**Appendix - Model documentation for Figure 3 in Energy Use: Electricity System in West Africa and Climate Change Impact (ABiodun S. Momodu)**

"$ per B$"= 10^9

Units: USD/Billion USD

Aggregate demand[WAPP Member Countries]=

-Government Expenditure[WAPP Member Countries]+Consumption[WAPP Member Countries

]+Investment[WAPP Member Countries]

Units: Billion US$

average tariff[WAPP Member Countries]=

6.1,7.2,5.9,14.1,4,10.6,12.3,7.4,5,9.7,6.6,10.6,5.4,7.5

Units: Cents/(kWh)

Base GDP[WAPP Member Countries]=

8.29,10.68,31.76,0.94,37.54,7.14,1.06,2.05,12.75,7.14,486.79,13.61,4.21,4.09

Units: Billion US$

"Base generation -2015"[WAPP Member Countries]=

326,655,7570,228,12867,654,74,55,519,397,29459,2592,167,849

Units: GWh

Base Per Capita Electricity Demand[WAPP Member Countries]=

429.96,436.18,733.46,514.52,869.43,451.87,440.12,412.21,429.49,419.95,561.68

,571.32,425.88,516.23

Units: kWh/Person/Year

Base Population[WAPP Member Countries]=

1.08798e+007,1.81056e+007,2.27016e+007,1.99092e+006,2.74099e+007,1.26086e+007

,1.84433e+006,4.50344e+006,1.75997e+007,1.98991e+007,1.82202e+008,1.51293e+007

,6.45318e+006,7.30458e+006

Units: Person

capacity factor[WAPP Member Countries]=

0.81,0.81,0.78,0.84,0.81,0.855,0.81,0.81,0.81,0.72,0.795,0.87,0.72,0.87

Units: Fraction

capacity life time[WAPP Member Countries]=

20,20,20,20,20,20,20,20,20,20,24,25,25,25

Units: Year

Capacity under Construction[WAPP Member Countries]= INTEG (

intitiating capacity[WAPP Member Countries]-completion[WAPP Member Countries

]\*construction time[WAPP Member Countries],

time to adjust capacity[WAPP Member Countries]\*-scrapping[WAPP Member Countries])

Units: MW

cents to US$=

0.01

Units: Cents/US$

Change in Expected Income[WAPP Member Countries]=

(GDP[WAPP Member Countries]-Expected Income[WAPP Member Countries])/Expectation Formation Time

[WAPP Member Countries]

Units: Billion USD/Year

(GDP - Expected 1ncome)/Expectation Formation Time

change in GDP[WAPP Member Countries]=

(Aggregate demand[WAPP Member Countries]-GDP[WAPP Member Countries])/Production adjustment time

[WAPP Member Countries]

Units: Billion USD/Year

CO2 foot print from electricity generation[WAPP Member Countries]=

"Cumulative Emission-WAPP System"[WAPP Member Countries]/Population[WAPP Member Countries]

Units: tCO2

completion[WAPP Member Countries]=

Capacity under Construction[WAPP Member Countries]/construction time[WAPP Member Countries]

Units: MW/Year

construction time[WAPP Member Countries]=

6,6,7,8,6,6,7,6,8,7,7,8,6,7

Units: Year

Consumption[WAPP Member Countries]=

Marginal Propensity to Consume[WAPP Member Countries]\*Expected Income[WAPP Member Countries]

Units: Billion US$

conv GWhtokWh=

1e+006

Units: kWh/GWh

Cost stream from electicity generated[WAPP Member Countries]=

grid electricity generated[WAPP Member Countries]\*(Op Cost[WAPP Member Countries

]+Tx Cost[WAPP Member Countries])

Units: USD

cum cap u construction=

SUM(Capacity under Construction[WAPP Member Countries!])

Units: MW/Year

Cum Grid Cap=

SUM(Grid Generation Capacity[WAPP Member Countries!])

Units: MW

cum grid electricity generated=

SUM(grid electricity generated[WAPP Member Countries!])

Units: \*\*undefined\*\*

cum per cap demand[WAPP Member Countries]=

SUM(Per Capita Electricity generated[WAPP Member Countries!])\*conv GWhtokWh

Units: kWh/Person

cumulative cost=

SUM(Cost stream from electicity generated[WAPP Member Countries!])

Units: USD/Year

cumulative electricity generated[WAPP Member Countries]=

SUM(grid electricity generated[WAPP Member Countries!])

Units: MWH/Year

"Cumulative Emission-WAPP System"[WAPP Member Countries]=

SUM(emission rate from electricity generation WA[WAPP Member Countries!])

Units: tCO2

cumulative income[WAPP Member Countries]=

SUM(Income stream from electricity generated[WAPP Member Countries!])

Units: USD/Year

cumulative profit=

SUM(WAPP System profit[WAPP Member Countries!])

Units: \*\*undefined\*\*

electricity intensity[WAPP Member Countries]=

per capita income[WAPP Member Countries]/Per Capita Electricity generated[

WAPP Member Countries]

Units: US$/kWh

emission factor grid electricity generation[WAPP Member Countries]=

0.4504,0.5544,0.2608,0.6216,0.2608,0.6344,0.5824,0.4544,0.464,0.6936,0.4624

,0.6536,0.4544,0.7616

Units: tCO2/(MWH)

From WAPP GEF Calculation

emission rate from electricity generation WA[WAPP Member Countries]=

grid electricity generated[WAPP Member Countries]\*emission factor grid electricity generation

[WAPP Member Countries]\*GWhtoMWh

Units: tCO2

Expectation Formation Time[WAPP Member Countries]=

7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5,7.5

Units: Year

Expected Income[WAPP Member Countries]= INTEG (

Change in Expected Income[WAPP Member Countries],

GDP[WAPP Member Countries])

Units: Billion USD

GDP[WAPP Member Countries]= INTEG (

change in GDP[WAPP Member Countries],

Base GDP[WAPP Member Countries])

Units: Billion USD

Government Expenditure[WAPP Member Countries]=

10,10,10,10,10,10,10,10,10,10,8,10,10,10

Units: Billion US$

Grid Base Capacity[WAPP Member Countries]=

134,135,1195,39,2185,109,26,22.6,86,138,5061,468,133,180

Units: MW

grid electricity generated[WAPP Member Countries]= ACTIVE INITIAL (

Grid Generation Capacity[WAPP Member Countries]\*capacity factor[WAPP Member Countries

]\*hours in a year\*MWh per GWh,

"Base generation -2015"[WAPP Member Countries])

Units: GWh/Year

Grid Generation Capacity[WAPP Member Countries]= INTEG (

completion[WAPP Member Countries]-scrapping[WAPP Member Countries],

Grid Base Capacity[WAPP Member Countries])

Units: MW

GridCapacity=

SUM(Grid Base Capacity[WAPP Member Countries!])

Units: \*\*undefined\*\*

GWhtoMWh=

1000

Units: MWH/GWh

Historical and Estimated Growth Rate for West Africa= WITH LOOKUP (

Time,

([(2010,0)-(2060,1.8e+009)],(2010,2.98e+008),(2015,3.6e+008),(2020,4.31e+008

),(2025,5.15e+008),(2030,6.14e+008),(2035,7.31e+008),(2040,8.69e+008),(2045

,1.031e+009),(2050,1.223e+009),(2055,1.449e+009),(2060,1.716e+009) ))

Units: Person

source:

http://www.worldometers.info/world-population/nigeria-population/

Historical emission from WAPP= WITH LOOKUP (

Time,

([(2008,0)-(2012,3e+012)],(2008,1e+009),(2009,1.1e+009),(2010,1.7e+009),(

2011,2.12e+009),(2012,2.5e+009) ))

Units: tCO2/Year

hours in a year=

18.5\*300

Units: H/Year

Income stream from electricity generated[WAPP Member Countries]=

grid electricity generated[WAPP Member Countries]\*(1-losses)\*average tariff

[WAPP Member Countries]\*cents to US$

Units: US$/Year

intitiating capacity[WAPP Member Countries]=

-scrapping[WAPP Member Countries]+target capacity[WAPP Member Countries]

Units: MW/Year

Investment[WAPP Member Countries]=

2,1,20,20,20,20,20,20,20,20,40,20,20,20

Units: Billion US$

losses=

0.2

Units: Dmnl

Marginal Propensity to Consume[WAPP Member Countries]=

0.8,0.8,0.8,0.95,0.9,0.85,0.85,0.89,0.86,0.8,0.95,0.87,0.82,0.84

Units: Dmnl

MWh per GWh=

0.001

Units: MWH/GWh

Net Population Growth Rate[WAPP Member Countries]=

Population[WAPP Member Countries]\*pop growth rate[WAPP Member Countries]

Units: Person

Normal Expected Income[WAPP Member Countries]= WITH LOOKUP (

ratio of per capita income to normal[WAPP Member Countries],

([(2010,0)-(2100,3)],(2010,1.0586),(2017.16,0.868421),(2020,0.743),(2040,

0.78),(2060,0.98),(2100,1.1) ))

Units: Dmnl

normal per capita income[WAPP Member Countries]=

822,717,1495,428,1474,573,589,484,755,469,3298,1072,808,658

Units: USD/Person

Op Cost[WAPP Member Countries]=

0.2

Units: USD/MWH

Per Capita Electricity generated[WAPP Member Countries]= ACTIVE INITIAL (

grid electricity generated[WAPP Member Countries]\*conv GWhtokWh/Population

[WAPP Member Countries],

Base Per Capita Electricity Demand[WAPP Member Countries])

Units: kWh/Person/Year

per capita income[WAPP Member Countries]=

GDP[WAPP Member Countries]\*"$ per B$"/Population[WAPP Member Countries]

Units: USD/Person

pop growth rate[WAPP Member Countries]=

0.0273,0.0298,0.0243,0.033,0.0242,0.0274,0.0245,0.0262,0.0302,0.0408,0.0271

,0.0315,0.0224,0.0271

Units: Fraction/Year [0.0198,0.0381,0.001]

Population[WAPP Member Countries]= INTEG (

Net Population Growth Rate[WAPP Member Countries],

Base Population[WAPP Member Countries])

Units: Person

Pressure to Add Additional Capacity[WAPP Member Countries]= WITH LOOKUP (

Ratio of Per Capita Demand to Normal[WAPP Member Countries],

([(2015,0)-(2065,20)],(2010,11),(2020,8.7),(2030,7.86),(2040,6.27),(2050,

5.2),(2060,4.5),(2065,4.7) ))

Units: Dmnl

Production adjustment time[WAPP Member Countries]=

1,1.5,1.5,1.5,1.5,1.5,1,1.5,1.5,1.5,1,1.5,1.5,1.5

Units: Year

Projected capacity= WITH LOOKUP (

Time,

([(2010,5000)-(2025,40000)],(2011,10609),(2015,17371),(2020,24109),(2025,

31728) ))

Units: MW

Projected energy demand= WITH LOOKUP (

Time, ([(2010,0)-(2025,2e+009)],(2011,6.5346e+008),(2015,1.07298e+009),(2020,1.49344e+009

),(2025,1.98175e+009) ))

Units: MW\*H

Ratio of Per Capita Demand to Normal[WAPP Member Countries]=

Per Capita Electricity generated[WAPP Member Countries]/Base Per Capita Electricity Demand

[WAPP Member Countries]

Units: Dmnl

ratio of per capita income to normal[WAPP Member Countries]=

per capita income[WAPP Member Countries]/normal per capita income[WAPP Member Countries]

Units: Dmnl

real per capita elec demand[WAPP Member Countries]=

SUM(Per Capita Electricity generated[WAPP Member Countries!])

Units: MW\*H/Person/Year

scrapping[WAPP Member Countries]=

Grid Generation Capacity[WAPP Member Countries]/capacity life time[WAPP Member Countries]

Units: MW/Year

target capacity[WAPP Member Countries]=

(Grid Generation Capacity[WAPP Member Countries]\*Pressure to Add Additional Capacity

[WAPP Member Countries])/time to adjust capacity[WAPP Member Countries]

Units: MW/Year

time to adjust capacity[WAPP Member Countries]=

20,21,20,21,20,21,20,21,20,21,20,21,20,21

Units: Year

Time to adjust capacity is best varied between 20 and 25 years

based on sensitivity analysis conducted on simulation period of

(50 - simulation period); half simulation period (25); quarter

period (12.5); one-fifth (10 Years) and one-tenth (5) years

respectively

time to adjust capacity 1= WITH LOOKUP (

Time,

([(2010,0)-(2060,20)],(2010,5),(2015,5),(2020,10),(2030,10),(2040,15),(2055

,18) ))

Units: Year

Tx Cost[WAPP Member Countries]=

0.1

Units: USD/MWH

WAPP System profit[WAPP Member Countries]=

Income stream from electricity generated[WAPP Member Countries]-Cost stream from electicity generated

[WAPP Member Countries]

Units: USD