system & fired together with HFO
- At import terminal, pellets are unloaded, hydrate is dissociated by heat exchange with sea water, methane is compressed & fed into pipeline. Other and lower temp. can also be used
- The frozen hydrate is transported at atm. pressure in large bulk carriers to market, where the hydrate is melted & the gas recovered



Flow Diagram for Hydrate Slurry Process



Block Diagram for Hydrate Slurry Separation

Gas Utilisation: A Case for LPG Production

Liquefied Petroleum Gas (LPG)

- Biomass is the mainstay of cooking in rural area, ***70% of rural population rely on wood*** as ***primary cooking fuel***
- Nigeria's flared gas can serve the cooking needs of 320 million people (Goldemberg 2000)
- Nigeria's LPG ***consumption*** in 2013 ***~ 250,000 Tonnes***
- Air pollution from LPG stove is nearly zero, producing fewer GHGs per unit of energy sources than biomass fuels (Smith 1999)
- Shift from biomass fuel to gaseous fuel can ***reduce air pollution (GHGs), health risk & deforestation.***
- Lack of adequate energy services in rural area has serious environmental & health effects (Goldemberg 2000)
- Fuelwood do not obtain high combustion efficiency (Smith 1999). They emit pollutants that contribute to Greenhouse gases & impacts health adversely

- ***Propane or butane*** or a ***mixture*** of these ***compressed to liquid at room temp***. (200 to 900kPa depending on composition)
- LPG recovery from AG gas requires treatment, the gas must be ***compressed***. If sour, it must be ***sweetened*** & finally, ***dehydrated*** & ***chilled***
- LPG is produced from the liquid part of the associated gas which condenses during gas chilling.
- After gas chilling, liquids are separated from the gas in a separator vessel & then pumped to a distillation column where the LPG is separated from the other fractions in the liquids & then transferred to pressurized buffer tanks from where it can be bottled & distributed
- LPG is filled in bottles for domestic use as fuel
- It's also used as aerosol propellant (in spray cans) & refrigerant (e.g. in air conditioners)
- ***Energy to volume ratio is 74% of gasoline***.

AG Gas Utilisation: LPG Production

Membrane Solutions

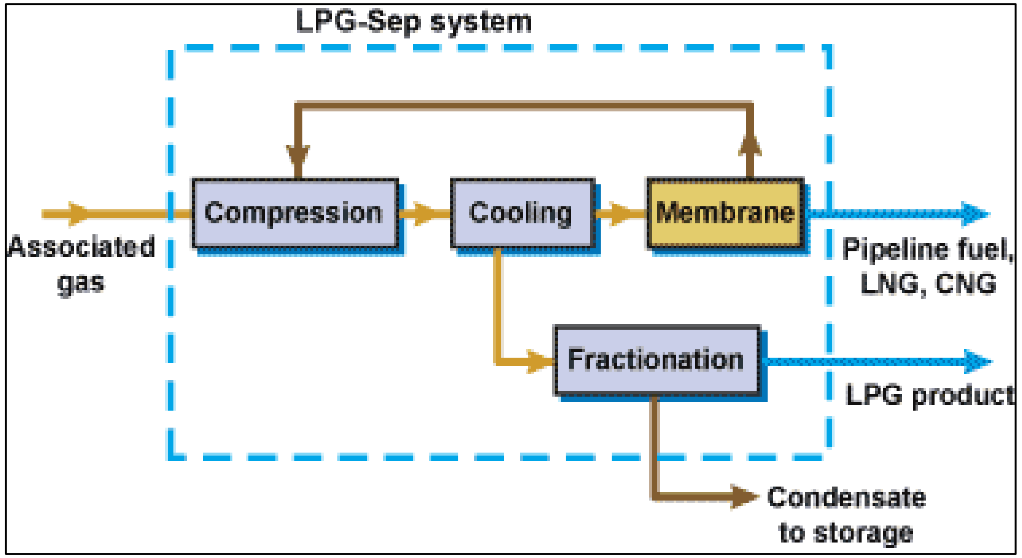
- *Maximize volumes of LPG product & production of clean fuel gas*
- ***Hybrid approach** renders optimal utility of both **refrigeration** & **membrane unit*** for enhanced liquids recovery (Cond. & LPG)

(i) conventional compression to 350 psi
(ii) cooling and C3+ condensation by chilled water at 60°F
(iii) membrane gas separation to lean out the gas
(iv) fractionation to produce spec LPG & condensate

- *Preferentially permeate the heavy hydrocarbons*
- *Feed gas is converted into **4 spec-quality streams**:*

  1. Spec-quality LPG (30/70 blend of C3/C4)
  2. Spec-quality (conditioned) fuel gas – Min. CAT Methane No. 70
  - fuel for power generation or sold as CNG, piped gas
  3. Spec-quality C5+ condensates – RVP = 17 psi
  4. Propane Product

- ***1 MMScf/d** = 13,400 kg/d = 13.4 Tons/d = **1,072 of 12.5-kg-bottles/day***
- ***10 MMScf/d** = 134,000 kg/d = 134 Tons/d = 134,000 kg/d = **10,720 of 12.5-kg-bottles/day***
- *CAPEX: Plant expenses, cost of bulk transport, bottling & distribution*



Power Project Feasibility

- ***Utilisation of conditioned fuel gas(1 MMScf/d = 4 MW)***
- US$23 Million CAPEX for 40 MW power project (20 units of 2MW Generators and Transmission cost over 20-km)

Natural Gas Liquids (NGL):

- ***processed purified product*** consisting of ***ethane, propane, butane*** or some ***higher alkenes separately***, or in ***a blend.***
- ***Raw material for petrochemical industry*** & is often processed from the condensate

Gas Pricing Mechanism

Structuring Gas Price (upstream vs Midstream)

- Need to Set standard for selling gas at a minimum price:
- Midstream should take charge for transmission infrastructure

2 factors that guide pricing directive

- ***'In-the-field'*** or ***At-the-field-gate'*** - *the price for* processed gas that is ready to leave the gas plant onwards delivery
- ***'price to-deliver-it-to-the-customer'*** - depends on volume & distance, equitable price to sustain the investment

Basis for Gas Pricing (Economic concepts of cost)

1. ***Average Cost***: overall cost per unit of output. It is measured by the sum of both investment & direct costs
2. ***Marginal Cost:*** Increment in total cost resulting from a unit change in output
3. ***Opportunity Cost:*** Unrelated to production cost. Refers to the foregone value of resource when the value of that resource is not utilised in its best alternate.

- Pricing reforms hinge on country-specific political, social & economic circumstances

***3 A's Objectives of Govt. Pricing Policies* (World Energy Council, 2001)**

1. ***Accessibility***
2. ***Availability***
3. ***Acceptability***

***3 objectives upon of Govt. domestic pricing policies* (Oxford Institute of Energy, 2012)**

1. *Efficiency of resource allocation*
2. *Satisfaction of specific financial targets*
3. *Considerations of social equity*

- ***Prices need to reflect*** the ***real opportunity value*** of gas development
- ensure ***financial viability of utilities*** & fair ***redistribution of resources*** to the poor
- ***Set prices*** high enough to cover the ***cost of delivering the service, ensure adequate payment collection, protecting vulnerable industrial & household consumers from inflationary effect of higher prices***

Conclusion/Recommendation

Impact of Ag Gas Utilisation on Economic Growth

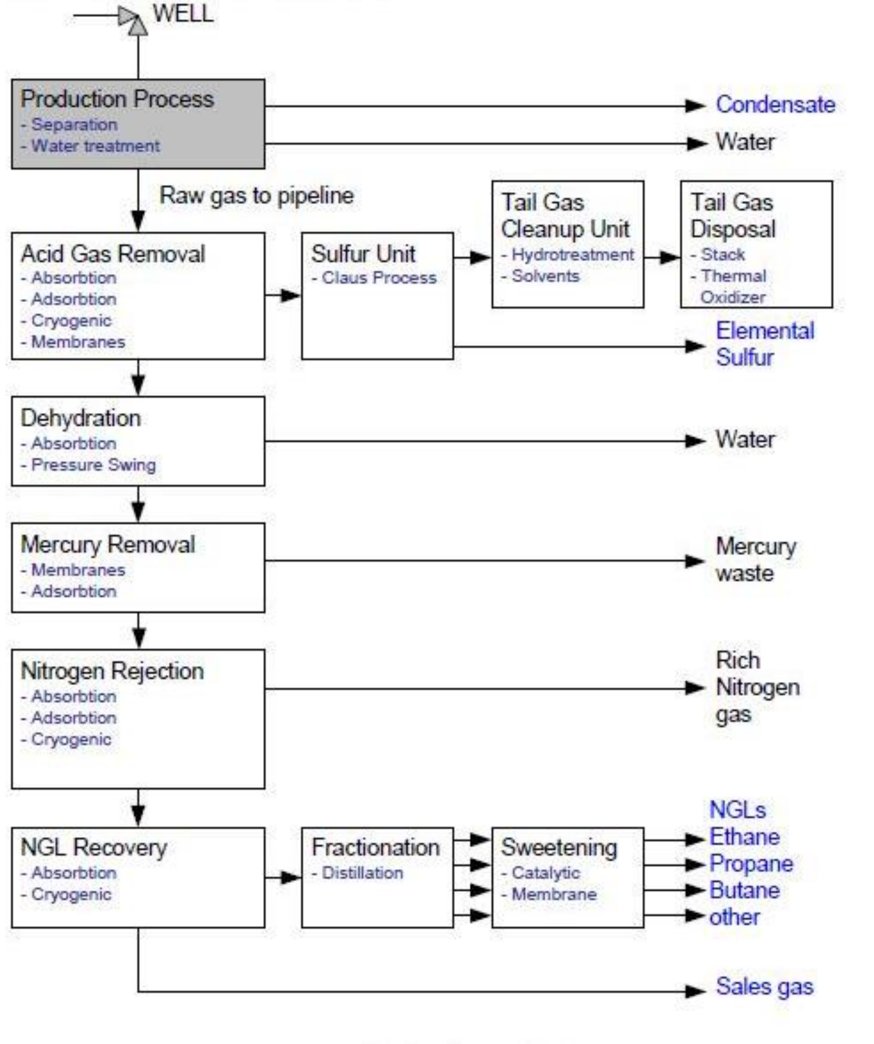
- Enables Nigeria to expand its economy
- Expands infrastructure
- Creates job & expand manpower base
- Flared gas can be converted into investments which will lead to a ***safer, conducive & healthier environment***
- Meet future energy needs
- Value creation & preventing wastage of useful fuel
- ***Poverty reduction potential:*** If flared gas is used to expand power distribution to unconnected households, it would have a major poverty impact.
- Local buses retrofitted for use of gas as fuel serves as alternative to regular motor fuel

Recommendation

- Need for operators to ***adopt non-pipeline technologies*** that can capture gas & transport to markets
- ***Firm commitment*** from Govt. thru ***introduction of fiscal incentives*** to ***encourage*** gas utilisation & flaring reduction
- Need for ***alliance btw Govt.*** & ***energy sub-sectors*** to ***ensure compliance with protocols on gas flaring***
- Need for Govt. to ***introduce adequate energy prices, investment*** & ***stability*** for operators
- ***Need for more studies*** to determine how the projects might best be ***structured institutionally & commercially***, preparation of a detailed utilization strategy & ***socioeconomic surveys*** to deal with pricing

THANK YOU

AG Gas Utilisation



Typical gas plant

- Associated gas recovery cost 4 times more than straight extraction of Non-Associated Gas (ESMAP, 2001)

Nigeria Gas Master Plan

3-Tier pricing system, groups end-users:

- Prices for ***strategic domestic sector*** (power generation) will be set on a ***cost of supply basis***
- Price for ***industrial sector*** (feedstock) will set on a ***product netback*** whereby the price of gas is a function of the ***price of the output produced by the buyer***
- Prices for ***commercial sector*** (fuel) will be set on an ***alternate fuel basis***