IRRP Modeling Inputs and Assumptions

Cost & Performance of Existing and Future Plants

Dispatch Decisions for Power Plants

- IPM dispatches units based on variable cost (FOM+VOM+Fuel costs), which is the short-run marginal cost for a power plant
- Such a SRMC approach is consistent with competitive wholesale electricity market (WEM)
- Current dispatch decisions do not conform to this approach, as it relies on regulated tariffs (which includes additional costs associated with capital recovery)
  - Hence the needs for additional fixed cost adders to approximate current dispatch decisions (at least for the short term)
- Ghana is expected to move towards a competitive WEM shortly, and IPM modeling results could help evaluate the implications for changing dispatch for cost-recovery and negotiations for bilateral contracts in a WEM
  - IRRP will work with GRIDCo to understand how upcoming market rules will impact modeling (and how IPM can be used for evaluating the draft rules)

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Performance & Cost - Existing and Under-Construction Units

Existing & UC Plants	Fixed O&M	Var. O&M	Heat Rate	Variable Marginal Cost	Est. Regulated Tariff	Estimated Capital Cost Adder to MCs
	2016$/kW-yr	2016$/MWh	Btu/kWh	Uscents/kWh	Uscents/kWh	Uscents/kWh
Akosombo	9.16	0.98	-	0.28	2.02	85.13
Kpong	9.16	0.98	-	0.25	4.14	242.24
TAPCO (T1)	18.70	5.00	8,483	7.01	10.77	279.91
TICO (T2)	30.94	4.90	8,400	7.10	11.00	290.10
MRP	12.38	4.50	12,468	9.83	13.00	222.38
TT1PP	14.30	6.50	11,180	9.09	11.68	192.72
TT2PP	11.83	4.50	12,468	9.81	11.68	139.31
SAPP 1	11.83	4.50	7,800	7.02	15.30	616.49
VRA Solar	-	166.90	-	16.69	20.18	51.97
Bui	27.74	1.63	-	1.34	10.47	216.04
CENIT	11.83	4.50	11,180	12.86	15.82	220.24
Trojan 1	34.00	5.50	8,440	7.97	18.20	716.72
KTPP	12.30	3.50	10,800	9.39	12.00	194.13
KarpowerShip 1	177.83	3.50	8,514	10.56	13.89	247.76
BXC Solar	-	201.80	-	20.18	20.18	-
Ameri_2016	14.54	5.00	8,800	7.19	13.00	432.64
Trojan 2B	34.00	5.50	8,440	12.29	21.90	673.18
Trojan 2A	34.00	5.50	8,440	12.29	21.90	673.18
GP Chirano Plant	17.50	3.50	11,000	14.89	15.00	8.56
Safisana	35.00	4.20	13,500	15.92	16.00	1.44
GP Tarkwa Plant	17.50	3.50	9,926	13.49	15.00	112.52
GP Darmang Plant	17.50	3.50	10,630	14.40	15.00	44.38
SAPP 2	16.00	3.50	7,800	6.98	14.25	541.59
AKSA	16.00	3.50	8,500	8.38	12.00	269.81
Trojan 3	34.00	5.50	8,100	7.66	11.80	307.91
KarpowerShip 2	177.83	3.50	8,514	10.56	13.89	247.76
Cenpower	16.00	3.50	7,830	7.00	14.00	521.14
Amandi	30.94	4.90	8,200	6.96	12.00	375.55
Early Power	16.00	3.50	7,500	10.31	15.00	348.85

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Performance and Cost of New Builds

Cap Type	Potential Builds				Fuel cost	Generation Cost
	Capital Cost	Fixed O&M	Var. O&M	Heat Rate	$/MMBtu	Uscents/kWh
	2016$/kW	2016$/kW-yr	2016$/MWh	Btu/kWh		
Biogas	4200	410.3	5.5	18,000	3.00	**17.55**
Biomass	3700	110.3	4.5	18,000	5.00	**16.30**
Combined Cycle	1300	15.0	3.5	7,250	7.66	**7.87**
Combustion Turbine	1100	11.5	4.2	10,000	9.99	**12.06**
Hydro Small	5000	45.0	3.9	0		**13.75**
Solar PV - 2018	1295	24.8	0.0	0		**11.06**
Solar PV - 2020	1108	24.8	0.0	0		**9.70**
Solar PV - 2026	1002	24.8	0.0	0		**8.93**
Wind Turbine	3100	46.7	0.0	0		**15.02**
Coal Steam Turbine	5000	65.0	6.0	8,800	2.82	**11.21**
Nuclear	7000	100.0	2.3	12,000	0.28	**12.49**

- Information based on IRRP assumptions, based on review of US EIA modeling assumptions in 2016
- Coal and Nuclear costs include estimated fuel infrastructure costs
- VOM and FOM are based on recent US EIA modeling assumptions, with some modifications
- Solar PV capital costs show a declining trend and is based on average costs of the recent 50 MW Bui Solar PV tender process in 2016

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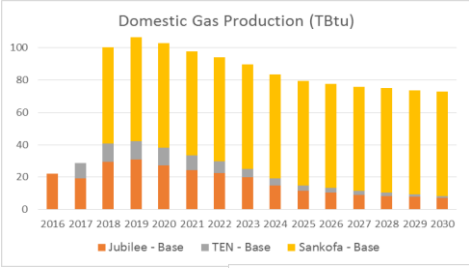
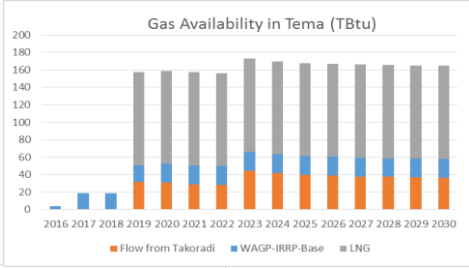
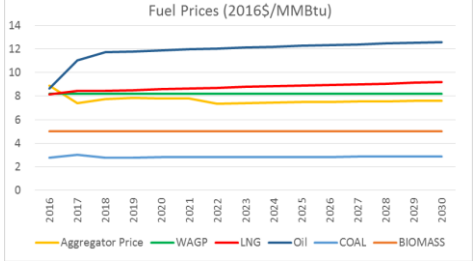
Gas Supply Availability and Prices





- Gas is available in Southeast and Southwest only by 2030 (i.e., no major gas pipeline growth)
- 90% of Sankofa and 100% of associated gas is forced to be consumed by the power sector



- Assumes WAGP reversal by 2019 to move gas from Takoradi to Tema
- 2 million tons of LNG import capability in Tema assumed, but LNG prices higher than domestic gas

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IRRP Modeling Inputs and Assumptions

Transmission Limits

6a

Total Transfer Capacity (TTC) Calculation

TTC Definition: The amount of electric power that can be moved or transferred reliably from one area to another area of the interconnected transmission systems by way of all transmission lines (or paths) between those areas under specified system conditions.

- IPM needs TTCs between each zones in order to determine how much can be transmitted from one zone to another, assuming there is limited generation capacity in the receiving zone and excess capacity in transmitting zone
- IPM also has the option to build "transmission links" between zones, which can then be used for more detailed transmission planning
- IRRP team has worked with GRIDCo system planning unit, and used using PV analysis in PSS/E to determine TTCs between the four zones
- Transmission Losses in each zone are calculated using peak power flow cases and a Loss Load Factor (LLF)
- IRRP is continuing to review and finalize the TTC numbers, with GRIDCo support

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Transmission Constraints (MW): 2016 to 2018

Source	Destination	Non-Firm TTC	Firm TTC	Contingency
South West	South East	476	450	161 kV Mallam - Winneba
			454	161 kV Mallam – Cape Coast
			292	330 kV Volta - Aboadze
South East	South West	403	373	161 kV Mallam - Winneba
			392	161 kV Mallam – Cape Coast
			120	330 kV Volta - Aboadze
South West	Ashanti	370	0 (NC)	161 kV Dunkwa – New Obuasi
			331	161 kV Prestea - Obuasi
South West	North	60	0	161 kV Juabeso - Mim
South East	Ashanti	207	178	161 kV Nkawkaw - Konongo
			170	161 kV Nkawkaw – K2BSP
			193	161 kV Akwatia – New Obuasi
Ashanti	North	61	9	
North	Ashanti	68	13	

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Transmission Constraints (MW): 2019 to 2030 (w/ Gen Limits)

Source	Destination	Non-Firm TTC	Firm TTC	Contingency
South West	South East	601	589	161 kV Mallam - Winneba
			200	330 kV Volta - Aboadze
South East	South West	357	350	161 kV Mallam - Winneba
			80	330 kV Volta - Aboadze
South West	Ashanti	630	603	161 kV Dunkwa – New Obuasi
			609	161 kV Prestea - Obuasi
South West	North	30	0	161 kV Juabeso - Mim
South East	Ashanti	227	193	161 kV Akwatia – New Obuasi
			201	161 kV Nkawkaw - Konongo
			194	161 kV Nkawkaw - Anwomaso
Ashanti	North	297	295	161 kV Kumasi - Techiman
			219	330 kV Anwomaso- Kintampo
			294	161 kV Kumasi - Kenyase
			292	161 kV Obuasi - Kenyase
North	Ashanti	0	0	

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Transmission Constraints (MW): 2019 to 2030 (w/o Gen Limits)

Source	Destination	Non-Firm TTC	Firm TTC	Contingency
South West	South East	786	715	161 kV Mallam - Winneba
			0	330 kV Volta - Aboadze
			641	161 kV Mallam – Cape Coast
South East	South West	666	569	161 kV Mallam - Winneba
			263	330 kV Volta - Aboadze
			601	161 kV Mallam – Cape Coast
South West	Ashanti	768	698	161 kV Dunkwa – New Obuasi
			718	161 kV Prestea - Obuasi
			0	330 kV Dunkwa - Anwomaso
South West	North	30	0	161 kV Juabeso - Mim
South East	Ashanti	243	199	161 kV Akwatia – New Obuasi
			207	161 kV Nkawkaw - Konongo
			198	161 kV Nkawkaw - Anwomaso
Ashanti	North	478	413	161 kV Kumasi - Techiman
			152	330 kV Anwomaso- Kintampo
			233	161 kV Kumasi - Kenyase
			392	161 kV Obuasi - Kenyase
North	Ashanti	198	60	

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Annual Energy Loss Results (Initial Estimates)

	2016-2018	2019 +
Zone	**%Losses**	**%Losses**
South East	3.44	1.60
South West	0.95	1.15
Ashanti	0.61	0.29
North	0.49	0.15

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IRRP Modeling Inputs and Assumptions

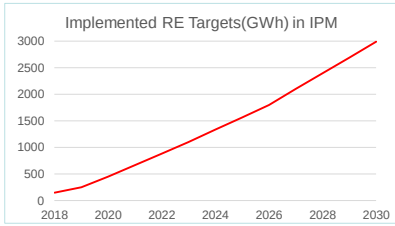
Renewable Energy Target & Resources

12a

RE Target Implementation

- RE Target: 10% installed capacity by 2020
- RE Target: 10% generation by 2030, starting from 2018 (implemented in IPM)
- RE technologies that count towards Target: Solar PV, wind, biomass, biogas, small hydro
  - This may be more stringent than the actual RE target, which allows for other technologies (solar rooftops, irrigation pumps, lanterns, etc.) to count against the target

	2018	2019	2020	2023	2026	2030
Ghana Consumption (GWh)	16338	17373	18,012	20,541	23,179	27,704
10% RE target by 2030 (GWh)	150	250	450	1,100	1,800	2,707



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Renewable Feed in Tariff from PURC (October 2016)

TPYE OF TECHNOLOGY	October 2016-10 Year Tariff		October 2016-Indicative Tariff with 20yr fix term	
	GHp/kWh	**US ¢/kWh**	GHp/kWh	**US ¢/kWh**
Wind	65.3529	**16.5551**	57.0898	**14.4538**
Solar PV	59.7750	**15.1421**	51.3385	**12.9977**
Hydro <= 10MW	52.9428	**13.4114**	45.5979	**11.5444**
Hydro (<= 10MW and <= 100MW)	56.5312	**14.3204**	48.6881	**12.3267**
Tidal Wave (Ocean Wave)	52.9428	**13.4114**	45.5879	**11.5418**
Run-of-River	52.9428	**13.4114**	45.5879	**11.5418**
Biomass	69.1225	**17.5100**	59.5326	**15.0723**
Biomass (Enhanced Technology)	72.8589	**18.4565**	62.7507	**15.8871**
Biomass (Plantation as Feed Stock)	78.1092	**19.7865**	67.2726	**17.0319**
Landfill Gas	69.1225	**17.5100**	59.5326	**15.0723**
Sewage Gas	69.1225	**17.5100**	59.5326	**15.0723**
Geoplutonic (Geothermal)	46.5817	**11.8000**	40.1191	**10.1572**

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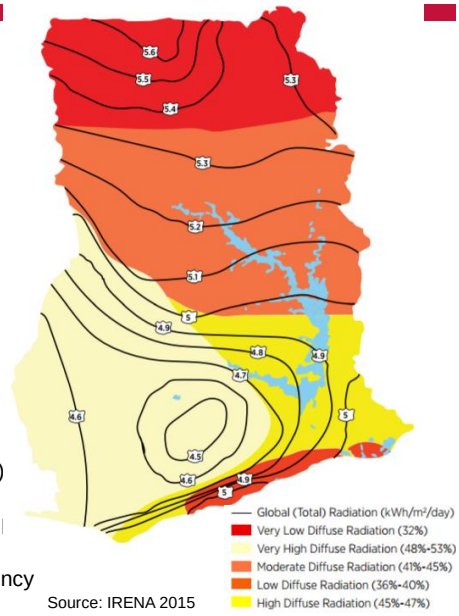
Solar Resource

- Abundant Solar resource in Ghana (IRENA Study)
- Key Issues
  - Transmission and distribution impacts
  - Land Availability and Cost
  - Operational integration of RE, and addressing intermittency
  - Module costs are rapidly decreasing, increasing its viability
- The way forward with Solar
  - More studies on solar integration into the grid is needed
  - Existing grid integration reports (e.g., GIZ) needs to be further evaluated
  - Hydropower can act as storage (~1 GW), **proximity to hydro plants is not necessary,** as grid can balance intermittency



Source: IRENA 2015

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Solar PV Characteristics in IPM Model

- Cost Input for IPM

EXISTING BUILDS

Plant Name	Variable O&M (FIT) (2016 US¢/kWh)
BXC	20.77
VRA Solar	~17

Solar capacity factors at 17%, based on BXC profile

POTENTIAL BUILDS

Plant Name	Capital Cost (2016 USD/kWh)	Fixed O&M (2016 USD/kW-yr)	Energy Cost (2016 US¢/kWh)
MoP (20MW)	-	-	~11.7
IRRP Solar 2018	1420	24.8	11.1
IRRP Solar 2020	1,300	24.8	9.7
IRRP Solar 2026	1,110	24.8	8.9

- Other Inputs

SOLAR CAP/LIMIT

IPM Model Regions	Max. Capacity (MW)
Ashanti GH	140
North GH	400
South West-GH	280
South East-GH	290

IRRP Assumptions:
Several 20-50 MW size plants can be build in the short term, and larger sizes can be incorporated over time.

Transmission improvements can further increase size of solar plants (more analysis needed)

Information from other studies (GIZ) can help support our analysis

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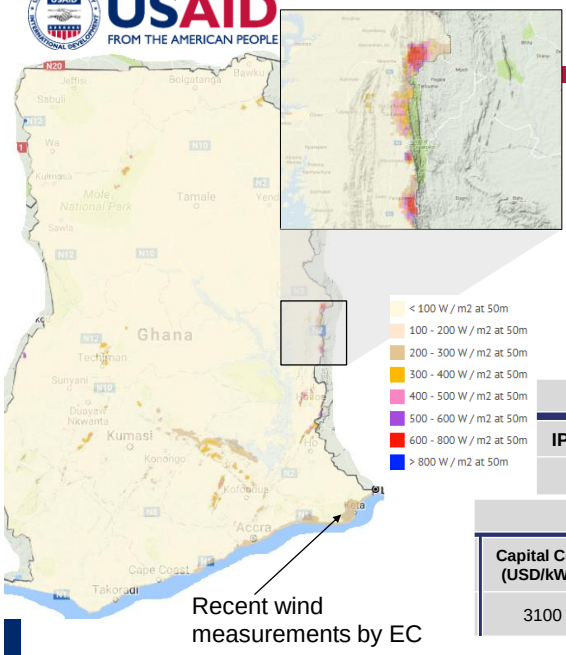
Wind Resource



- Wind speed assessments seem to indicate high resource availability along the coast in the south-east , and along the Ghana-Togo border.
- Transmission and transport infrastructure could limit development in short term
- More assessments are needed in the northern areas

WIND CAP/LIMIT

IPM Model Region	Max. Capacity (MW)
South East-GH	350

POTENTIAL BUILDS

Capital Cost (USD/kWh)	Fixed O&M ($/kW-yr)	Energy Cost (US¢/kWh)	FIT – 10 yr (US¢/kWh)
3100	46.7	16.3	16.6

Source: NREL 2016

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Small Hydropower Resource

Name	Capacity (MW)	Year of Study	Installed Cost [2016 USD/kW]	Energy Cost [2016 US ¢/kWh]
Pwalugu	70	2014	5971	30.1
Hemang	60	2012	4975	26.3
Juale	87	1992	3982	11.9
Daboya	43	1992	5300	17.8
Kulpawn	36	1992	9117	29.7
Koulbi	68	1984	5769	15.3
Ntereso	64	1984	4248	16.1
Jambito	55	1984	4557	21.1
Lanka	95	1984	5208	23.4
Jomoro	20	1984	6597	23.4
Asuaso	25	1984	5748	16.9
Sodukrom	17	1984	9337	35.5
Kojokrom	30	1984	4740	15.9
Tanoso	56	1984	3273	11
Abatumesu	50	1984	4797	15.7
Awiasam	50	1984	3305	12.4

- Most hydro resource studies are outdated, and needs to be updated (10 ongoing studies led by MoEn)
- Impact of Climate Change has not been considered
- Costs are very sensitive to environmental and social impacts; 15% additional costs have been added to account for E/S impacts in IRRP calculations
- High costs imply that additional incentives might be necessary to promote small hydro – but better hydrological and feasibility studies are needed

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Small Hydropower Resource

CAPACITY LIMIT in IPM	
IPM Model Regions	**Max. Capacity (MW)**
North GH (Pwalugu, Juale)	157
South West-GH (Hemang +)	140

- Costs are very dependent on specifics
- FIT for small hydro may need to be reviewed
- IRRP will assess climate change impacts in future

POTENTIAL BUILD COST in IPM			
Capital Cost (2006$/kW)	**Fixed O&M ($/kW-yr)**	**Cost of Energy (US¢/kWh)**	**FIT – 10 yr (US¢/kWh)**
5000	45	14.3	14.32

Capital Cost based on average of Bui and Hemang costs in pre-feasibility studies

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Biogas

CAPACITY LIMITS in IPM	
IPM Model Regions	**Max. Capacity (MW)**
Ashanti-GH	5
North-GH	20
South West-GH	10
South East-GH	10

POTENTIAL BUILDS in IPM			
Capital Cost (US$/kW)	**Fixed O&M (US$/kW-yr)**	**VOM (US¢/kWh-yr)**	**Cost of Energy (US¢/kWh)**
4200	410	5.5	17.55

Biomass

CAPACITY LIMITS in IPM	
IPM Model Regions	**Max. Capacity (MW)**
Ashanti-GH	50
North-GH	100
South West-GH	200
South East-GH	200

POTENTIAL BUILDS in IPM			
Capital Cost (US$/kW)	**Fixed O&M (US$/kW-yr)**	**VOM (US$/kWh-yr)**	**Cost of Energy (US¢/kWh)**
3700	110.3	4.5	16.4

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IRRP Modeling Results

DRAFT Reference Case

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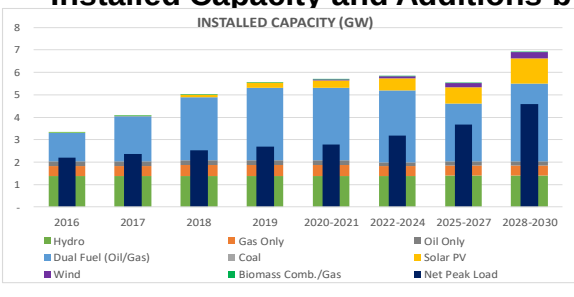
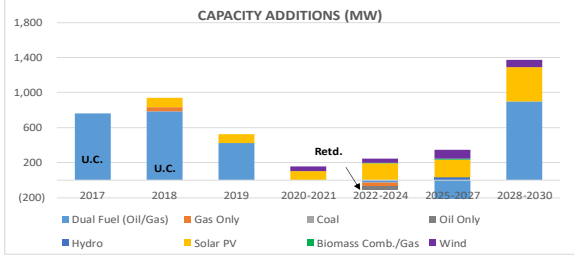
Installed Capacity and Additions by Technology



- Beyond 2020, only three "run-years", represent all of the years
- ~1400 MW of under-construction plants expected to be online in 2017 and 2018

Under Construction Units				
Plant	Type	Capacity (MW)	OnLine Date	Firm Retirement Date
Trojan 3	Gas CT	50	Jan-18	Apr-22
SAPP 2	LCO/Gas CC	360	Mar-17	
KarpowerShip 2	HFO/Gas CC	450	Jan-18	Dec-25
AKSA	HFO CT	370	Apr-17	Dec-23
Cenpower	LCO/Gas CC	340	Jan-18	
Amandi	LCO/Gas CC	190	Apr-19	
Early Power	LPG CC	400	Dec-17	



- New "unplanned" RE builds (solar PV, wind, and biomass) are needed to meet 10% RE targets by 2020
- By 2030, new combined cycle and combustion turbine plants are needed to meet peak demand + reserve margin, and energy demand
- Coal and Nuclear plants are not economical under current conditions

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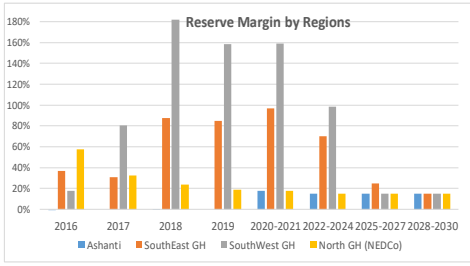
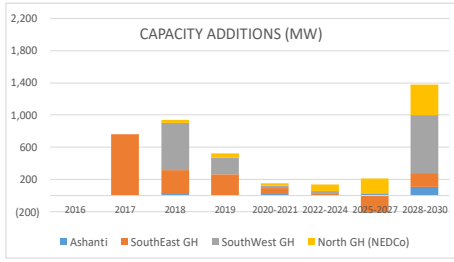
Reserve Margin & Cap. Additions by Model Region





- With under-construction plants in South-East and South-West Ghana coming online in 2017-19, reserve margins rise in the near term and only renewable "unplanned" builds are needed until 2023
- Beyond 2027, new CCs and CTs are needed across Ghana to meet growing demand and maintain RM
- Currently, sufficient gas (domestic gas, WAGP, and LNG) and oil supply are assumed, and additional scenarios with limited fuel supply are being evaluated

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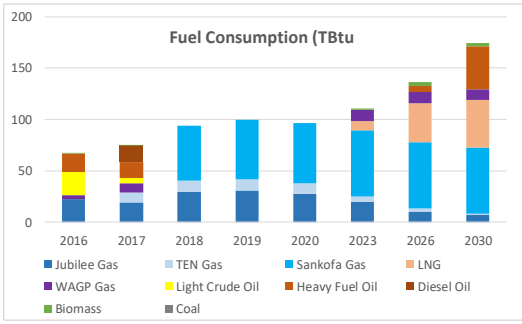
Fuel Consumption by Type



- In 2016 and 2017, LCO is needed to meet domestic gas and WAGP disruptions
- WAGP supply is limited to about 30 MMcfd (maximum) throughout the modeling period
- Sankofa 90% take or pay is fully enforced, and all of the associated gas production is also forced to be consumed
- By 2030, additional consumption from LNG and HFO to compensate for decreasing domestic gas supply and limited WAGP (Model currently does not allow for gas to Ashanti or North Ghana)

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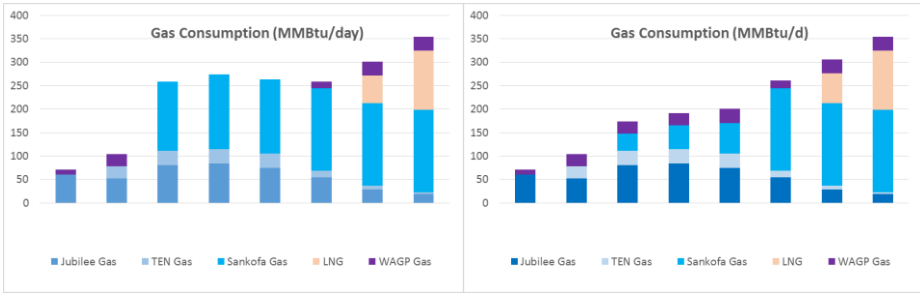
Sankofa Gas Take or Pay



- Gas consumption is very sensitive to gas prices, and further analysis is required to assess economic consumption (with and without Sankofa take or pay)
- Gas reliability is a key motivator for LNG; however, additional contractual obligations will further constrain economics

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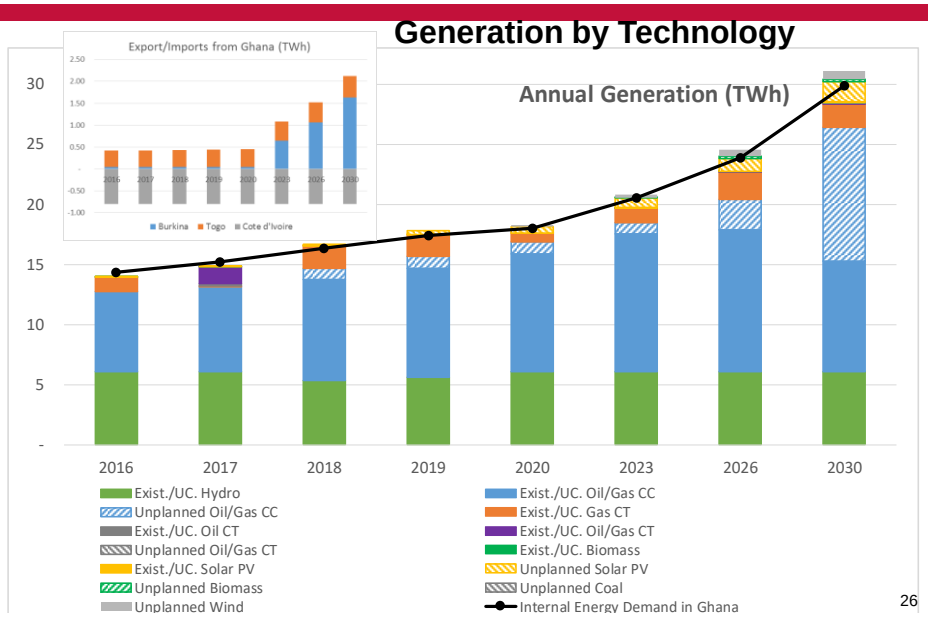
Generation by Technology



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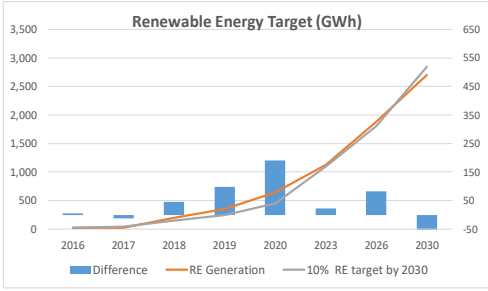
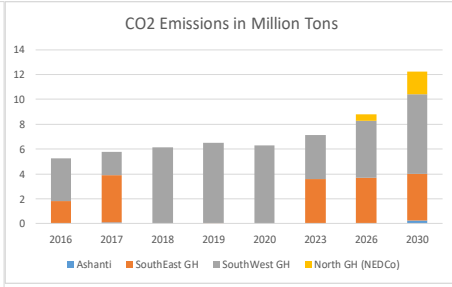
RE Targets and CO2 Emissions





- RE targets are met with increased solar and wind builds
- RE Targets limit rise in CO2 emissions, as the near-term new builds are all renewable
- CO2 emissions from the power sector rise from about 4.9 million tons of CO2 in 2016 to about 12 million tons in 2030.
- The rise in CO2 emissions is primarily due to greater consumption of oil and gas beyond 2020 to meet rising demand

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Marginal Capacity and Energy Prices

Capacity Prices $/kW

Region Group	2016	2017	2018	2019	2020	2023	2026	2030
Ashanti Group	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.26
Northern Ghana	0.00	0.00	0.00	0.00	0.00	0.00	100.33	49.96
SouthEast Ghana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.28
SouthWest Ghana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.12

Energy Prices $/MWh

Region Group	2016	2017	2018	2019	2020	2023	2026	2030
Ashanti Group	83.05	89.04	0.58	0.63	0.98	67.75	93.35	100.64
Northern Ghana	83.05	89.04	0.59	0.63	0.98	67.75	93.35	100.64
SouthEast Ghana	83.05	89.04	0.58	0.63	0.98	67.75	93.35	100.64
SouthWest Ghana	83.05	89.04	0.58	0.63	0.98	67.75	93.35	100.64

- Capacity prices from 2026+ indicate the need for new power plants to meet growing peak load (+ RM) and energy demand.
- RE builds and gas generation from 2018+ do not count for energy or capacity prices, as they are required to meet RE targets and Sankofa take or pay (constraints mean no marginal cost to the system)
- Forced single price for all of Ghana, but zonal prices can also be easily created

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Detailed Plant-level Dispatch, Cost, and Pro-forma

					Available Capacity								Capacity Factors							
	Plant Name	Model Region	Fuel Type	Capacity Type	2016	2017	2018	2019	2020	2023	2026	2030	2016	2017	2018	2019	2020	2023	2026	2030
1	CENIT	SouthEast Ghana Group	Oil	Oil Combustion	100	100	100	100	100	100	100	100	0%	0%	0%	0%	0%	0%	0%	0%
2	Trojan 2B	SouthEast Ghana Group	Oil	Oil Combustion	16	16	16	16	16				0%	0%	0%	0%	0%			
3	Trojan 2A	Ashanti Group	Oil	Oil Combustion	16	16	16	16	16				0%	0%	0%	0%	0%			
4	GP Tarkwa Plant	SouthWest Ghana Group	Oil	Oil Combustion	33	33	33	33	33	33	33	33	0%	0%	0%	0%	0%	0%	0%	0%
5	GP Chirano Plant	SouthWest Ghana Group	Oil	Oil Combustion	30	30	30	30	30	30	30	30	0%	0%	0%	0%	0%	0%	0%	0%
6	GP Darmang Plant	SouthWest Ghana Group	Oil	Oil Combustion	20	20	20	20	20	20	20	20	0%	0%	0%	0%	0%	0%	0%	0%
7	SAPP 2	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combined Cycle		370	370	370	370	370	370	370		55%	0%	0%	0%	93%	93%	93%
8	Cenpower	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combined Cycle			340	340	340	340	340	340			0%	0%	0%	9%	93%	93%
9	KarpowerShip 1	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combined Cycle	247	247							95%	29%						
10	AKSA	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combined Cycle		250	375	375	375	375				39%	0%	0%	0%	0%		
11	TAPCO (T1)	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combined Cycle	305	305	305	305	305	305	305		32%	35%	83%	83%	75%	0%	55%	
12	TICO (T2)	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combined Cycle	320	320	320	320	320	320	320	320	87%	88%	88%	88%	88%	77%	88%	70%
13	Amandi	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combined Cycle				190	190	190	190	190				41%	27%	88%	88%	87%
14	KarpowerShip 2	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combined Cycle			450	450	450	450					95%	95%	95%	95%		
15	TT1PP	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion	100	100	100	100	100	100	100	100	0%	0%	0%	0%	0%	0%	0%	0%
16	KTPP	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion	200	200	200	200	200	200	200	200	0%	0%	0%	0%	0%	0%	0%	0%
17	Trojan 1	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion	25	25	25	25	25				0%	0%	0%	0%	0%			
18	Early Power	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion		144	144	378	378	378	378	378			0%	0%	0%	0%	0%	0%
19	MRP	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion	70	70	70	70	70	70	70	70	0%	0%	0%	0%	0%	0%	0%	0%
20	Safisana	SouthEast Ghana Group	Biomass	Biomass Combustion/Bi	0	0	0	0	0	0	0	0	26%	85%	0%	0%	0%	85%	85%	85%
21	TT2PP	SouthEast Ghana Group	Gas	Gas Combustion Turbine	45	45	45	45	45	45	45	45	0%	0%	0%	0%	0%	0%	0%	0%
22	SAPP 1	SouthEast Ghana Group	Gas	Gas Combustion Turbine	180	180	180	180	180	180	180	180	32%	3%	0%	0%	0%	0%	91%	91%
23	Trojan 3	SouthEast Ghana Group	Gas	Gas Combustion Turbine			50	50	50						0%	0%	0%			
24	Ameri_2016	SouthWest Ghana Group	Gas	Gas Combustion Turbine	230	230	230	230	230				0%	0%	90%	90%	90%			
25	Ameri_2021	SouthWest Ghana Group	Gas	Gas Combustion Turbine						230	230	230						0%	8%	25%
26	Bui	Northern Ghana Group	Water	Hydro	330	330	330	330	330	330	330	330	27%	27%	0%	1%	0%	27%	27%	27%
27	Akosombo	SouthEast Ghana Group	Water	Hydro	900	900	900	900	900	900	900	900	56%	56%	48%	47%	51%	56%	56%	56%
28	Kpong	SouthEast Ghana Group	Water	Hydro	140	140	140	140	140	140	140	140	71%	71%	2%	10%	28%	71%	71%	71%
29	Cote d'Ivoire Dummy	Cote d'Ivoire	Water	Hydro	150	150	150	150	150	150	150	150	62%	62%	1%	1%	1%	62%	62%	62%
30	Burkina Dummy	Burkina Group	Water	Hydro	10	10	10	10	10	110	110	110	1%	0%	1%	1%	1%	0%	0%	0%
31	VRA Solar	Northern Ghana Group	Sun	Solar PV	2	2	2	2	2	2	2	2	17%	17%	17%	17%	17%	17%	17%	17%
32	BXC Solar	SouthEast Ghana Group	Sun	Solar PV	18	18	18	18	18	18	18	18	15%	15%	15%	15%	15%	15%	15%	15%
33	ASHA COMBINED CYCLE	Ashanti Group	Oil/Gas	Oil/Gas Combined Cycle								48								95%
35	NORT COMBINED CYCLE	Northern Ghana Group	Oil/Gas	Oil/Gas Combined Cycle							101	335							95%	95%
37	SOUT COMBINED CYCLE	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combined Cycle				115	115	115	115	699			95%	95%	95%	95%	95%	95%
38	SOUT COMBUSTION TURBI	SouthEast Ghana Group	Oil/Gas	Oil/Gas Combustion								50								1%
39	SOUT COMBUSTION TURBI	SouthWest Ghana Group	Oil/Gas	Oil/Gas Combustion								432								4%
40	ASHA SOLAR PV	Ashanti Group	Sun	Solar PV			20	20	20	20	20	20			19%	19%	19%	19%	19%	19%
41	ASHA SOLAR PV	Ashanti Group	Sun	Solar PV					20	40	40	40					19%	19%	19%	19%
42	ASHA SOLAR PV	Ashanti Group	Sun	Solar PV							20	80							19%	19%

IRRP PROJECT -- NOT FOR DISTRIBUTION

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Illustrative Pro-forma (for existing VRA units)

Specification	2016 (real2016$)	2017 (real2016$)	2018 (real2016$)	2019 (real2016$)	2020 (real2016$)	2021 (real2016$)	2022 (real2016$)	2023 (real2016$)	2024 (real2016$)	2025 (real2016$)	2026 (real2016$)	2027 (real2016$)	2028 (real2016$)	2029 (real2016$)	2030 (real2016$)
Capacity (MW)	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	2081.80	1776.80	1776.80	1776.80
Reserve Margin Capacity (MW)	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	2075.00	1775.00	1775.00	1775.00
Generation (GWh) - Annual	8600.31	8717.44	9977.83	7666.52	6912.18	6912.18	7708.06	7708.06	7708.06	9752.66	9752.66	9752.66	7264.41	7264.41	7264.41
Generation (GWh) - Off Peak	8600.31	8717.44	9977.83	7666.52	6912.18	6912.18	7708.06	7708.06	7708.06	9752.66	9752.66	9752.66	7264.41	7264.41	7264.41
Average Capacity Factor (%)	47.16	47.80	54.71	42.04	37.90	37.90	42.27	42.27	42.27	53.48	53.48	53.48	46.67	46.67	46.67
CO2 Emissions (MTons) - Annual	1922.78	1876.58	2574.17	1295.49	882.07	882.07	1318.25	1318.25	1318.25	2451.44	2451.44	2451.44	1075.45	1075.45	1075.45
NOX Emissions (MTons) - Annual	12.66	14.72	20.19	10.16	6.92	6.92	10.34	10.34	10.34	19.23	19.23	19.23	8.43	8.43	8.43
SO2 Emissions (MTons) - Annual	0.94	0.30	0.41	0.21	0.14	0.14	0.21	0.21	0.21	0.39	0.39	0.39	0.17	0.17	0.17
GH RPS 10% Constraint 2017-01-30($/MWh)	0.00	0.00	0.00	0.00	0.00	0.00	18.05	18.05	18.05	212.46	212.46	212.46	74.89	74.89	74.89
Fuel Consumption (TBtu) - Annual	27.77	28.76	39.45	19.86	13.52	13.52	20.20	20.20	20.20	37.57	37.57	37.57	16.48	16.48	16.48
Fuel Expense (000$) - Annual	248828.63	212237.54	306128.23	155360.92	105563.27	105563.27	149083.03	149083.03	149083.03	282693.75	282693.75	282693.75	125213.95	125213.95	125213.95
Fuel Cost ($/MWh) - Annual	28.93	24.35	30.68	20.26	15.27	15.27	19.34	19.34	19.34	28.99	28.99	28.99	17.24	17.24	17.24
Fuel Cost ($/MWh) - Off Peak	28.93	24.35	30.68	20.26	15.27	15.27	19.34	19.34	19.34	28.99	28.99	28.99	17.24	17.24	17.24
Average Fuel Price ($/MMbtu)	8.96	7.38	7.76	7.82	7.81	7.81	7.38	7.38	7.38	7.52	7.52	7.52	7.60	7.60	7.60
VO&M Expense (000$) - Annual	21437.68	22020.94	28322.90	16776.63	13080.37	13080.37	16980.19	16980.19	16980.19	27178.19	27178.19	27178.19	14803.28	14803.28	14803.28
VO&M Cost ($/MWh) - Annual	2.49	2.53	2.84	2.19	1.89	1.89	2.20	2.20	2.20	2.79	2.79	2.79	2.04	2.04	2.04
FO&M Expense (000$)	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	399180.75	308103.48	308103.48	308103.48
FO&M Cost ($/kW-yr)	191.75	191.75	191.75	191.75	191.75	191.75	191.75	191.75	191.75	191.75	191.75	191.75	173.40	173.40	173.40
Capital Expense (000$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capital Cost ($/kW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capacity Price ($/kW-yr)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.30	9.30	9.30	11.25	11.25	11.25
Capacity Revenue (000$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19296.69	19296.69	19296.69	19973.15	19973.15	19973.15
Average Marginal Energy Price ($/MWh) - Annual	83.05	89.05	69.56	70.12	69.98	69.98	67.83	67.83	67.83	95.26	95.26	95.26	101.64	101.64	101.64
Average Marginal Energy Price ($/MWh) - Off Peak	83.05	89.05	69.56	70.12	69.98	69.98	67.83	67.83	67.83	95.26	95.26	95.26	101.64	101.64	101.64
Energy Revenue (000$)	714245.36	776294.69	694064.87	537579.43	483709.09	483709.09	522825.96	522825.96	522825.96	929086.34	929086.34	929086.34	738371.99	738371.99	738371.99
Overnight Capital Expense (000$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depreciation (000$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Revenue (000$)	714245.36	776294.69	694064.87	537579.43	483709.09	483709.09	522825.96	522825.96	522825.96	948383.03	948383.03	948383.03	758345.14	758345.14	758345.14
Allow. Revenue (000$) GH RPS 10% Constraint 2017-01-30	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.58	-0.58	-0.58	-0.20	-0.20	-0.20
Net Capacity Revenue (000$)	-399180.75	-399180.75	-399180.75	-399180.75	-399180.75	-399180.75	-399180.75	-399180.75	-399180.75	-379884.06	-379884.06	-379884.06	-288130.32	-288130.32	-288130.32
Net Energy Revenue (000$)	443979.05	542036.21	359613.75	365441.88	365065.45	365065.45	356762.69	356762.69	356762.69	619213.83	619213.83	619213.83	598354.55	598354.55	598354.55
Total Variable Expense (000$)	270266.31	234258.48	334451.12	172137.56	118643.65	118643.65	166063.22	166063.22	166063.22	309871.93	309871.93	309871.93	140017.23	140017.23	140017.23
Total Expense (000$)	669447.05	633439.23	733631.87	571318.30	517824.39	517824.39	565243.96	565243.96	565243.96	709052.68	709052.68	709052.68	448120.71	448120.71	448120.71
Net Income (000$)	44798.30	142855.46	-39567.00	-33738.87	-34115.30	-34115.30	-42418.00	-42418.00	-42418.00	239330.35	239330.35	239330.35	310224.43	310224.43	310224.43
After-Tax Income (000$)	44798.30	142855.46	-39567.00	-33738.87	-34115.30	-34115.30	-42418.00	-42418.00	-42418.00	239330.35	239330.35	239330.35	310224.43	310224.43	310224.43
Total Sources Cash (000$)	44798.30	142855.46	-39567.00	-33738.87	-34115.30	-34115.30	-42418.00	-42418.00	-42418.00	239330.35	239330.35	239330.35	310224.43	310224.43	310224.43
Net After Tax Cash Flow (000$)	44798.30	142855.46	-39567.00	-33738.87	-34115.30	-34115.30	-42418.00	-42418.00	-42418.00	239330.35	239330.35	239330.35	310224.43	310224.43	310224.43
Net Present Value 2016-2030 (000$)	504263.86														

Questions? Discussion…