Master Thesis

Sustainable Energy for the African Bottom Billion

16th December, 2010

By Yoshihisa Ohno

A thesis submitted to the faculty of

Graduate School of Public Policy, Tokyo University, Tokyo Japan

Thesis adviser

Professor Hideaki Shiroyama, Ph,d.

Graduate School of Public Policy, The University of Tokyo

Table of Contents

Bibliography

Author	Title	Date
AGECC	AGECC Summary Report "Energy for a Sustainable Future"	28 Apr, 2010
Abeeku Brew-Hammond and Francis Kemasuor	Renewable Energy for Rural Areas in Africa	Apr, 2008
Institute of StatisticaL, Social and Economic Research, University of Ghana	Guide to Electric Power in Ghana	Jul, 2005
International Monetary Fund	World Economic Outlook Database	Apr, 2010
JEPIC	The Electric Power Industry of Overseas Countries Vol. 2	Mar, 2010
Oak Ridge National Laboratory	Comparison of Costs and Benefits for DC	Feb, 1987
OECD/IEA	World Energy Outlook 2008	2008
Peter Stein, Stein Brothers AB	The Economics of Burundi, Kenya, Rwanda, Tanzania and Uganda	Apr, 2009
Tatsujiro Suzuki, Hideaki Shiroyama, Miwao Matsumoto	The Social Acceptance of Energy Technology	15 Aug, 2007
The Energy Center, Kwame Nkrumah University Of Science and Technology	Energy - My Vision / Flagbearers on Enrgy in Ghana	Sep, 2010
UNDP	Reducing Rural Poverty through Increased Access to Energy Services: A Review of the Multifunctional Platform Project in Mali	2004
UNDP , UNIDO, IEA	Energy Poverty: How to make modern energy access universal?	1 Sep, 2010
UNDP, WHO	The Energy Access Situation in Developing Countries	Nov, 2009
UNDP, the World Bank, ESMAP	Energy Services for the Millennium Development Goals	2004

List of figures

List of tables

List of Abbreviations and Acronyms

AfriWEA	African Wind Energy Association
AGECC	United Nations Secretary Generals Advisory Group on Energy and Climate Change
AU	African Union
B.T.W.A.L.	Biogas Technologies West Africa Limited, Ghana
BP	BritishPetroleum
BPC	Botswana Power Corporation
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corp
COMESA	Common Market for Eastern and Southern Africa
CSD	The United Nations Commission on Sustainable Development
CSP	Central Solar Power
CSP	Central Solar Power
EAC	African Community
EAC	East African Community
EAPP	Eastern Africa Power Pool
ECA	United Nations Economic Commission for Africa
ECG	Electricity Company of Thana Limited
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
ENE	Empresa Nacional de Electricidade
ESMAP	Energy Sector Management Assistance Program, the World Bank
EU	European Union
FIT	Feed-in Tariff
GVEP	Global village energy partnership
HCB	Hidroelectrica De Cahora Bassa Sa
HVAC	High Voltage Alternating Current
HVDC	high Voltage direct current

HVDC	High Voltage Direct Current
ICT	Information and communications technology
IEA	International Energy Agency
IMF	International Monetary Fund
IMF	International Monetary Fund
IsDB	Islamic Development Bank
JEPIC	Japan Electric Power Information Center, Inc
JICA	Japan International Cooperation Agency
KNUST	Kwame Nkrumah University of Science and Technology, Ghana
LDCs	Least Developed Countries
MEE	Ministry of Electricity & Energy, Egypt
MFP	multifunctional platform
MOU	minutes of understanding
MPIL	Madagascar Petroleum International Limited
NEPA	National Electric Power Authority, Nigeria
NGO	non governmental organizations
NREA	New & Renewable Energy Authority, Egypt
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PHCN	Power Holding Company of Nigeria
PV	Photovoltaics
SNEL	Societé Nationale d' Electricité
SSA	Sub-Saharan Africa
TANESCO	Tanzania Electric Supply Company Limited
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
UPDEA	Union of Producers, Transporters and Distributors of Electric Power in Africa
US	The United states of America
USAID	United States Agency for International Development
WAPP	West African Power Pool
WESTCOR	Western Power Corridor
WHO	World Health Organization

1. Purpose of this thesis

The purpose of this thesis is find out whether, when, and how can the rural Africans (hereinafter referred to as ""bottom billion") get the access to sustainable energy, in other words grid electricity (or enough reliable electricity such as biogas, multifunctional platforms or micro hydro plants). It is sure renewable energy such as solar or wind make high impact for off-grid people, nevertheless as we are aware that rural African people are uncomfortable when they are said they should be satisfied by a just a small solar unit, this thesis looks for the day when they have the access to modern energy.

First we will review the current condition of energy production and consumption in Africa, by global, regional and national viewpoints. Second, the thesis will report the recent trend in Africa, looking into projects on the ground (mainly based on business experiences and research travels). Third, the thesis will work on a new approach, to group countries into four categories by electrification rate, and analyze energy policies of some countries. Finally, the thesis will look out for the preferable energy policy for countries which have low energy access.

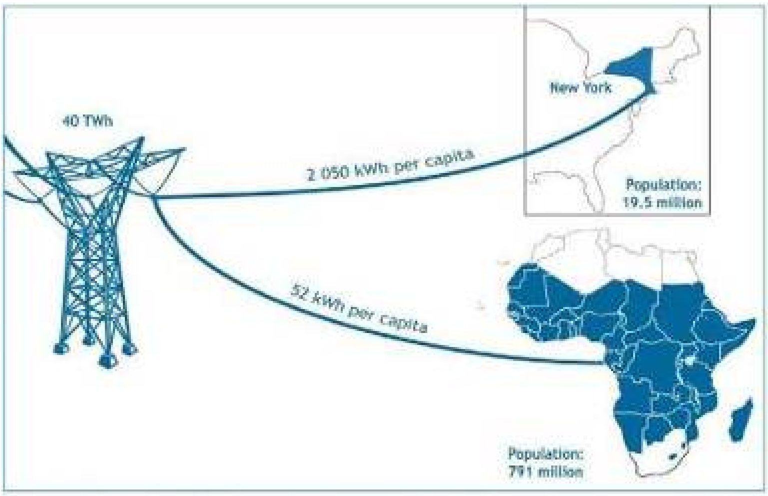
****

While a typical child of OECD countries goes to school in daytime to study or play, almost all African Children has to work from the morning to night, just to eat and live on. Whereas a typical mother of OECD countries just switch on washing machines or cooking range for housekeeping and cooking, African mothers have to walk the river for washing, or collect waters or branches. And when a father of OECD country just have to switch on the conveyor to move heavy materials, Africans have to convey them by hand.

When an NGO installs a solar panel on a roof of a lucky African house and turn on the light, the family members go mad with joy. Of course anybody, however poor or live in rural, has the right to use energy, the day when all African home is connected with electric grid will never come.

There are too many reasons why the poorest Africans cannot have access to energy. The utilities / power companies can't afford the cost to construct transmission lines, in lack of generation capacity, too much transmission loss until the power reaches rural area, financial problem for maintenance, lack of human power to collect the bill…..

Figure 1 Electricity consumption in New York and Sub-Saharan Africa



Source: "Energy Poverty: How to make modern energy access universal? " September 2010, by UNDP, UNIDO and IEA

The latest report "Energy Poverty: How to make modern energy access universal?" issued by UNDP, UNIDO and the IEA, shows that The electricity access in total Sub-Saharan Africa is 31%, but if excluded The Republic of South Africa, which generates more than 40 percent of electricity in Africa, only 28% is connected to the electric grid. Moreover, the report further tells that when excluded The Republic of South Africa, the electricity supplied to 791 million people of Sub-Saharan Africa (around 40 TWh) equals to the electric power sent to the inhabitants of New York, which accounts for only 19.5 million people.

But when the day rural people get at sustainable energy tool, has been already happening across the Continent. And if the political, commercial and financial conditions were satisfied, it may come true to more people. The purpose of this thesis is to analyze the energy policy and market of African countries, to seek the best way for universal access of sustainable energy.

More importantly , the another purpose of this thesis is, to find out any tendency of country and energy access in Africa, which has told be relatively "no direction between regions, countries".

****

This thesis has a significance of its own, because it examined the energy policies of specific African countries, and as a result it derived a cross-sectorial analysis, and most importantly, visualized the tendency of rural electrification in Africa on a geographical map[1].

---

[1] Professor Abeeku Brew-Hammond, the greatest authority on energy of Africa, approved "I

The regions and countries are defined as follows;

Region		Country
Northern Africa		Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Canary Islands (Spain)
Western Africa		Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Saint Helena Ascension and Tristan da Cunha (UK), Senegal, Sierra Leone, Togo
Eastern Africa		Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mayotte (France), Mozambique, Réunion (France), Rwanda, Seychelles, Somalia, Tanzania, Uganda, Zambia
Central Africa		Angola, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, São Tomé and Príncipe
Southern Africa		Ceuta (Spain), Madeira Islands (Portugal), Melilla (Spain), Botswana, Lesotho, Zimbabwe, Namibia, South Africa, Swaziland

have definitely never seen a map like this before and I can confirm that this is very original contribution to the current debate on increasing energy access in Africa”

2. The outline of Energy in Africa

2-1 Purpose of this Chapter

Chapter two "The outline of Energy in Africa" is written to review the present energy demand and supply about Africa, principally from statistical data of fossil fuels. However, it should be noted that as most energy consumed in poor African countries is non-commercial (biomass or kerosene), these statistic figures does not give account for all.

2-2 Petroleum

2-2-1 Africa in the World

Along with the rapidly rising oil demand and oil prices, not only world oil majors but also national oil companies of China or Russia have been investing huge amount for African crude oil interests. For example China National Offshore Oil Corporation (CNOOC), who failed to buy Unocal Corporation of US, secured the interests of Nigeria [2], Kenya [3], and Uganda [4]. As well, China National Petroleum Corp (CNPC) reached an oil and gas cooperation agreement with Nigeria and won the tender[5]. Moreover, Sino Union Energy Investment Group Ltd. bought 10% shares of Madagascar Petroleum International Limited ("MPIL") [6]. Meanwhile from Russia, Gazprom is gaining ground for Nigeria

Figure 2 Crude Oil Reserves by Region

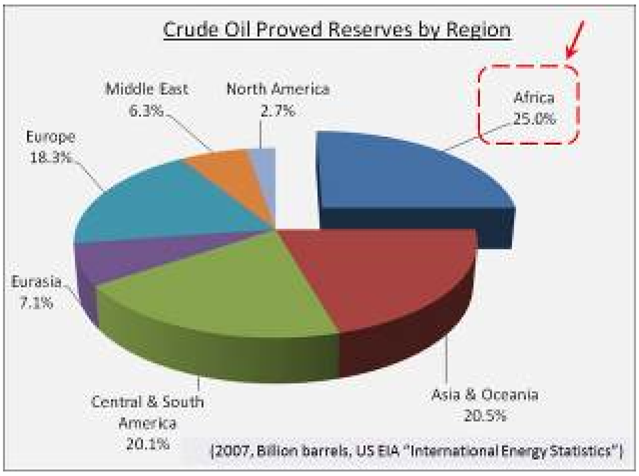


Table 1 World Oil Production

Africa	3,129	3.5%
Asia & Oceania	25,133	27.8%
Central & South America	5,946	6.6%
Europe	24,674	27.3%
Middle East	6,393	7.1%
North America	25,135	27.8%
World Total	90,409	100.0%

(2007, thousand barrels per day, US EIA "International Energy Statistics")

---

[2] "Cnooc Buys Oil Interest In Nigeria", 10 Jan 2006, Washington Post, http://www.washingtonpost.com/wp-dyn/content/article/2006/01/09/AR2006010901779.html

[3] "China's CNOOC drills Kenya's deepest oil well", Oct 28, 2009, Reuters http://www.reuters.com/article/idUSLS68117820091028

[4] "Uganda holds oil talks with Total, CNOOC", Market Watch, June 26, 2010, http://www.marketwatch.com/story/uganda-holds-oil-talks-with-total-cnooc-2010-06-26

[5] "CNPC may expand its Nigerian oil refinery", March 03rd, 2008, Shanghai Daily, http://china-wire.org/?p=65

[6] "Sino Union Hits Oil on Madagascar", November 10, 2009, Petroleum Africa http://www.petroleumafrica.com/en/newsarticle.php?NewsID=8622&PHPSESSID=6f13c24c6bce7992aa438f2400c7e685

and Libya, and Lukoil attempted to buy the oil field of Uganda (but failed)[7].

Although the African continent shares one fourth of world oil reserve (Figure 1), they are consuming only 3.5 percent of petroleum products of the world (Table 1) because African oil producing nations are just pulling out from their underground or sea, and exporting to OECD countries.

More than 60 percent of oil is used for transportation in Africa[8]. The top five oil consumers Egypt, South Africa, Nigeria, Libya and Algeria are all coastal countries, who are oil producers in turn. So, the much of their huge consumption of oil should be accounted for tanker oil or used for refineries.

With regard to land transportation, the African continent accounts for 20.4% of the world's land, and the people live across their extensive national land. However, only major roads are paved by concrete, and others are rough roads. Of course most people cannot afford neither a car nor gasoline, so it can be concluded that only a few people or companies or governments consume almost all oil in Africa by their motor vehicles.

Table 2 Oil Consumption of Africa by Region

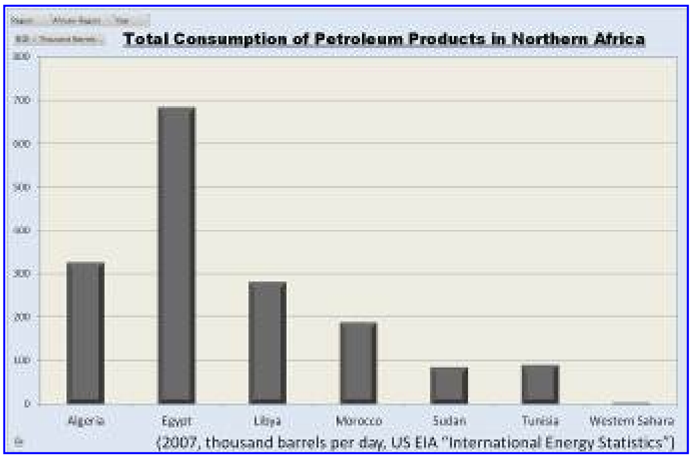
Northern Africa	1,580	50.5%
West Africa	512	16.4%
Eastern Africa	287	9.2%
Central Africa	127	4.1%
Southern Africa	623	19.9%
Africa Total	3,129	100.0%

(2007, thousand barrels per day, US EIA "International Energy Statistics")

2-2-2 Africa by Region

In 2007, The largest oil consumer in Africa was Egypt who shares 21.6 percent, followed by South Africa (18.2%), Nigeria (9.3%) and the top three countries share almost half (49.1%) of Africa. And added by Libya, Algeria, Morocco, Tunisia, Sudan, Kenya, and Angola, 82.2% of oil in Africa is consumed by just ten countries. And when counted by region, North, South and Central Africa shares 87 percent for oil consumption of all regions[9].

Figure 3 Oil Consumption of Northern Africa



2-2-3 Northern Africa

In Northern Africa, Egypt, Libya and Algeria uses 76.9% of oil products. Egypt, the first oil producing nation in

---

[7] "Russia's LUKOIL eyes Uganda's oil industry", 8 Feb 2010, Reuters http://af.reuters.com/article/investingNews/idAFJOE61706820100208

[8] 2008 Energy Balance for Africa, IEA

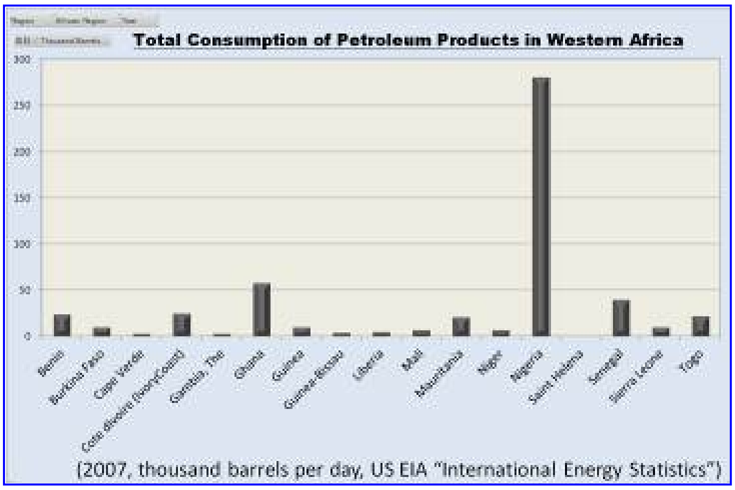
[9] International Energy Statistics, The U.S. Energy Information Administration

Africa started its industry from 1860 (Egypt has 150 years history of oil production[10]) also has a pipeline to convey Middle East oil to the Mediterranean Sea. More importantly, Egypt is an important international transit point of oil, located with the great Suez Canal. Algeria and Libya are also major oil producers.

2-2-4 Western Africa

Nigeria, who consumes more than half of oil in this region is the largest oil producer not only in Western Africa, but also in Africa. The 5th oil producer of OPEC entered into a 23 billion dollar oil exploration contract with China on May 2010, and also established a joint venture with Russian Gazprom on September 2008. On the other hand Nigeria is frequently experiencing strikes or riot of oils workers, and stops the supply[11].

Figure 4 Oil Consumption of Western Africa



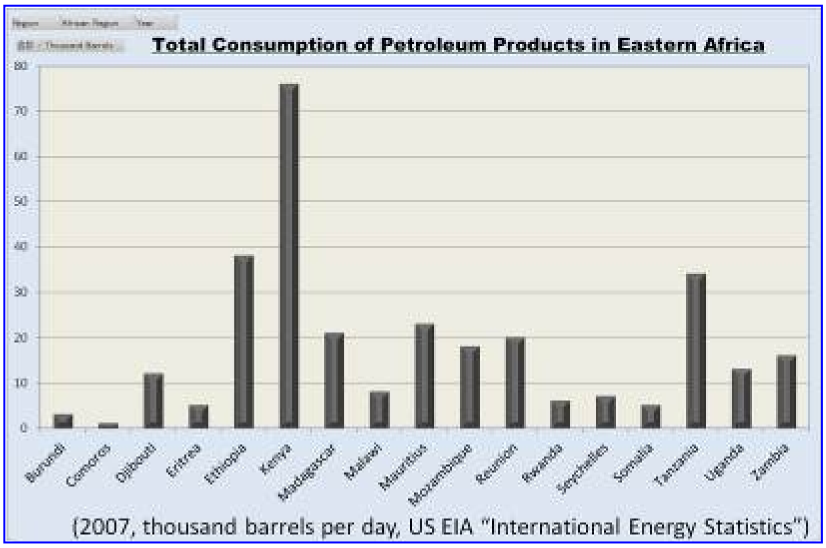
Added with Ghana (9.6%), Senegal (7.3%) and Cote d'Ivoire (5.5%), the four countries use 79.2 percent of petroleum products in Western Africa. Ghana has recently attracting attention for its offshore oil fields, and world Oil Majors such as Total, Exxon Mobil, BP and China CNOOC have been scrambling to the 18 billion barrel oil field[12].

2-2-5 Eastern Africa

In Eastern Africa, Kenya (26.4%), Ethiopia (12.2%) and Tanzania (10.1%) shares 48.7 percent of oil products consumption.

Kenya, Tanzania and Ethiopia are equipped with important harbors which pass almost all maritime trade package goes in and out, and island country Madagascar is of course faced with the sea, so their oil consumption consequently rises.

Figure 5 Oil Consumption of Eastern Africa



---

[10] The Industry Overview - Egypt Oil & Gas http://www.egyptoil-gas.com/overview.php

[11] Global Issues http://www.globalissues.org/article/86/nigeria-and-oil

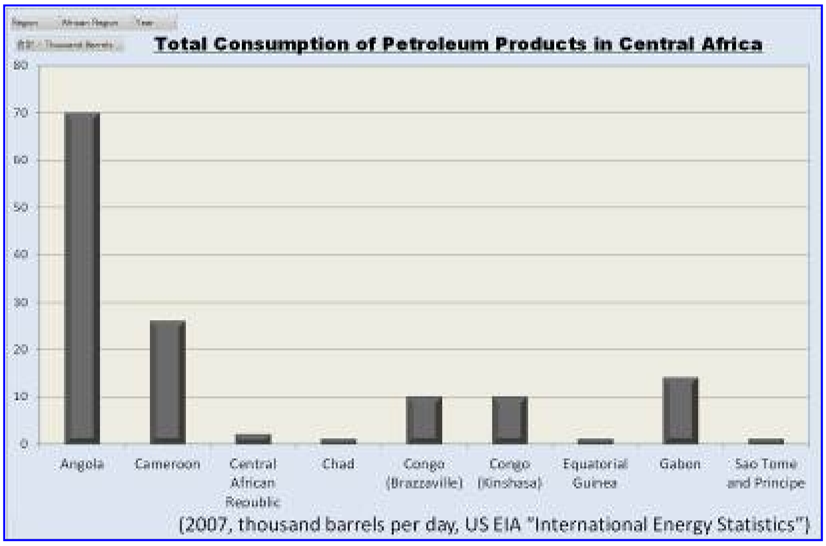
[12] "Cnooc, GNPC Said to Bid $5 Billion for Jubilee Stake", 22 Oct 2010, BusinessWeek http://www.businessweek.com/news/2010-10-22/cnooc-gnpc-said-to-bid-5-billion-for-jubilee-stake.html

Although this region stands for only 9.2 percent of oil consumption for Africa for year 2007, East African countries who have been showing steady and rapid economic growth for these years[13], are now moving toward to form the East African Community (EAC), a regional intergovernmental organization of the Kenya, Uganda, Tanzania, Rwanda and Burundi with its headquarters in Arusha, Tanzania.

2-2-6 Central Africa

In Central Africa, Angola alone explains 47.3 percent of petroleum product consumption in 2007, is followed by Cameroon (21.3%), Gabon (11.3%), Congo / Kinshasa (8.7%) and Congo / Brazzaville (6.7%) which are all oil producers, shares 95.3 percent of oil in Central Africa.

Figure 6 Oil Consumption of Central Africa

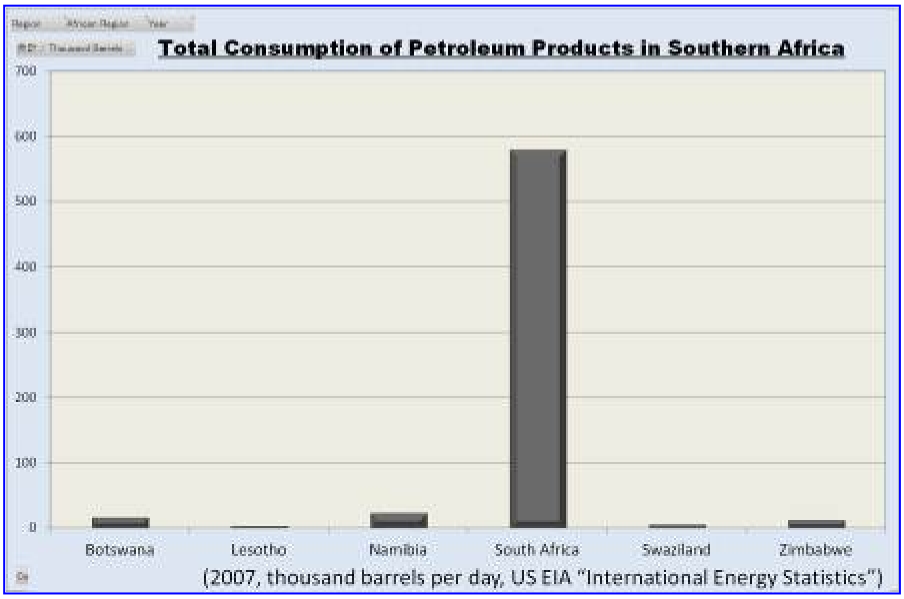


2-2-7 Southern Africa

South Africa, the largest economy in Africa consumes 18.2 percent of the whole continent and 91.2 percent in the region.

Although a huge coal exporter and an offshore oil producer itself, South Africa has to import a big amount of crude oil from Saudi Arabia, Iran, Kuwait, Russia, Angola and Nigeria to meet the domestic oil demand In other words,

Figure 7 Oil Consumption of Southern Africa



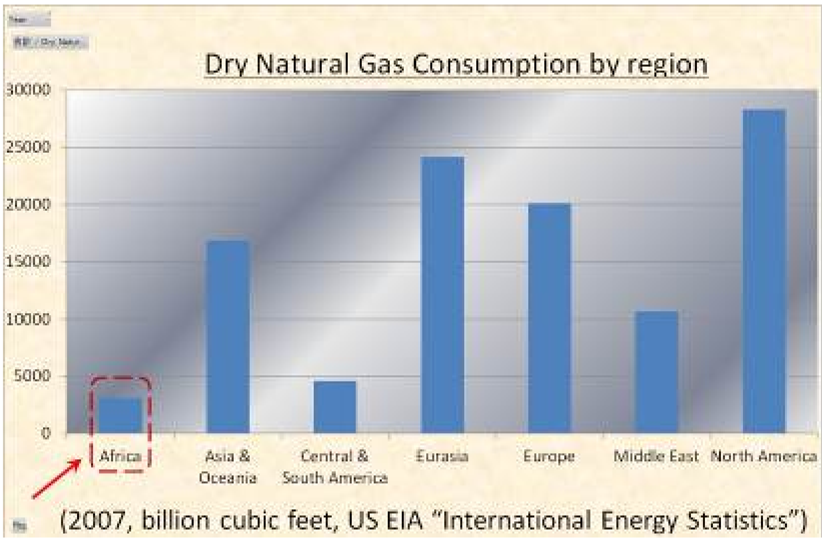
[13] THE ECONOMICS OF BURUNDI, KENYA, RWANDA, TANZANIA AND UGANDA By Peter Stein, Stein Brothers AB Report prepared for Swedfund International AB Spring 2010

South Africa is abundant in solid fuel but in short of liquid fuel[14].

2-3 Natural Gas

2-3-1 Africa in the World

Figure 8 World Natural Gas Consumption, by Region



Africa is the least natural gas consumer in the world. Most of Africa's known natural gas reserves (78 percent) are in Nigeria. The rest are mainly in Algeria, Egypt, Libya, Angola, Mozambique, Namibia and Tanzania.

2-3-2 Africa by Region

Although large natural gas field was found in Nile Delta (Egypt) or in Hassi (Algeria), the major thermal power fuel is coal, and therefore natural gas consumption is so less compared with other regions. Even in Nigeria, almost all natural gas is consumed not for thermal power generation but for industrial.

Table 3 Africa Natural Gas Consumption top 10

	Region	Country	Dry Natural Gas Consumption	
1	Northern Africa	Egypt	1,082	35.1%
2	Northern Africa	Algeria	934	30.3%
3	West Africa	Nigeria	374	12.2%
4	Southern Africa	South Africa	208	6.8%
5	Northern Africa	Libya	188	6.1%
6	Northern Africa	Tunisia	122	4.0%
7	West Africa	Cote dIvoire (IvoryCoast)	53	1.7%
8	Central Africa	Equatorial Guinea	53	1.7%
9	Central Africa	Angola	29	1.0%
10	Eastern Africa	Tanzania	19	0.6%
		Total	3,063	99.5%

(2007, billion cubic feet, US EIA "International Energy Statistics")

Therefore, the consumers of natural gas in Africa are very limited. The top five countries consumes 90.5%, and the top 10 countries share 99.5%, which means only 10 countries among 56 African nations consumes dry natural gas.

2–4 Coal

2-4-1 Africa in the World

In 2007, Africa produced 4.0 percent and consumed 3.1% of coal of the world. On the other hand 99.7percent of production and 95.3 percent of consumption is concentrated in Southern Africa region. 95 percent of electric power in the Republic of South Africa is generated by coal (the remaining 5% is nuclear).

[14] International Energy Statistics, The U.S. Energy Information Administration http://www.eia.doe.gov/cabs/South_Africa/Oil.html

Figure 9 World Coal Consumption

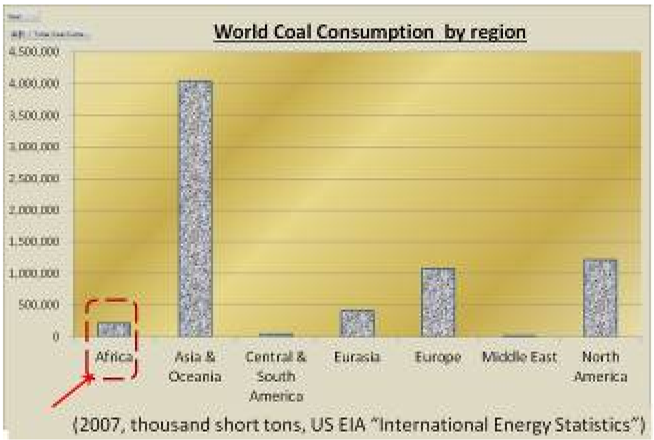
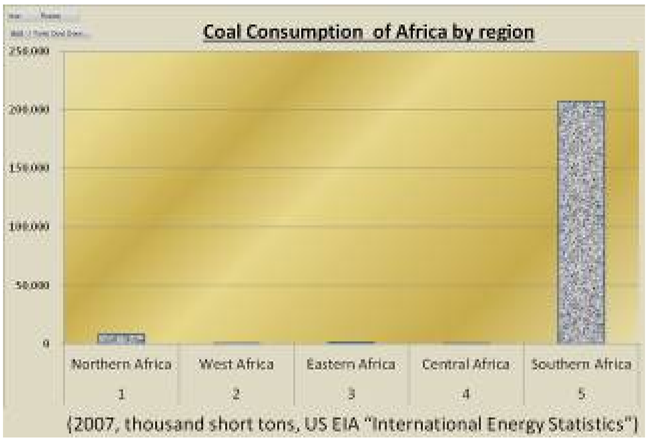


Figure 10 Coal Consumption of Africa by Region



2 –5 Grid Electricity

2-5-1 Africa in the World

In 2007, the African countries used only 3.1 percent of electricity generated on the earth. Although a huge amount of oil, natural gas and coal is produced in African countries, the majority of mineral resources are exported rather than domestic usage.

Figure 12 Electricity Generation of Africa by Source

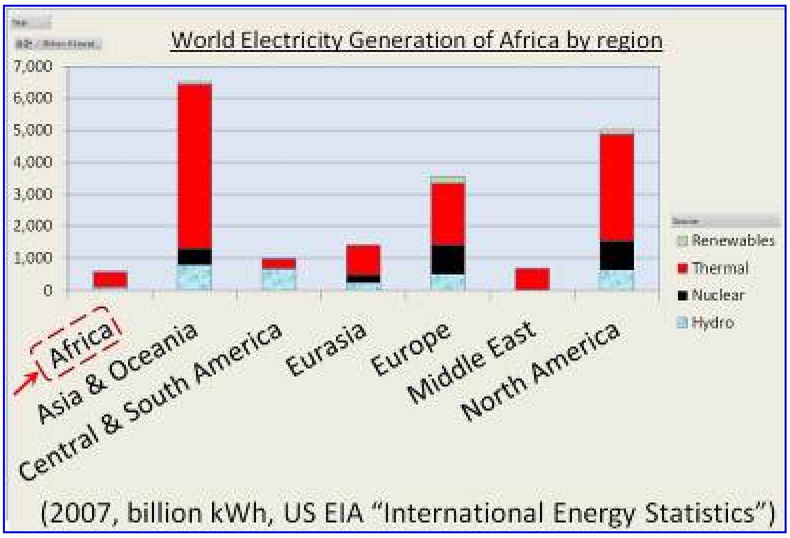
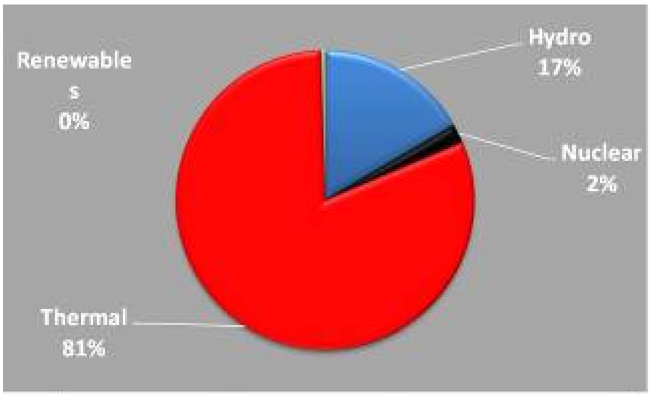


Table 4 World Electricity Generation by source and region

Billion Kilowatthours	Hydro		Nuclear		Thermal		Renewables		Total	
Africa	96	3.2%	12	0.5%	469	3.7%	3	0.6%	579	3.1%
Asia & Oceania	792	26.8%	506	19.5%	5,138	40.3%	83	17.8%	6,520	34.7%
Central & South America	660	22.3%	19	0.7%	299	2.3%	28	6.1%	1,007	5.4%
Eurasia	244	8.2%	246	9.5%	911	7.2%	3	0.6%	1,404	7.5%
Europe	514	17.4%	905	34.9%	1,926	15.1%	214	45.6%	3,559	19.0%
Middle East	22	0.8%	0	0.0%	651	5.1%	0	0.0%	674	3.6%
North America	632	21.3%	905	34.9%	3,346	26.3%	138	29.3%	5,021	26.8%
Total	2,962	100.0%	2,593	100.0%	12,740	100.0%	469	100.0%	18,764	100.0%

(2007, billion kWh, US EIA "International Energy Statistics")

Figure 13 World PV Market (2009)



(2007, US EIA "International Energy Statistics")

Table 5 Electricity Generation of Africa by Source

Source	Electricity Generation	
Hydro	96	16.6%
Nuclear	12	2.0%
Thermal	469	80.9%
Renewables	3	0.5%
Total	579	100.0%

(2007, billion kWh, US EIA "International Energy Statistics")

The dominant electric source in Africa is thermal, and most of them are generated from coal fired power plants in the Republic of South Africa, by state owned power company Eskom.

We should be aware that in Africa, the power capacity does not mean the amount of generator output that can supply electricity to the grid, because most facilities of power stations, substations and power lines have not given proper maintenance. For example the available capacity of SNEL (Société nationale d'électricité), Congo DRC is 48 percent (2007), and ZESA (Zimbabwe Electricity Supply Authority), Zimbabwe is 55% (2007), according to The Southern African Power Pool[15]. Therefore, Congo DRC and Zimbabwe are losing 1,272 megawatt, and 920 megawatt respectively. Besides, Boali 1 and 2 Hydro Power Stations, the main generators in the Central African Republic, has not provided maintenance since they were commissioned from 1954 and 1976[16]. And among six thermal generators in the country, only one is operating.

Old power equipment not only brings lowered efficiency but also blackouts, so many African countries have been suffering from abrupt discontinuation of power supply, which causes serious economic losses to industry.

[15] Southern African Power Pool (SAPP) Annual Report 2009
[16] The Electric Power Industry of Overseas Countries Vol. 2, JEPIC, Mar, 2010

2-5-2 Africa by Region

Table 6 Electricity Generation of Africa by Source and Region

African Region	Hydro		Nuclear		Thermal		Renewables		Total	
Northern Africa	18	19.1%	0	0.0%	198	42.2%	1	40.4%	217	37.5%
West Africa	13	13.5%	0	0.0%	27	5.7%	0	2.1%	40	6.8%
Eastern Africa	40	41.4%	0	0.0%	9	1.8%	1	47.0%	50	8.6%
Central Africa	16	17.0%	0	0.0%	4	0.8%	0	0.3%	20	3.4%
Southern Africa	9	8.9%	12	100.0%	232	49.5%	0	10.2%	253	43.6%
Total Africa	96	100.0%	12	100.0%	469	100.0%	3	100.0%	579	100.0%

Percentage

African Region	Hydro		Nuclear		Thermal		Renewables		Total	
Northern Africa	18	8.5%	0	0.0%	198	91.0%	1	0.5%	217	100.0%
West Africa	13	32.9%	0	0.0%	27	67.0%	0	0.1%	40	100.0%
Eastern Africa	40	80.1%	0	0.0%	9	17.4%	1	2.6%	50	100.0%
Central Africa	16	82.1%	0	0.0%	4	17.9%	0	0.0%	20	100.0%
Southern Africa	9	3.4%	12	4.7%	232	91.8%	0	0.1%	253	100.0%
Total Africa	96	16.6%	12	2.0%	469	80.9%	3	0.5%	579	100.0%

(2007, billion kWh, US EIA "International Energy Statistics")

Percentage

In 2007, Northern and southern African countries generated 81.1 percent of electric power in Africa, which means the remaining three regions just less than 20 percent. Moreover, South African region generated 70 percent of electricity in SSA countries. The reason is clear, northern and southern Africa are huge resources (needless to say oil, gas, coal, uranium, diamond, bauxite, …) exporters while most of the economy of other countries are based on agriculture. And in context of power sources, while Northern and Southern African countries mainly uses thermal (more than 90 percent), Eastern and Central African countries heavily relies on hydro-electric power which quite often causes power crisis due to droughts.

2-5-3 Electrification Rate by Region and Country

With reference to their similar geological, meteorological and historical background, African regions characterize their countries in some phases, such as language, natural resources, or industry. However when it comes to electrification rate, it is widely believed that;

Northern Africa……Relatively high (Only Sudan shows low electrification rate)

Other regions………No tendency (But Southern Africa is somewhat better than other regions because Eskom of South Africa is providing power to neighboring countries)

Table 6 shows many African countries except Northern Africa have very low electricity access, and most of them are LDCs (Least Developed Countries) as well. Even in the major oil producing countries such as Angola (74% no access to electricity), Sudan (69%) and Gabon (63%), the electric grid is extended to just from 26% to 37% of their population.

And we can also learn from Table 6 that among the 22 countries with electricity access less than 20%, 95% countries are LDCs. Only Kenya is not the LDC member, but the reason is not because Kenya is a wealthy country but because the country has a steady income as the main trading port of Eastern Africa, and somewhat industrialized than other countries. In Kenya, most of the population lives without electricity outside of capital Nairobi, and remains still very poor.

Table 7 Electrification Rate of African Countries

No.	Africa region	Country	Population without electricity access	LDC
1	Central Africa	Chad	97%	○
2	Eastern Africa	Burundi	97%	○
3	Western Africa	Liberia	97%	○
4	Central Africa	Central African Rep.	95%	○
5	Eastern Africa	Rwanda	95%	○
6	Western Africa	Sierra Leone	95%	○
7	Western Africa	Gambia	92%	○
8	Eastern Africa	Malawi	91%	○
9	Eastern Africa	Uganda	91%	○
10	Western Africa	Niger	91%	○
11	Western Africa	Burkina Faso	90%	○
12	Central Africa	Congo DR	89%	○
13	Eastern Africa	Tanzania	89%	○
14	Western Africa	Guinea-Bissau	89%	○
15	Eastern Africa	Ethiopia	85%	○
16	Eastern Africa	Kenya	85%	×
17	Southern Africa	Lesotho	84%	○
18	Western Africa	Mali	83%	○
19	Eastern Africa	Madagascar	81%	○
20	Eastern Africa	Zambia	81%	○
21	Western Africa	Guinea	80%	○
22	Western Africa	Togo	80%	○
23	Western Africa	Benin	75%	○
24	Central Africa	Angola	74%	○
25	Central Africa	Equatorial Guinea	73%	○
26	Central Africa	Cameroon	71%	×
27	Central Africa	Congo	70%	×
28	Southern Africa	Swaziland	70%	×
29	Western Africa	Mauritania	70%	○
30	Northern Africa	Sudan	69%	○
31	Eastern Africa	Eritrea	68%	○
32	Southern Africa	Namibia	66%	×
33	Central Africa	Gabon	63%	×
34	Eastern Africa	Comoros	60%	○
35	Southern Africa	Zimbabwe	59%	×
36	Western Africa	Senegal	58%	○
37	Southern Africa	Botswana	55%	×
38	Western Africa	Côte d'Ivoire	53%	×
39	Western Africa	Nigeria	53%	×
40	Eastern Africa	Djibouti	50%	○
41	Western Africa	Ghana	46%	×
42	Western Africa	Cape Verde	30%	×
43	Southern Africa	South Africa	25%	×
44	Eastern Africa	Seychelles	4%	×

(WHO-UNDP The Energy Access Situation in Developing Countries)

We can further see that almost all electric power in Africa is supplied by national owned company, whether the rural electrification rate is high or low, so we can say privatization of power utility is not requisite for developing power. On the other hand, the policy planning and achieving is rather important.

Table 7B Electric Power supply structure of Sub-Saharan African countries

Region	Country	Power supply		Rural electrification		Non−electrification rate
		National Company	Private Company	Government	Private Company	
Northern	Sudan	●				31%
Western	Benin	●				25%
Western	Burkina Faso	●		●		10%
Western	Côte d'Ivoire	●		●		47%
Western	Gambia	●		●		8%
Western	Ghana	●		●		54%
Western	Guinea	●		●		20%
Western	Guiné-Bissau	●				11%
Western	Liberia	●				3%
Western	Mali		●	●		17%
Western	Mauritania	●				30%
Western	Niger	●		●		9%
Western	Nigeria	●				47%
Western	Senegal	●		●		42%
Western	Sierra Leone	●				5%
Western	Togo	●				20%
Eastern	Burundi	●				3%
Eastern	Eritria	●				32%
Eastern	Ethiopia	●				15%
Eastern	Kenya		●	●	●	15%
Eastern	Madagascar		●	●		19%
Eastern	Malawi	●		●		9%
Eastern	Mauritius	●		●		
Eastern	Mozambique	●				
Eastern	Rwanda	●				5%
Eastern	Somalia	●				
Eastern	Tanzania	●		●		11%
Eastern	Uganda	●		●		9%
Eastern	Zambia	●				19%
Central	Angola	●				26%
Central	Cameroon	●	●	●		29%
Central	Central Africa	●				5%
Central	Chad	●				3%
Central	Congo DRC	●		●		11%

Central	Gabon		●			37%
Central	Republic of Congo	●				
Southern	Botswana	●		●		45%
Southern	Lesotho	●		●		16%
Southern	Namibia	●		●		34%
Southern	South Africa	●		●		75%
Southern	Swaziland	●				30%
Southern	Zimbabwe	●		●		41%

2-6 Summing-up

This chapter overviewed the production and consumption of macro fossil fuel in Africa, and it can be concluded that most of the gas and oil is consumed in the Northern region, the Republic of South Africa, Nigeria, and Angola. Natural gas is not so dominant in Africa. With regard to coal, 99.7percent of production and 95.3 percent of consumption is concentrated in Southern Africa region.

In most of developed countries, electricity is generated by thermal (coal or natural gas), on the other hand developing countries rely on hydro or diesel. From another perspective, Eskom of the Republic of South Africa generated 70 percent of electricity in SSA countries.

Here we can conclude that the consumption of energy in Africa is well IMBALANCED, more than the disproportion of mineral resources. Many people feel the energy in Africa is in imbalance, but we could see HOW imbalanced

3. Analysis of sustainable offgrid energy technology options for African Bottom Billion

3-1 Purpose of this chapter

The purpose of this chapter "Analysis of sustainable energy technology options for African Bottom Billion", is to first turn up the energy needs of rural African people, and then to focus on sustainable energy technologies by collecting up projects on the ground of Africa.

3-2 Basic Needs for Energy

The needs for energy can be well described along with the eight Millennium Development Goals (MDGs)[17].

Table 8 UN Millennium Development Goals and energy demand

Goal		Mechanical power	Heating/ cooling	Electricity, ICT
Goal 1	End poverty and hunger	Irrigation, farming, transportation	Cooking stoves, husking	Lighting, motor, communication, computers
Goal 2	Universal education		Warming, cooling	Lighting, data processing, printing, Communication, TV, computers
Goal 3	Gender Equality	Transportation, farming, husking,	Cooking stoves, LPG	Communication, computers
Goal 4	Child Health	Transportation	Warming	Communication, computers
Goal 5	Maternal Health	Transportation	Warming, cooling vaccine	Medical apparatus, Communication, computers, computers
Goal 6	Combat HIV / AIDS	Transportation		Medical apparatus, Communication, computers
Goal 7	Environmental Sustainability	Transportation	Efficient heating, cooling	Communication, computers
Goal 8	Global Partnership	Transportation		Communication, computers

17 United Nations, Division for Sustainable Development, Global village energy partnership

Table 8B Demand and technologies of offgrid energy

Demand	Unstable energy		Stable energy			
	Solar + battery	Wind+ battery	Micro Hydro	Biogas	MFP	LPG
Lighting	○	○	○	○	○	×
motor	×	○	○	○	○	×
communication	○(mobile phone)	○	○	○	○	×
computers	×	○	○	○	○	×
printing	×	○	○	○	○	×
TV	×	○	○	○	○	×
husking	×	×	○	○	○	×
cooling vaccine	○	○	○	○	○	×
Irrigation	○	○ (mechanical)	○	○	○	×
Cooking stoves	×	×	×	×	×	○
Warming	×	×	×	×	×	○

Micro hydro, biogas and multi-functional platform can be regarded as on-grid energy, as long as they can secure water flow, waste or diesel fuel. Solar and wind can supply small amount of energy when they are equipped with battery. But as electricity is not suitable to cause fever, LPG is needed for cooking or warming. Wind energy for irrigation is better to use the mechanical power, not converting electricity because the efficiency of direct pumping is quite superior than once converting to electricity.

<Water, irrigation and energy>

Clean water is one of the most important factor to live on, but many Africans have to walk for hours every day, to fetch water. However these years, underground water can be pumped by wind turbines, solar or biogas, and irrigation for agriculture can also be run by solar. Moreover, a multifunctional platform can supply clean water to a village, and run a husker.

Figure 14 Prepaid underwater pumping system (Source: Aquameter)

<Cooking and energy>

As principal diet in SSA (yams, maids, plantain, beans) needs to be boiled or fried, many woman and children in SSA have to walk around to fetch biomass. Moreover, the smoke from cooking stoves hurt the pulmones of many women, which causes serious diseases[18]. One solution was made by Ghana Government, to prepare a supply chain of LPG to the villages[19]. Solar cookers are another approach for clean cooking but as the initial cost is quite often too expensive for African bottom billions, they are not yet so popular (They are also less efficient at this stage).

<Education and energy>

Figure 15 A school in rural Azanu Public School, Ghana (24th September 2010, photo credit: Author)

In rural Africa, still many children cannot go to school because they have to work for daily life. If an MFP supply water to households or grind cereals, children can go to school. Many schools are not connected with the electric gird, so the students can only study in a dark room in daytime. A solar battery charger can supply light for classrooms. If a teacher can use a computer and printer, he can record everything about the students, and he can also print out many useful documents.

< Gender Equality and energy>

The MFP was invented for village women, for their Gender Equality. As the same reason with children, many women can avoid the tired, boring, and risky work of water / biomass collecting. Moreover, some women established own job so that they can earn cash by themselves[20].

<Health and energy>

Figure 16 A solar refrigerator (Source: GVEP)

In rural Africa, many hospitals are in lack of gas electricity, so the meet difficulty in urgent patient in the night. As well, sterilization is difficult without gas. And they cannot update their knowledge or miss important news without TVs, or internet. And solar power refrigerators are becoming popular.

< Mobile Phones and energy >

[18] GVEP 2003 Annual Report

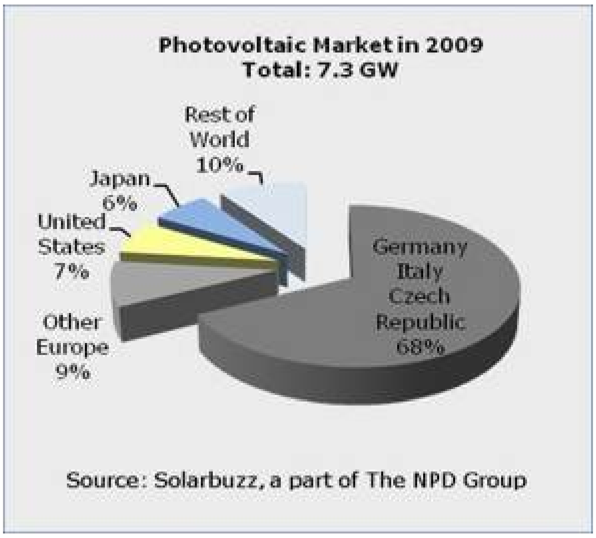
[19] Cited from e-mail discussion between Professor Abeeku Brew-Hammond, KNUST Ghana and the author, on October 2006

[20] "There is huge room for eMulti-Functional Platform in Senegal", June 22, 2007, UNDP, http://www.policyinnovations.org/ideas/innovations/data/senegal

While many African bottom billions in the 21th century uses mobile phone, most of them are not connected with the electric grid, and they have no access to modern energy. The reason why even people who even don't have lights in their house can use mobile phones, is because the consumed power of mobile phone is so little, and they run by battery which can be charged at the village (the charging of mobile phones don't need grid electricity in their house). As well, they can be used at almost anywhere, as long as they are in service area.

Of course they have to pay a lot for communication charge and to charge the battery, but as the required electric power is quite less than other apparatus, such as lights, TVs, fans, refrigerators or washing machine, which are commonly used in OECD households, and of course communication is very important for daily work and life, mobile phone quickly spread around entire Africa. And recently, some mobile phones are able to connect to the internet, so Africans can use Google and other PC services.

Figure 17 Photovoltaic Market in 2009



3-3 Solar

In the developed world, PV (photovoltaic) has been growing very rapidly, with support of hospitable subsidies and Feed-in Tariff (FIT) policy to urge the development to utilities, households and building roofs, and local authorities. In 2009, 77 percent of PV in the world has been installed at EU countries (Germany, Italy, Czech and others), while the former world champion Japan shared 6 percent, and the US, widely backed-up by President Obama's green energy policy, was 7 percent[21].

Figure 18 Solar Shop "Kenital Solar", Kenya (1st November 2008, photo credit: Author)

Driven by international projects, Africa was the world leading market in the 1990s. But while the developed world developed so fast in this decade, the small houses equipped with solar system in entire Africa remained unchanged with a few hundred thousands, the market share of Africa scaled-back as a part of "rest of the world",

[21] Marketbuzz 2009: Annual World Solar PV Market Report
http://www.solarbuzz.com/Marketbuzz2009-intro.htm

which accounts for 10 percent.

Actually, many PV systems installed in Africa are donations from former colonial powers, international organizations, NGOs and individuals (Of course, some donations came from African governments, firms and individuals, but support from EU, USA, China, Japan and Russia remains the large part).

Figure 20 Product lineup of Chloride Excide (Source: Chloride Excide)

In that case, the life of the system depends not on the status of solar panel but predominantly on the life of battery, because while solar panels can be used for more than five, or even ten years, batteries can only work for two or three years at best. Therefore, the lucky households, hospitals or schools which were donated solar system, should prepare for the next battery every two or three years. And in case the donors selected Chinese or Indian solar systems (to reduce their expense), many plants fail to provide their guaranteed performance, and very often, break down over a short term.

Figure 22 Solar mobile phone charger in Tomefa Village, Ghana (20th September 2010, photo credit: Author)

However, some private solar shops are in business some African countries. For example in Kenya, a local capital solar shop “Kenital Solar (Figure 15)” which was established in 1988, is now selling various types of solar systems to Kenyan people, and has been earning sound profit for years. They are selling solar systems, solar refrigerators and solar water pumps.

Another solar shop in Kenya “Chloride Excide” (Figure 16) was established in 1963 by UK capital. There are totally eleven shops in Kenya, and more shops in other East African countries, such as Uganda, Zambia, Rwanda, Burundi and Democratic Republic of the Congo. Chloride is not a specialized store of PV, selling wind power generators or car batteries, but the PV system was laid on the closest area from the main entrance, and a large advertising display of “Solar” is put next to the shop logo. Presently the shares have been totally sold to Kenyan local capital, but their mail products are still UK brand, and they sell BP solar which is the major UK solar manufacturer. However, they also sell solar panels of Total Energie (South Africa), Suntech (China), charge controllers of Morning Star (USA) and Phocos (Germany), inverters of Xantrex Canada (China), solar lights of Phocos (Germany), and solar refrigerators of Sundanzer (Hungary).

As the electric power is unstable in many African countries, some people who are even connected to the electric grid invest on solar home systems.

== Local Solar Business ==

Although the global price for solar panels have been selling off rapidly, a household photo voltaic system is still not affordable for African bottom billions. However if a solar system is donated to a village, it can not only offer sustainable jobs, but it can dramatically change the economy of villagers.

<Case One: Tomefa Village, Ghana>

Figure 22 Solar mobile phone charger in Tomefa Village, Ghana (20th September 2010, photo credit: Author)

People in Tomefa Village, Ghana, live on fishing at Lake Volta. As the village is too far away from the electric grid, the priority to extend the grid to this village is very low for Electricity Company of Thana Limited / ECG, who supplies electricity to Southern Ghana. Therefore, as an onsite generator, the Ministry of Energy installed a small wind turbine. However, as the wind turbine has been broken for many years, no electricity at all has been consumed in Tomefa Village. So, when a villager charges a mobile phone, she or he has to use a taxi (or boat) to go to the closest town, which cost them 50 Pesewa (around U$ 0.35), pay 50 Pesewa (around U$ 0.35) for charging, and then pay 50 Pesewa (around U$ 0.35) to come back, totally 1.5 Ghanaian cedi (around U$ 1.4)[22]. They can go by boats to lower the cost, but as they are fishermen who know the risk to rollover, they don't want to use them. Equally important, one day should be used for mobile phone charging if they go and return by boats, which deprives them of time to earn money.

Usually, mobile phones are needed charging every four or five days. And as the villagers of Tomefa are fishermen, they are in more need of mobile phones to make contact with people on the ground. Therefore, Tomefa villagers had to pay more than ten Ghanaian cedi (around U$ 51) per month. If there are five people in a family, roughly fifty Ghanaian cedi (around U$ 255) per month, which is too much for fishermen whose monthly income is sometimes less than fifty Ghanaian cedi (around U$ 255).

Then the Ministry of Energy, along with Japan International Cooperation Agency (JICA), donated a solar panel to the village which started operation on 22th September 2009. A mobile phone can be charged by 40 Pesewa (around U$ 0.28), 27 percent of the former total charge.

[22] Cited from the hearing investigation to three fishermen of Tomefa Village, Ghana, on 20th September 2010

Within the 40 Pesewa, some amount is paid for the three administrative men who take care of charging, operating the chargers or distributors, which means that the solar mobile charging system is also providing jobs.

<Case Two: Bleamezado Village, Ghana>

Similar to Tomefa, the Ministry of Energy of Ghana, along with Japan International Cooperation Agency (JICA), donated a solar panel to Bleamezado Village. The charge fee for a mobile phone is 30 Pesewa (around U$ 0.21), because the villagers or Bleamezado are poorer than Tomefa and not able to afford 30 Pesewa (around U$ 0.28).

Figure 23 , 24 Solar mobile phone charger in Bleamezado Village, Ghana (24th September 2010, photo credit: Author)

Bleamezado Village is a farm, so most of the villagers earn money only two times per year (such like many other farmers in Africa). In contrast, Tomefa fishermen can have daily income when they sell their fish.

The income of a typical farmer in Bleamezado Village is between 30 Ghanaian cedi (around U$ 20) and 100 Ghanaian cedi (around U$ 70), depending on their crop[23]. When their income is at the bottom (30 Ghanaian cedi / U$ 20), a family with five people have to pay more than 9 Ghanaian cedi / U$ 6.24), roughly one third of their income for mobile phone charging. Even the Bleamezado Village is very lucky to be selected as the site to install the solar panel, the mobile phone charging heavily weighs on their domestic economy.

Figure 25 The administrator of Bleamezado Solar system (24th September 2010, photo credit: Author)

On the other hand, one lady got a job by looking after the villagers' mobile phones. A mother of two young boys, she always take care of them, especially the younger one.

[23] Cited from the interview with the Administrator of Bleamezado Village and Mr. John Smorley, Kwame Nkrumah University Of Science and Technology, on 24th September 2010

****

From the two cases in Ghana, it was proven that the African bottom billions can greatly improve their economy, even from the smallest energy of solar. And the solar panels can even create new jobs. However, two large challenges still not solved;

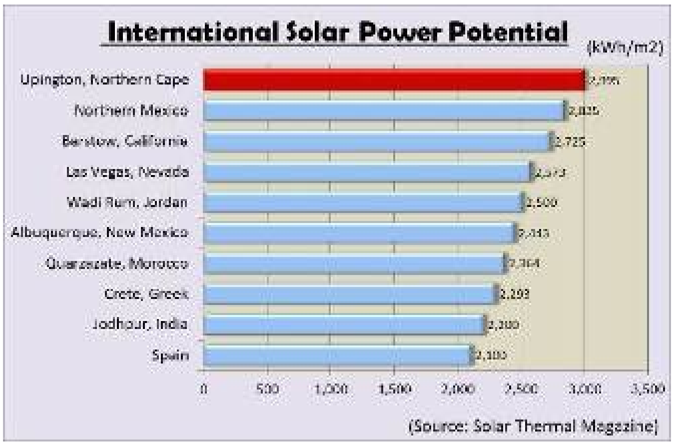
1. The African bottom billion cannot afford solar systems.
2. Solar charging is just a fraction of the need, and the final goal is the access to sustainable, reliable and affordable electricity which can only be supplied by the electric grid.

== Solar Heater ==

In businesses, such as hotels, hospitals or factories, rather than individual households, solar heaters are better utilized. For example on the roof of the African Regent Hotel in Accra, Ghana, 52 solar panels and 26 tanks have been supplying heating water for the hotel since it was opened[24].

There is some demand for solar water heaters, but many of the purchasers buy just for fashion rather than practical use. (These type of people who buy solar heater just for well-looking can be found all around in Africa.)

Figure 26 International Solar Power Potential



== Central Solar Power (CSP) ==

A strong sunshine seems to be good for solar power, but too high temperature conversely lowers the efficiency of solar panel. Therefore, photo voltaics is not always the best usage for solar power. Many part of the African continent lay under very strong sunshine (even South Africa has stronger Annual radiation than Jordan).

A much more leading-edge solar technology, compared with photo voltaic system or solar heater, is Central Solar Power (CSP). Many CSP projects have been started recently in Spain, the United States, and in the Middle East.

Figure 27 Central Solar Power (CSP) system (source: DESERTEC)

A CSP plant collects reflected radiation of the sun from thousands of

24 Cited from the interview with the mana… 19th November 2010

mirrors which track the sun to the top of 150 to 200 meters high the central receiver, and then irradiates them to the molten salt. The salt then generates steam to motivate a steam turbine, same as a common steam turbine generator. One big advantage for this complicated system is that, as the salt stores heat of concentrated sunshine, the turbine still keeps working for 7 or 8 hours even after the sunset.

The largest CSP project to date is “Desertec” funded by the DESERTEC Foundation, mainly promoted by a Swiss electrical engineering company ABB, which is developing the CSP system.

Their spectacular plan is to generate electricity by CSPs located in Northern Africa, and then transmit them to Europe (under sea) and Middle East via high Voltage direct current (HVDC) cables, which is their another competitive technology[25].

The idea itself to convert unlimited energy of the sun to electricity, and to export to Europe is not so bad, but the composition is similar to how the European people took out resources to Europe or the rest of world.

Figure 28 DESERTEC Project (source: DESERTEC))

Simply put, the electricity generated by Desertec would not reach to most of African bottom billion, because;

A) As the conversion system (from DC to AC) is very expensive[26], very few would be constructed for local usage.

B) Even if the fund for a conversion system was raised, a very expensive substation is also needed to supply electricity.

C) And even if a conversion system and a substation was financed, a long long grid is needed to deliver the electricity to people.

D) Many people in the Northern African area already has access to electricity.

E) There is neither duty nor motivation for the Desertec or the Northern African countries to send their power to Sub-Saharan Africa.

---

25 Desertec website http://www.desertec.org/en/concept/technologies/

26 Comparison of Costs and Benefits for DC and - Oak Ridge National Laboratory http://www.google.com/url?sa=t&source=web&cd=4&ved=0CC8QFjAD&url=http%3A%2F%2Fwww.w2agz.com%2FLibrary%2FPower%2520Delivery%2FAC-DC%2520Cost%2520Comparison%2520ORNL-6204.pdf&ei=U0v2TMuxE4HCvgOMtZmyCw&usg=AFQjCNHI65yGezLiitV_fJSK4NxGQkAV6A

3-4 Wind

According to AfriWEA (African Wind Energy Association) website, although the wind power resource is relatively low in the equatorial belt region, Northern and Southern area is abundant in strong wind. And with respect to the wind power market, whereas only 148MW was the total wind capacity in Africa in the year 2002, which accounts 0.5 percent of global market, large scale wind farm has been planned recently.

Figure 29 Zafarana 430MW wind farm in Egypt (source: NREA, Egypt Govt.)

For example, there are some large wind farms in Morocco. Tetouan wind farm (54 MW in operation since the year 2000, Over 200 000 MWh/year), Amogdoul wind farm (60 MW in operation since April 13th 2007) and Dahr Saadane wind farm (140 MW in operation since June 28 2010, generating around 536 GWh per year).

The Zafarana wind farm in Egypt, owned by New & Renewable Energy Authority (NREA) of Egypt's Ministry of Electricity & Energy (MEE) and financed by Denmark, Germany and Spain, is the largest wind farm in Africa. The total output would be 430MW, and will be completed within ten years.

On March 31, Japanese JICA signed to supply fund for 220MW wind farm to thes Egyptian Government. More recently, the Egypt Government approved a 1,000MW offshore wind plant in the Suez on July 2nd 2010, which will be completed until 2020.

== Small Wind Turbines ==

African Wind Power, a manufacturer of small scale wind turbines (from 0.5kW to 1kW) based in South Africa, has installed plants in Mozambique, Namibia, South Africa, Zimbabwe, Lesotho and Zimbabwe. (They have also built plants in the United States, Canada, United Kingdom Scotland and Antarctica).

Figure 30 Small Wind Power plant in Zimbabwe (Source: AfriWEA)

Most are small wind turbine owners are public or private firms, and some of them are donated by foreign governments. The 3kW plant in Mozambique is supplying power for water pumping, power tools lighting and communications to eco-friendly tourist resort. In Namibia, the wind turbine is operated with PV system and diesel generator as hybrid renewable power system from 1999, feeding electricity to a lodge house and restaurant equipped with a Ranch welcoming tourists. In

South Africa, the state owned telecommunication Service provider is operating telephone hubs by the power from wind turbines. The Dutch Government donated small wind turbines to a fishing co-operative village, and to a clinic in Zimbabwe.

== Local Wind Turbine Supplier ==

Unlike solar panels, wind turbine seems affordable by relatively simple technology, so many local wind turbine suppliers might be found in Africa. For one case, one wealthy man in Tema, Ghana who was fed up with everyday blackout telephoned one the owner of local electric shop(Figure 26) Mr. Emmanuel Ecanssey, presently 56 year old (Figure 26), and ordered him to design, manufacture, install and operate a wind turbine (Figure 27). Then, the local engineer Mr. Ecanssey studied about wind power generation, designed, manufactured, and finally constructed the plant.

Figure 32, 33 Mr. Emmanuel Ecanssey, Local electric shop in Ghana (23th September 2010, photo credit: Author)

Mr. Ecanssey who lives on repair or modification of electrical equipment at his tiny workshop, designed the wind turbine and generator, collected parts, finished fundamental construction, assembled and wired the whole plant, and unbelievably, the first hand-made wind plant has been operating for 4 years since 20006, without any failure. The generated power is stored in the accumulators, and consumed in night, because the demand of electricity for the household is very low in the daytime[27].

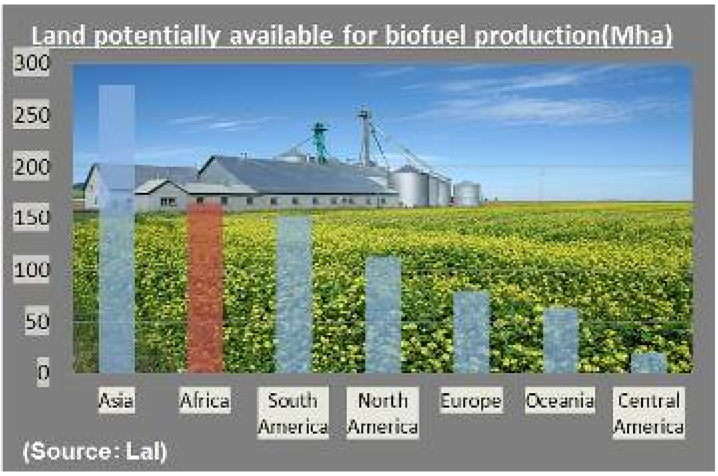
Figure 33, 34 Local made 1kW wind turbine in Ghana (23th September 2010, photo credit: Author)

[27] Cited from the interview with Mr. Emmanuel Ecanssey on 23rd September 2010 at his electrical shop, Ghana (figure 27)

Presently Mr. Ecanssey is giving advice to another wind turbine project of Kwame Nkrumah University of Science and Technology (KNUST, the most famed engineering college in Africa), but most of the time he stays in his small workshop as he has been doing for decades.

This engineer Mr. Ecanssey might be a special case, but it can also be an important example to prove that sustainable energy is able to be developed by local African village.

Figure 35 Land potentially available for biofuel production



3-5 Biofuel

While Africa has the second largest biofuel potential in the world, only next to Asia, no country has become a biofuel-dominant country like Brazil. The first reason why they have not became like Brazil is because the ethanol in that country is developed by the state owned company Petrobras. Second reason is the lack of infrastructure to export the biofuel to EU or to the US, their main markets. The third reason is the buying power from their customers, namely EU, United States and Japan because all of them have a compulsory target of biofuel mixture, and thinking to purchase biofuel from Africa to meet the target.

****

When the crude oil price jumped to 150 dollars in year 2008, biofuel projects were started all over the world, of course including Africa. The main driver of the boom was not ethanol which requires huge investment for refinery, but jatropha biodiesel because;

- Jatropha does not need so much water
- Jatropha can be grown up in many areas (Africa, Asia, United States, South America, Australia, Europe, and even in Russia)
- Jatropha is a nonfood crop
- Jatropha can be harvested three or four times per year
- Jatropha is already familiar to many farmers as a material of soap, support for vines (such as grapes or vanillas), or repellent harmful wild animals

In Kenya, an NGO "Green Africa Foundation" which is closely related to the Kenyan Government, has been operating a jatropha test farm for years, and ready to start commercial farm[28]. (Just waiting for finance.)

Figure 36 Jatropha test plant in Kenya (17th Noveember 2007, Kitui, Kenya, photo credit: Author), Figure 37 Wild Jatropha fruit in Uganda (11th Noveember 2007, Hoima, Uganda, photo credit: Author)

Figure 38 Interview with Ambassador Dennis Awori (the Kenyan Embassy to Japan, on 14th October 2008, photo credit:

When the author visited Uganda and Kenya for marketing research of jatropha, we were welcomed with great courtesy by the Governments and Investment Authorities who were earnestly searching business chances for biofuel business. And after our press conference about the jatropha business in Kenya was

[28] Cited from the interview with the founder / Chairman of Green Africa Foundation, Kitui, Kenya, on 17th November 2007

broadcasted on TVs and CNN[29], the author received numerous emails from farmers or developers in Africa, and even from India who wanted to join the project. Unfortunately we could not continue the jatropha business, however we became aware many people are willing to biofuel business in Africa[30].

Then, why no major African biofuel company has appeared till now? The first reason is the sudden drop of crude oil prices, which made almost all biofuel projects to be unprofitable. Next, the Subprime mortgage crisis and the financial crisis made developers difficult to raise funds. Moreover, oil majors began investing in other profitable biofuel sources, such as algae.

All in all, no major and serious money began biofuel in Africa until now, and no viable biofuel policy has been realized yet. In some countries, targets for biofuel has been enshrine into law, but many of them are lacking the roadmap toward the goal.

3-6 Biogas

In the rural area of many developing countries, human and animal waste is just released to nature, so causing the a big problems such as followings[31];

- Degradation of surface water bodies
- Contamination of Underground water
- Health hazards from discharge of pathogens
- Reduction of marine ecosystem productivity
- Odor Nuisance and health-related impacts

Figure 39 A Biogas plant at African Regent Hotel in Accra (19th September 2010, photo credit: Author)

The biogas technology has been developed in Africa for more than thirty years, that supplies sanitary toilets, prevents wastes to harm underground water, supplies gas for cooking, and even supply gas for power generation. In the villages, the animal waste annoying the families can be stored and capped with a top, so that the ugly smell no longer hang over.

One advantage for biogas plant is, when there is a people, the power source is provided

29 The press conference was held on 18th November 2007, at the Kenyatta Conference Centre, Nairobi, Kenya

30 Cited from the interview with Ambassador Dennis Awori at the Kenyan Embassy to Japan, on 144th October 2008

31 Source: Dr. John Afari Idan, BTWAL

every day. In other words, people need biogas plant for toilet, cooking and electricity, and biogas plants need human waste that was cooked by the methane of biogas plant. Therefore, this is very much sustainable cycle.

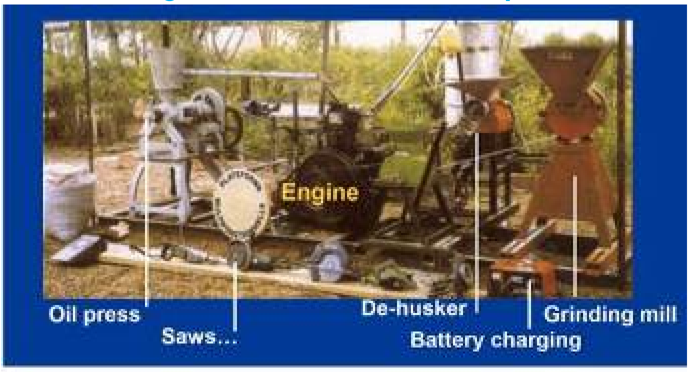
And not only rural farms, many kinds of buildings have been using biogas, such as hotels, Stores, Markets, Abattoirs, Meat & Fish processing factories, Churches, Mosque's, Public Places, Restaurants, Hotels, Cinema's, Schools, and even Police and Military Barracks, Prisons are benefiting from biogas plants. The biogas plant at African Regent Hotel in Accra, Ghana, has been supplying with no failure since the hotel was opened from 2007.

Figure 40 Dr. John Afari Idan, C.E.O, BTWAL. (BTWAL Head Lffice, Ghana, 23th September 2010, photo credit:

The challenge for biogas is the capital. According to Dr. John Afari Idan, the Chief Executive Officer of B.T.W.A.L., the largest biogas company in Africa, although the materials needed for biogas plant is relatively simple, the engineering is much complicated so that the plant cannot be cheap as it looks like. Additionally, an installation of biogas plant requires a feasibility study beforehand. However, as the electricity can be supplied as cheap as 0.06 to 0.08 Ghanaian cedi (from U$ 0.04 to U$ 0.06) per kilowatt-hour, and able to supply a public toilet service by 0.10 to 0.20 Ghanaian cedi (from U$ 0.07 to U$ 0.14), the benefit for the African bottom billion is very large[32].

3-7 Multi-Functional Platform

Figure 41 A Multifunctional platform



(Source: (UNDP)
Susan Mcdade Gender and Energy for Sustainable and Development

The multifunctional platform (MFP) is a diesel generator accompanied with a complex set of mechanical and electrical devices such as grinder, husker, water pump, sewing machine, welder, and so on. The MFP was first introduced in Mali from 1996 to 1998 for the first stage, providing 45 units, and now on the second stage which is installing 450 units to the "eligible" villages of Mali, and also to other countries such as Senegal and Burkina Faso.

32 Cited from the interview with Chief Executive Officer, B.T.W.A.L., Dr. John Afari Idan on 23rd September 22010, at Accra, Ghana

(Senegal plans to establish another 400 machines by 2010 and another 600 by 2015.[33])

The main purpose of MFP is to act over women' daily routine works such as fetching water, grinding cereals, de-husks rice or maize, de-shells nuts, which are sharing most of rural women's time, and losing chances to take care of their children, parents, and earn money.

The MFP was deployed by the United Nations Development Programme (UNDP), the UN's global anti-poverty agency in charge of the global development. The UNDP financially supports the dissemination of MFP with NGOs, international organizations, and private investors, along with the Government, regional authorities, and local authorities.

An MFP will not walk to the village by itself someday, but should be based on women's request. If a woman needs the help of MFP, she should form up a group of women. Next, the group has to negotiate with the village to pay for balance of subsidy of the total cost (between 20 and 60 percent of the $7,500 hardware cost. Some, or even many of the male villagers are not welcoming the new payment, so many requests might get shot down at this point.

After the women group obtained the approval from the villagers, then they apply to the local government. Finally, the UNDP conducts a three-month feasibility study to determine whether the village meets a population criteria for eligibility (villages have to have between 500 and 2000 residents), and to assess the willingness and ability of the village to pay for the MFP. After the UNDP approves the request of a village, they install, and some people are trained for maintenance.

When a platform comes into a village, it entirely changes many lives of women, especially for supplying them a way to earn income. For example, one woman in Senegal started hew new business using the village's new manual sewing machine, while others began soap manufacturing. In a village of Mali, the income of a woman of Bantantinty Village of Senegal, the income of women rose from $10 US per year to 240 per year, 24 times. In other reports from Mali, the income for women rose from US$34 to $101 (three times), or from US$40 to US$100(2.5 times). The income not only made them richer, but also independent from their husbands, and made their live in dignity[34].

However, the platforms not always work favorably. As the engine is driven by diesel, profits from platform-related enterprises fell by 90 percent when the oil price surged in 2002. Therefore, the UNDP is now planning to develop a new platform which can be driven

---

[33] There is huge room for eMulti-Functional Platform in Senegal, United Nations Development Programme, June 22, 2007, http://www.policyinnovations.org/ideas/innovations/data/senegal

[34] Technological Innovation: Multi-functional Platforms in Mali, http://www.geni.org/globalenergy/research/ruralelectrification/casestudies/mali/index.shtml

by local biofuel.

One more major problem comes from its multiple functions. When one small trouble that is unable for village engineer to fix, they have to wait for weeks or even months for a professional to visit the village. Since the battery charger of an MFP of one Senegalese village broke down, the related function stopped for more than two years.

And some old type MFPs cannot supply electricity, one of the most required service for the village people, especially women. However, as their village is already installed, a new model, in other words electricity would never come to their village.

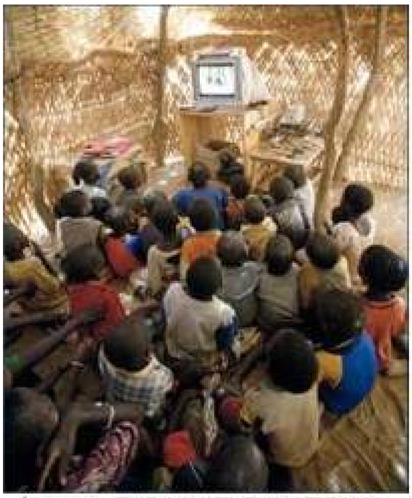
Figure 42 A MFP in Burkina Faso, Figure 43 Water pumped by power from the MFP, in Burkina Faso

(Source: THE MULTI-FUNCTIONAL PLATFORM /January 2009, INDP)

(Source: THE MULTI-FUNCTIONAL PLATFORM /January 2009, INDP)

Figure 44 Car batteries can be powered by the MFP, in Burkina Faso, Figure 45 Children studying by television driven by the electricity from the MFP , in Burkina Faso

(Source: THE MULTI-FUNCTIONAL PLATFORM /January 2009, INDP)



(Source: THE MULTI-FUNCTIONAL PLATFORM /January 2009, INDP)

****

The spread of multi-functional platforms is still under way. In Burkina Faso, 235 village communities have already set up MFPs, and as the government admited the impact for poverty reduction, they decided to set up approximately 3,031 Multifunctional Platforms in the country's villages, including 2,031 with a power system or water supply, by 2015.

As a practical solution for energy, poverty reduction and also for gender issues, the multi-functional platform is one of the best substitute tools before the electric grid is extended to the villages.

3-8 Micro Hydro power stations

In Africa, hydro-electric power is one major source for electricity because of their abundant resources. Hydro-electric power is a typical, and most historic renewable energy, but it has many advantages;

1. When the output of other renewable energy such as solar or wind fluctuate with respect to sunshine or wind, the output of micro-hydro plants are constant, in other words reliable.
2. When solar doesn't work in night or rain, micro-hydro plants can supply power in the night or in rainy / cloudy days, when people need light or other needs.
3. At the same time, constant power supply means micro-hydro plants (basically) don't need batteries, which lost huge of energy and costly. In turn, micro-hydro plants can charge car batteries for home-use, and of course charge mobile phones.
4. The output of home solar system is less than 3 kilowatt (in many cases less than 1 kilowatt), and the output small wind power plant is also less than 1 kilowatt. However, micro-hydro plants can supply 20, 30 or even 50 kilowatt, enough to electrify a village. And it means, micro-hydro plants are able to supply electricity for mechanical power, such as water pumping, husking, drying, so the villagers can start new businesses.
5. Most sites for micro-hydro plants are located in the rural area, and many people live near the river.
6. When diesel fuel required for MFPs are very expensive, micro-hydro plants needs no fuel.
7. Micro-hydro plants basically need only little amount of maintenance (just take care of drain ditches to remove leafs or rocks).

Figure 46, 47 A micro hydro plant at the Energy Kiosk, Kibai, Kenya (30th October 2008, photo credit: Author)

The biggest barrier for micro-hydro plants is needless to say, their costs. And as most of the cost comes from the construction of plant, a micro-hydro plant generally costs more than U$ 200,000, which is a huge amount for a small village[35]. Therefore, in a practical sense, a micro-hydro plant cannot be installed in rural African village without subsidy or grant.

Meanwhile, the location is also a big matter for the construction. Many books or reports say "There are huge hydro resources in Africa", and that is not a misreport, but they generally say so just because there are many big rivers in Africa, and ignore the requirements for plant. As micro hydro-electric power plants change the potential energy of water intake to electric power (figure 44), first and foremost, a waterfall (however small or large) is required. Additionally, the waterfall should have access for construction equipment, but in many cases waterfalls are difficult to go by cars because there are no roads. Moreover, the low point should be able to construct a house or power plant, and of course should have access for construction or maintenance. Finally, the village / households should be located at least within 2 kilometers from the power plant, for power transmission.

Figure 48 The fall close used for the micro hydro plant at the Energy Kiosk, Kibai, Kenya (30th October 2008, photo credit: Author)

All in all, micro hydro-electric power plant is the best energy source for African bottom billions. However, a good business scheme or subsidy is crucial at this point.

[35] Cited from the Chief Engineer of Tanaka Hydro Corporation, Tokyo, Japan on November 2006 at the head Office of Tanaka Hydro Corporation.

3-9 Summing-up

Rural African people spend lots of time and money for their daily needs of water, cooking, food processing, agriculture, education, health, and mobile phone charging. However, as recent energy technologies enabled some practical projects in the villages, more people might gain advantage in the future.

Solar is a really practical solution for small amount of energy, such as mobile phone charging. However the solar system for active projects were granted, and most of the villages / people cannot afford them. Central Solar Power (CSP) plants can generate more than the whole electric power of small African countries, but they are available at equatorial or very hot deserts which are too far from the demand.

Wind energy resources is generally abundant in Northern and Southern Africa, where are already consuming most of the energy in Africa. Local wind generator has been operating successfully, but not so many engineers can design and build up such plants by themselves. The feasibility needs one year, and construction cost is not cheap. Security risk for thunder and storm.

The production of biofuel is viable in many areas of Africa. Some countries have already designed policy for adding biofuel in petro or diesel, any farmers are ready to supply jatropha. Therefore, when the investors come back to Africa, and if the crude oil price soars up again, biofuel would gain momentum.

Biogas is a really sustainable and reliable energy technology. Wherever people or animal lives, the biogas plant secures its fuel so as to supply heat and electricity. More importantly, biogas plant can be a solution for both human/animal waste, and sanitary problem.

Multi-Functional Platform (MFP) can also supply reliable energy to a village. As the MFP is principally subsidized to solve gender problem, many women can be benefitted. However as the machine drives on diesel, it is vulnerable to international oil prices.

Micro hydro power plant can generate well reliable, stable power. One barrier is not so many sites are available, and another bottleneck is the construction cost, including the expensive feasibility study.

4. Analysis of Public Policies for Rural Electrification

4-1 Purpose of this chapter

The purpose of this chapter "Analysis of Public Policies for Rural Electrification" is to look into the energy policies of specific countries of the groups, and to find out why countries made successes or fail to provide electricity access with their people.

First we would like to divide African countries into 4 groups, pursuant to electricity access rate;

- Group A--------Countries close to the goal (Electricity access more than 70%)
- Group B--------Countries reaching to the goal (Electricity access 50%～69%)
- Group C -------Countries far from the goal (Electricity access 20%～49%)
- Group D -------Countries very far from the goal (Electricity access less than 19%)

Then, we will look into their features and energy policies.

****

100 percent access to grid electricity is very difficult, even in most developed countries, because expanding the grid to far remote areas for very few people is inefficient for both economically and electrically. As well, most the power would be lost in the air for heat, and the Voltage would be lessened.

However, the African bottom billions have the right to get the access to sustainable, reliable and affordable energy. Their first goal can be small solar, but the African governments should seek the way how their people can *ultimately have access to national, regional, local or micro grid*. And energy developers or financers should also find their chance to make sustainable profit.

In Africa, the electrification rate varies from 3 percent of chad to 100 percent of Mauritius, and the factors are not orderly. However has been widely believed that

1. **North Africa (except Sudan) has very high access to electricity.**
2. **For other regions / countries, THE PLANNING AND IMPLEMENTATION OFENERGY POLICY DOMINATES the economy, natural resources, temperature, geography, colonial master and history.**

On this thesis, Northern countries (except Sudan) have not been discussed because they are neither SSA or LDC countries, and most of them have very high percentage of electricity access. In fact, their electricity access rates are Tunisia 99%, Algeria, 98%, Egypt 98%, Libya 97%, Mauritius 94%, Morocco 85%[36].

And with regard to the remaining countries, we would like to look on economic / mineral status with the focus on electricity access, by grouping as follows;

---

[36] 1 February 2010 allAfrica.com

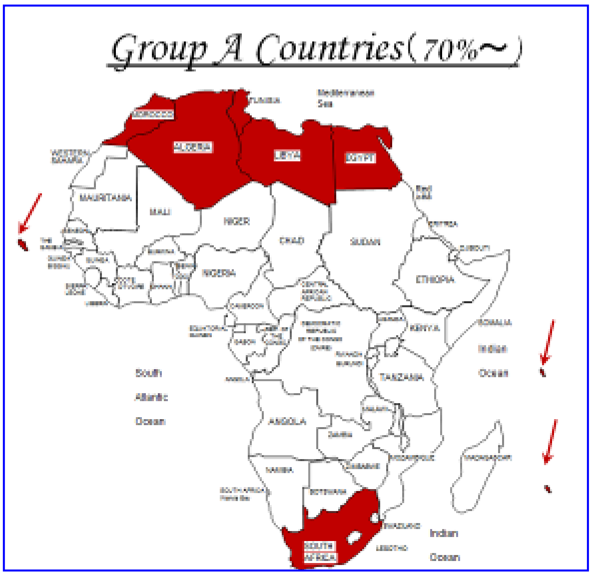
4-2 Group A
Countries close to the goal (Electricity access more than 70%)

Region	Country	Electrification Rate *1	Oil production *2	Natural Gas production *3	GDP /capita *4
Eastern Africa	Seychelles	96%	0	0	8,274
Southern Africa	South Africa	75%	191	115	6,648
Western Africa	Cape Verde	70%	0	0	4,040

*1---------- 2008, WHO-UNDP, "The Energy Access Situation in Developing Countries"
*2---------- 2009, thousand barrels per day, US EIA
*3---------- 2008, Billion Cubic Feet, US EIA
*4---------- 2009, IMF

Group A, the countries with energy access more than 70% are simple, they are the Northern / Mediterranean countries, Republic of South Africa, and some islands. In turn, when excluding Mediterranean countries, only one country in the African Continent has electricity access more than 70%.

Figure 49 Countries with electricity access more than 70%)



The Republic of South Africa (75%)

= Huge supply capacity and innovative distribution =

Eskom, the giant electric power utility of the Republic of South Africa generates more than 40 percent of electric power in the African Continent, but their main customer have been industries of diamond, metal, coal.

However the South Africa Government promoted rural electrification program from 1991 (close to the abolishment of Apartheid laws at 1991), and announced they will connect 1,750,000 households to the electric grid from 1994 to 2000. Surprisingly, they completed that goal at November 1999, one year earlier.

One more very unique approach taken by the Eskom is the famous "Prepaid electrification" system, which ensured the Eskom the income at the same time gave South African people the opportunity to buy electric power within their availability of payment.

****

Then, we can see that the reason why the Republic of South Africa has high rate of energy access, they have huge power capacity at the same time conducted good policy, with a unique technical approach.

Seychelles (96%) and Cape Verde (70%)

= Small and flat islands, easy to construct grid network =

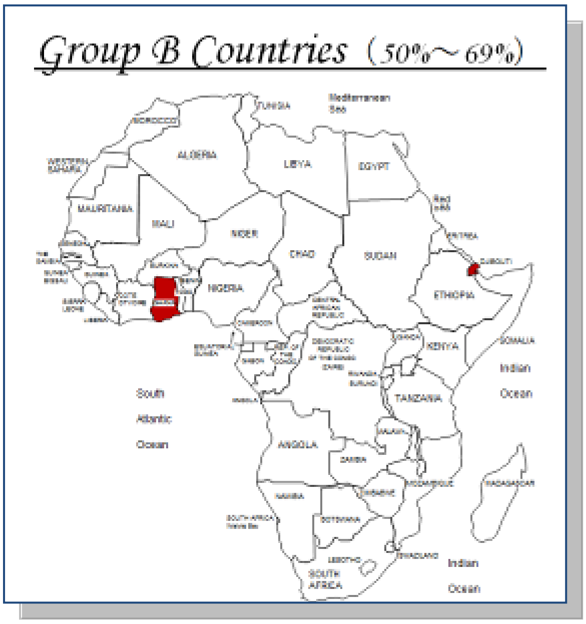
Seychelles and Cape Verde are both tourism-oriented countries, so modern energy access is close to OECD member countries. Moreover, their land is 455km² and 4,033km² with no high mountains, so it is easy to build the grid. Of course they should import diesel oil to run diesel generators, but it is better to connect to all households, rather than to sow seeds of discontent.

4-3 Group B
Countries reaching to the goal (Electricity access 50%～69%)

Region	Country	Electrification Rate *1	Oil production *2	Natural Gas production *3	GDP /capita *4
Western Africa	Ghana	54%	7	0	814
Eastern Africa	Djibouti	50%	0	0	1,370

Group B countries Ghana and Djibouti are very unique, special for the point of rural electrification in Africa.

Figure 50 Countries with Electricity access 50%～69%



Ghana (54%)

= Achievement of ambitious electrification policy =

Ghana is the only country in the West African region to have electricity access more than 50%, and the reason is they are taking on the right policy for rural electrification.

President Flt. Lt. Jerry John Rawlings (June – September 1979, and January 1993 –

January 2001, totally almost 20 years) promoted rural electrification program all around the country, called National Electrification Scheme (NES). First, the Ghana Government expands the main electric grid all over the country (called "Backbone"), and then subsidize half of the fee for a village to connect to the grid. As a result of this policy, among 4,221 villages which has the population of more than 500, 3,400 has been connected to the grid until 2003[37]. This program is still working, and when the author visited Ghana, one village was under construction for connection. But many villages of Northern Ghana and or rural area is still of grid.

Figure 51 The interview with Prof. Abeeku Brew-Hammond, Dean, KNUST Energy Center, at the Tech Energy Seminar Series in Accra(TEESSA 2010), British Council Auditorium, Accra, Ghana on 21 September 2010

One more unique policy in Ghana, is that every President candidate have to make and announce his/her energy policy at the election campaign, and people can check whether he/she is keeping words.

Djibouti (50%)

= High energy access at the coast area =

Djibouti is a small country, with land area 23,000km^2 and population 864,000, located in the Horn of Africa. (Djibouti is a new born country since it became independent from France on 1977.) As the economy of Djibouti which enjoys GDP per capita 1,370 is heavily dependent on their function of logistics hub, and their land is relatively small and flat, it is not difficult to extend the electric grid. However, the development in the rural area has been backward, and the electric grid is connected to very few tows. Therefore, most of the residents depend on kerosene for cooking and lighting.

A study by U.S.-based Geothermal Development Associates (GDA) says Djibouti has a resource of 30 megawatt geothermal power plant, which can add almost one third of their present power generation capacity of 85 megawatt[38].

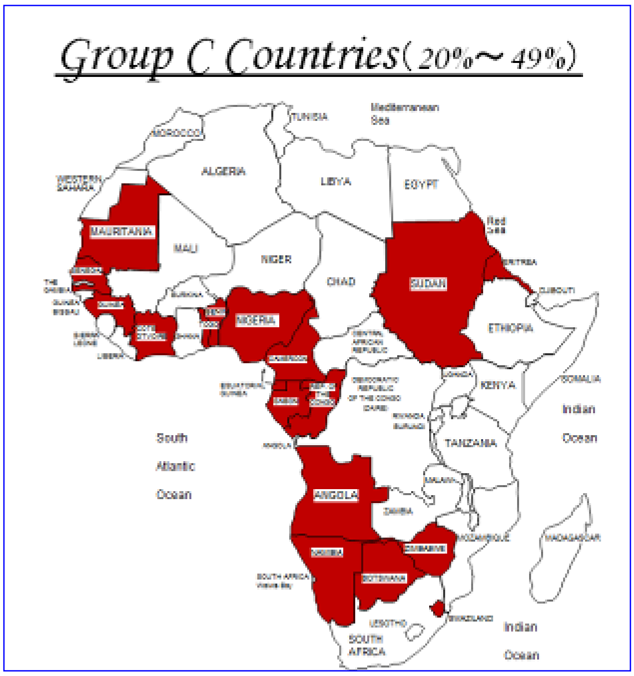
[37] Cited from the interview with Prof. Abeeku Brew-Hammond, Dean, KNUST Energy Center, at the Tech Energy Seminar Series in Accra(TEESSA 2010), British Council Auditorium, Accra, Ghana on 21 September 2010
[38] Country energy information Djibouti, September 2006, Developing Renewables

4-4 Group C
Countries far from the goal (Electricity access 20%～49%)

Region	Country	Electrification Rate *1	Oil production *2	Natural Gas production *3	GDP /capita *4
Western Africa	Côte d'Ivoire	47%	59	46	1,295
Western Africa	Nigeria	47%	2,211	2,565	1,689
Southern Africa	Botswana	45%	0	0	9,538
Western Africa	Senegal	42%	0	2	1,157
Southern Africa	Zimbabwe	41%	0	0	314
Eastern Africa	Comoros	40%	0	0	892
Central Africa	Gabon	37%	242	74	11,620
Southern Africa	Namibia	34%	0	0	4,076
Eastern Africa	Eritrea	32%	0	0	308
Northern Africa	Sudan	31%	487	0	1,822
Central Africa	Congo (Rep)	30%	274	265	4,739
Southern Africa	Swaziland	30%	0	0	3,097
Western Africa	Mauritania	30%	17	0	1,319
Central Africa	Cameroon	29%	77	69	1,309
Central Africa	Eq. Guinea	27%	346	292	16,401
Central Africa	Angola	26%	1,948	355	6,281
Western Africa	Benin	25%	0	0	906
Western Africa	Guinea	20%	0	0	438
Western Africa	Togo	20%	0	0	470

Group C countries, which have 20% to 49% access to the electric grid, lay on the west side of Africa(Except Sudan). Many of them have GDP per capita of more than U$ 1,000, and oil rich countries such as Angola, Eq. Guinea, Gabon and Nigeria are include in this group. Therefore, it can generally say western side African countries have electricity access more than 20 percent.

Figure 52 Countries with Electricity access 20%～49%



Nigeria (47%)

= Huge oil producer but suffering utility =

The oil exporting giant Nigeria is wealthy as a country, but most of the people are still very poor, whose live on less than one dollar per day.

The utility PHCN (Power Holding Company of Nigeria, formerly named NEPA) has been suffering from financial problem for a long time, and they have no fund to extend their grid to rural area. Under a disadvantaged management of NEPA, Nigeria was in power crisis for more than 30 years. No maintenance for existing facilities, and investment for grid expansion was halted from 1987 to 2003. One major reason why the gas producer Nigeria could not run gas fired power plants was, the contract price of natural gas for domestic power plants was kept much lower than international market price, so the gas producers preferred to export rather than sell to NEPA.

Gabon (37%)

= Mineral rich, but low energy access =

Electricity of Oil rich Gabon is still not developed, and most of primary energy is biomass (Electricity is only 6 percent of energy usage in Gabon). In the urban area, 70 to 90 percent is electrified, but many of the rural area is not connected to the grid.

Eritrea (32%)

= Energy for food security =

While the electrification rate of total Eritrea is more than 30 percent, rural area is not more than 3 percent. Therefore, the Ministry of Energy and Mines is planning to raise the electricity access to 50% until 2015, but this policy is also intended to improve the efficiency of food production. At present, non-commercial energy share more than 70 percent, and electricity is just 4 percent of total energy consumption. And as they want to bring down the dependence to imported oil, Eritrea is now seeking to exploit their abundant wind resources.

Cameroon (29%)

= Improving grid expansion =

Although an oil producing country, the amount oil production of Cameroon is less than 3 percent of neighboring oil giant Nigeria. And as the main product of Cameroon is aluminum, more than 60 percent of electric power is supplied to aluminum industry(the price for aluminum companies have been accused of too low). And while the other main product is cacao, the rural electrification rate is 10 percent, so Government of Cameroon established the Rural Electrification Agency(AER) to raise the access.

The AER is steadily and surely making progress. For example on June 2010, the raised fund of US$ 9.49 million for the electrification project of 33 localities in rural areas of four Regions of Cameroon (Center, North, North West and South), from the Islamic Development Bank (IsDB). And more recently, the AfDB approved funding for Construction and Extension of High Voltage /Medium Voltage /Low Voltage networks, and public lighting, amounting to US$ 47.70 million, on 15 September 2010[39].

4-5 Group D
Countries very far from the goal (Electricity access less than 19%)

Region	Country	Electrification Rate *1	Oil production *2	Natural Gas production *3	GDP /capita *4
Eastern Africa	Madagascar	19%	0	0	535
Eastern Africa	Zambia	19%	0	0	1,336
Western Africa	Mali	17%	0	0	688
Southern Africa	Lesotho	16%	0	0	721
Eastern Africa	Ethiopia	15%	0	0	409
Eastern Africa	Kenya	15%	0	0	992
Central Africa	Congo DR	11%	16	265	236
Eastern Africa	Tanzania	11%	0	20	573
Western Africa	Guinea-Bissau	11%	0	0	273
Western Africa	Burkina Faso	10%	0	0	614
Eastern Africa	Malawi	9%	0	0	325
Eastern Africa	Uganda	9%	0	0	529
Western Africa	Niger	9%	0	0	409
Western Africa	Gambia	8%	0	0	504
Central Africa	Central African Rep.	5%	0	0	512
Eastern Africa	Rwanda	5%	0	0	469
Western Africa	Sierra Leone	5%	0	0	374
Central Africa	Chad	3%	115	0	1,017
Eastern Africa	Burundi	3%	0	0	176
Western Africa	Liberia	3%	0	0	271

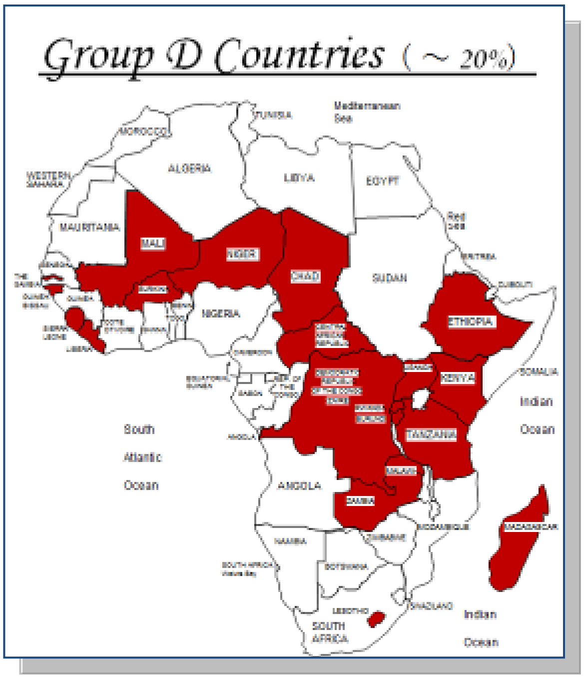
[39] Devex (24 November 2010 and 24 November 2010)

Figure 45 shows that the Eastern and inland Africa have very low access to electricity.

Most of these countries neither produce large amount of oil nor natural gas, so they have no income from resources, and they have to import fuels to run thermal power plants.

However, as it is very costly to transport oil or natural gas to inland Africa, many of their power generation depends on hydro.

Figure 53 Countries with electricity access less than 19%



Ethiopia (15%)

= Recent effort for rural electrification =

The economy of oldest independent country Ethiopia depends on traditional agriculture, and most of the power capacity of utility Ethiopian Electric Power Corporation (EEPCo), which was privatized in 1997, is hydro. Their plan to build 300 megawatt Tekeze Hydro Power Plant which will add one third of total capacity 900 megawatt, has been delaying.

On March 2008, EEPCo announced they will raise the access to electricity in Ethiopia, to 100 percent in 10 years period, that is, until 2018[40]. First EEPCo will invest four billion Birr (U$ 242 million) for the construction of six power generation stations, which will increase 3,000 megawatt (more than three times of their present capacity of 900 megawatt.) Additionally, they have already started the construction of 30 high power transmission and distribution projects, along with 2,000 kilometers of high voltage (132kV) and extra high voltage (230kV) transmission lines.

Besides, they have already begun the construction of international transmission lines to Sudan, Djibouti, and will soon begin the interconnection between Kenya. Thus, when the new power stations and transmission lines are completed, Ethiopia would be sure the key country for the East Africa Power Pool (EAPP).

[40] March 19, 2008, nazret.com "Ethiopia - EEPCo set to push access to electricity to 100 percent in 10 years"

Uganda (9%)

= Good Solar Policy =

Figure 54 the interview with Ambassador Biriggwa held at the Ugandan Embassy to Japan, on 14th October 2008

The Uganda Government established Rural Electrification Agency (REA) on 2003, at the same time started Rural Electrification Fund (REF) to promote the energy access. With the support of the World Bank and Japan (JICA), some micro hydro power plants have been installed.

With regard to renewable energy, the Ugandan Government is subsidizing half of the solar system price, and remit duty for solar companies[41]. They also designated by law to mix biofuel into gasoline or diesel, while the amount of biofuel is expected to be far less. And also they intended to construct biogas plants throughout the country, not much progress have been made thus far.

4-6 International grid connection

While Northern African countries have energy access close to 100 percent[42], other regions need to help each other to secure the power supply and communication / information sharing, and therefore, some international power networks have started at Western and Southern Africa. This is somewhat bright news for some Bottom Africans, because international gird requires newly built transmission lines which connect major cities and power stations, via small rural villages. (However, very few distribution lines comes down to households)

Figure 55 WAPP connection map

(Source : Operation Manual for WAPP Interconnected Power System, WAPP)

<WAPP>

The West African Power Pool (WAPP) was set up on the July 2006 to address the issue of power supply deficiency within West Africa. In their context, "West Africa" means the member countries of Economic Community of

41 Cited from the interview with Ambassador Biriggwa held at the Ugandan Embassy to Japan, on 14th October 2008

42 "Tunisia: Country Tops Electrification Rate in Africa", 1 February 2010, allAfrica.com http://allafrica.com/stories/201002020459.html

West African States (ECOWAS) except Cabo Verde, which means Benin, Burkina Faso, Cote D'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo.[43]

The WAPP divides these countries in two groups. In Group A, most of the countries are interconnected. As Group B countries are in relatively bad financial status than Group A, the development of power industry is well behind. Therefore, Group B countries are presently under institutional reform for regulation, utility, rural electrification, privatization, and introduction of IPPs (independent power producers) or private capital.

Figure 56 Power generation capacity of SAPP countries

No.	Country	Utility	Installed Capacity		Available Capacity at Feb 2008		2007 Peak Demand
1	Angola	ENE	1,155	2%	870	75%	535
2	Botswana	BPC	132	0.2%	90	68%	496
3	DRC	SNEL	2,442	4%	1,170	48%	1,075
4	Lesotho	LEC	72	0.1%	70	97%	109
5	Malawi	ESCOM	305	1%	246	81%	240
6	Mozambique	EDM	248.5	0.5%	173.8	70%	365
		HCB	2,250	4%	2,075	92%	
	Mozambique total		2,499	5%	2,249	90%	
7	Namibia	NamPower	393	1%	360	92%	449
8	South Africa	Eskom	43,061	79%	38,384	89%	36,513
9	Swaziland	SEB	51	0.1%	50	98%	196
10	Tanzania	TANESCO	897	2%	680	76%	653
11	Zambia	ZESCO	1,632	3%	1,200	74%	1,468
12	Zimbabwe	ZESA	2,045	4%	1,125	55%	1,758
	SAPP Total		54,684	100%	46,494	85%	43,857

(Source：SAPP 2009 Annual Report)

<SAPP>

The Southern African Power Pool (SAPP) was established on August 1995, and the present member countries are Botswana, Mozambique, South Africa, Lesotho, Namibia, Congo DRC, Swaziland, Zambia and Zimbabwe. Additionally they have three non-operating members, which are Malawi, Angola and Tanzania[44].

Figure 57 SAPP connection map

(Source：SAPP webiste "Interconnectors and Generators")

Among 12 member countries, South Africa in other words Eskom, represents 79 percent of total capacity of SAPP, but when look at the AVAILABLE capacity, Eskom shares 89 percent. Therefore, it is very inferable that Eskom is she main power supplier of Southern African region.

For example the Namibia state owned Nampower which has been suffering from the soaring prices of coal and diesel, stopped running their formerly main power stations Van Eck power plant (coal, 120 megawatt) and Paratus (diesel, 24 megawatt) after they

43 WAPP website http://www.ecowapp.org/about_us.html
44 SAPP Annual Report 2009

could import cheap electricity from Eskom via the SSAPP (Van Eck and Paratus are presently taken as emergency generators).

And in Botswana, the state owned utility Botswana Power Corporation began importing from Eskom, Hidroelectrica De Cahora Bassa Sa (HCB) and EDM - Electricidade de Moçambique (both Mozambique) for 80 percent of electricity demand. (Now Botswana is rushing to improve their independency of power generation, and planning to construct 600 megawatt coal fired power plant.)

<WESTCOR>

The Western Power Corridor (WESTCOR) is a joint project by the electric power utilities o Congo DRC, Angola, Namibia, Botswana and South Africa, to first develop the huge hydro resources in Congo DRC, and to second deliver to the member countries by HVDC transmission line[45].

Figure 58 WESTCOR connection map

(Source : WESTCOR POWER INTER-CONNECT SOUTHERN AFRICAN POWER POOL)

Table 9 WESTCOR Development Schedule

Project	MW	Status
Inga Ⅰ	351	in operation
Inga Ⅱ	1,424	in operation
Inga Ⅲ	4,500	Planning
Grand Inga	39,000	Planning
Total	*45,275*	

(Source: WESTCOR POWER INTER-CONNECT SOUTHERN AFRICAN POWER POOL, Westcor)

Inga One (351 megawatt) and Inga Two (1,424 megawatt) are already in operation, but the Inga site is expected to supply more than 45,000 megawatt of clean electric power at the final stage, which quite excesses the present consumption of Congo DRC (2,500 megawatt).

== Finance Scheme and technical function ==

[45] Westcor Power inter-Connect Southern African Power Pool http://www.africacncl.org/downloads/WESTCOR_POWER_INTER-CONNECT.pdf

All members of Westcor except Angola are also SAPP members, which shares equally 20 percent of the total project cost (U$ 1,044 million), amounts U$ 5,218 million. The power stations costs U$ 3,744 (72 percent), HVDC converters U$ 822 (16 percent), and HVDC lines U$ 652 (12 percent). The capital will be raised by project finance from World Bank, African Development Bank, Rand Merchant Bank, Southern African Development Bank.

Table 10 SAPP and WESTCOR member countries

SAPP	Westcor	Utility	Investment for Westcor	Task for Westcor
— (not linked)	Angola	ENE	20%	Investigate the thermal and gas Technologies.
Botswana	Botswana	BPC	20%	Investigate telecommunications proposal.
Mozambique	—		—	
South Africa	South Africa	Eskom	20%	Investigate transmission line technologies; EIA planning; energy intensive user proposal and "MOTRACO" company JV Structure.
Lesotho	—		—	
Namibia	Namibia	Nam Power	20%	Investigate the HVDC Technologies; the planning for the EIA; MOU between governments and regulatory Impact.
DRC	DRC	SNEL	20%	Planning for INGA III and Investigate of hydro technologies
Swaziland	—		—	
Zambia	—		—	
Zimbabwe	—		—	

(Source: WESTCOR POWER INTER-CONNECT SOUTHERN AFRICAN POWER POOL, Westcor/SAPP Annual Report 2009)

Presently the electricity flow of southern Africa is very much stabilized, generated in South Africa (by coal 93 percent, nuclear 5 percent and hydro only 1 percent) ,and distributed to the neighboring nations. In other words southern African countries all rely heavily on coal power, so when the price of coal soars up, many consumers cannot afford to use electricity. Moreover, South African Eskom has been in management difficulties for long years, and neither able to build new power plants nor keep the budget for maintenance their power plants and transmission facilities.

The total power generation capacity of South Africa is 46,570 megawatt, and among them, 42,999 megawatt 92 percent) is currently available[46]. Therefore, if Inga III hydro

[46] SAPP Annual Report 2009

power station is opened, roughly ten percent of new power capacity which will not be affected by market price, can supply electricity to SAPP countries (of course including South Africa).

== Transmission Route ==

The generated power from Inga Hydro Power Plant first goes to the substations of Inga III (Congo DRC), Kinshasa (Congo DRC) and Cuanza (Angola), by 400kV HVAC. Another 220kV transmission line to Congo Brazzaville (Republic of the Congo) which is now not functioning, is also planned. After the 400kV AC was converted into 500kV DC, the power will be sent to the shareholding utilities. Finally the transmission line of this project would reach more than 3,000 kilometers.

<EAPP>

The MOU for the Eastern Africa Power Pool (EAPP) was signed on February 24 2005, by seven African countries (Congo DRC, Egypt, Ethiopia, Kenya, Rwanda, Burundi and Sudan). Tanzania, Djibouti and Uganda Joined the EAPP later[47].

Figure 59 EAPP connection map

Source : The briefing paper of Mr. Safaa Hamed, Chief Engineer, Egyptian Electricity Holding Company at Energy Efficiency Workshop held on March, 2010 at Washington

The sponsors for EAPP are ECA, AU, UPDEA, COMESA and USAID. The master plan and grid code study was funded by the African Union, and technical assistance and capacity building will be funded by the EU. Finally, technical Assistance will also be provided by the Norwegian Government, which has been supporting African countries for a long time. The EAPP has already secured Euro 2.7 million ($4 million) from the EU. And the fund will also be used in the preparation of the Eastern Africa Power Market Development Plan.

By far, the training and the development of an information system is expected to be completed by end of 2010, and the member countries launched interconnection of national electricity grids of the Nile Equatorial Lakes countries in Uganda on September 8, 2009.

Presently the EAPP is expected to start by the beginning of 2011

[47] Cited from the briefing paper of Mr. Safaa Hamed, Chief Engineer, Egyptian Electricity Holding Company at Energy Efficiency Workshop held on March, 2010 at Washington.

Why non-East African countries, that is to say Egypt and Sudan are listed up in the EASTERN Africa Power Pool? The reason is because the East African countries do not have South Africa, and they need one BIG GENERATOR. Table 7 shows that the power generation capacity of Egypt alone shares 75 percent of EAPP countries, and in turn, the total of seven East African countries, the leading characters, represent only 13 percent.

In their MOU, the EAPP says that the expected power exchange would be;

Table 11 Power generation capacity of EAPP countries

Region	Country	MW	Rate
North Africa	Egypt	23,424	75%
	Sudan	1,268	4%
	Subtotal	*24,692*	*79%*
Central Africa	Congo DRC	2,475	8%
	Subtotal	*2,475*	*8%*
East Africa	Ethiopia	929	3%
	Kenya	1,286	4%
	Rwanda	67	0%
	Burundi	52	0%
	Tanzania	957	3%
	Djibouti	118	0%
	Uganda	515	2%
	Subtotal	*3,924*	*13%*
	Grand Total	*31,091*	*100%*

(Source: US EIA "International Energy Statistics")

1. Export Countries: Uganda. Ethiopia, Rwanda and DRC
2. Djibouti , Kenya, Burundi, Sudan and Tanzania are assumed to import
3. Most countries would benefit from reserve sharing
4. With regard to Egypt, it will have 60 % of total EAPP generation. Moreover, Egypt will not be a net importer or exporter of electricity or natural gas.

****

We could see that West, East and South African countries / electric utilities are now investing into international grid. Of course only the large cities would be connected, however as every rural electrification starts from a transmission line, the international grid connection must be appreciated. Equally important, the EAPP says one of their objectives is rural electrification.

4-7 Good Practices

Prepaid System (South Africa , Tanzania, Zambia)

For African electric power utilities, one greatest challenge is how to collect the bill. The utilities don't have enough resources to check the meters, or even install meters, and the consumers cannot afford the payment of power they used. Therefore, the Eskom of South Africa started to install pre-paid power system to their customers from late 1980s. First, the spec of prepaid cards differed by suppliers, so great confusion embarrassed both Eskom and the consumers, but after the unification of standards, the system have been operating well.

Figure 60 Prepaid electricity charging by mobile phone

(Source：TANESCO website)

Tanzania also introduced prepaid card system from late 2006. Their system named "LUKU" meter, to raise the collection ratio, reduce the meter checking expense, reduce the stoppage cost for the non-paying households. Presently more than 60 percent of their customers in Dar es Salaam, and recently they started recharging by mobile phone.

In Zambia, the state owned utility ZESCO started the prepaid system for home customers since 2007, instead of fixed charge billing system.

Investment in Maintenance (Burkina Fas, Malawi, Zambia)

Proper maintenance is very important for power industry. Many utilities cannot afford to invest in maintenance, so many power plants / substations / transmission lines, even constructed by grants or international loans, are not well functioning.

In this context, some countries can be listed up for good practice. Fist the available capacity of generators in Burkina Faso is more than 70 percent, much better than average African countries. The access rate of rural area has been rising from 5 to 10 percent annually. Second, Malawi established three companies for operation and maintenance (for each regions of North, Central and South).

In Zambia, the ZESCO started maintenance project under the support of World Bank, and now reforming their more-than-40-years-old power stations.

4-8 Unfortunate Experiences

Tanzania

= Too much expenditure for rural electrification =

More than 90 percent of the energy consumption of Tanzania is non-commercial, and electricity share only 1.2 percent of total energy. Tanzania imports 100 percent of oil, and produces very low amount of coal (0.3 percent of total energy consumption), hydro electric (0.6 percent) and natural gas (1.6 percent).

Table 12 **Combined Loan Summary 2009-2014 of TANESCO**

Total	2009	2010	2011	2012	2013	2014
Opening Balance	422,537	583,594	625,562	877,434	1,631,935	2,554,248
Drawdown	165,467	96,988	324,319	819,974	969,475	582,586
Repayment	(22,490)	(68,995)	(91,130)	(95,496)	(102,332)	(130,346)
Interest Due	58,056	68,583	66,425	73,435	92,357	95,974
Interest Paid	(39,976)	(54,608)	(47,742)	(43,412)	(37,187)	(59,714)
Closing Balance	583,594	625,562	877,434	1,631,935	2,554,248	3,031,255

(Source : TANESCO Cost of Service Study - Final Report)

The state owned electric power utility Tanzania Electric Supply Company Limited (TANESCO) began the project to supply electricity access to rural Tanzania, after two private power companies TANESCO (Tanganyika Electric Supply Company) and DARESCO (Dar es Salaam Electric Supply Company) were socialized in 1964.

TANESCO raised finance for rural electrification from foreign banking organs or grants, but unprofitable rural projects became to press the management. And as TANESCO was already state-owned, the deficit was covered by huge amount of subsidy[48]. After the consultation of the World Bank, TANESCO was planned to be privatized under "PLRPS / Programs for Liberalization and Reform on Power Sector", but due to the severe drought and frequent blackouts, the reform was halted on 2006.

Table 13 **Grid Based Generation of TANESCO**

GRID THERMAL:	Installed cap (MW)	Availability factor %
SONGAS I,II,III	185.[illegible]	87.31%
IPTL	100.0	82.38%
UBUNGO WARTSILA	100.0	87.31%
TEGETA GT	41.[illegible]	87.31%
MWANZA	80.0	82.38%
UBUNGO EPP	100.0	85.40%
KWIRA	200.0	85.40%
KINYEREZI	240.0	85.40%

GRID HYDRO:	Installed cap (MW)	Availability factor %
KIDATU	204.0	98%
KIHANSI	180.0	98%
MTERA	80.0	98%
NEW PANGANI FALLS	68.0	98%
HALE	21.0	48%
NYUMBA YA MUNGU	8.0	48%
UWEMBA	1.[illegible]	48%

Source : 100515 TANESCO Cost of Service Study - Final Report

48 "The Electric Power Industry of Overseas Countries Vol. 2", JEPIC, Mar, 2010

As a result of spinning off money-losing rural electrification project, the financial condition TANESCO was much improved

As well, the available power capacity of TANESCO has been greatly improved, so generally more than 85 percent of the output of thermal power plants, and close to 100 percent of large hydro power plants is available to generate electricity (the availability of small and medium sized hydro plants is close to 50 percent). On the other hand, frequent problems of substations have been reported, so even more amount of budget for maintenance is required.

The electricity access rate to the rural area of Tanzania has not been upgraded, first because only 60 percent of the electricity bill is paid, and second the TANESO has to pay high rate to IPPs.

TANESO seems to set the price level too low, so that they could not manage their company. For other sample, Burkina Faso kept their price high, so they have been successful for rural electrification.

4-9 Summing-up

In this chapter, we analyzed the electricity access of African countries by four groups, then overviewed about three international gird connection projects, and finally picked up good / bad practices.

<Group A>

Among the sub Saharan countries, only the Republic of South Africa excesses the energy access of 75 percent. The reason is not just because South Africa has abundant coal or nuclear power plant, but also they conducted rural electrification, and moreover, they adopted groundbreaking bill collecting system of prepaid card.

<Group B>

The countries in next group are isolated examples. Ghana had an aspiring leader who forced through rural electrification, and still running to raise the energy access. The presidential candidates discuss about their own energy policy, and people closely check whether they are keeping words.

Djibouti, a relatively small and flat country at a geographically strategic location, is based on their function of trading hub. It is not so difficult to extend the grid.

<Group C>

The countries with electricity access of 20%～49% is roughly on the Atlantic coast. A number of them produce oil or natural gas, and more than half countries records GDP capita of more than U$ 3,000. In spite of their wealthy public finance, as many countries focused on industrial output, rural energy policy has been lower priority task. As a result, he gap between urban and rural areas widens much larger than Group D countries.

<Group D>

Group D, the most energy-poor countries, are in a single phrase, inland or Indian Ocean coast countries. Presently they produce very little oil or gas, and most of their GDP per capita is less than U$ 500. The governments and utilities suffer from chronic budget shortage, so they have no fund for power plant / substation construction, maintenance, grid expansion and bill collecting.

However, some countries are attempting to raise the rural electrification access. Uganda set a policy to subsidize half of solar price, and Ethiopia is making effort to see 100 percent until 2018.

<International grid connection projects >

Presently, we could find four ongoing international grid connection projects in Sub Saharan Africa, West African Power Pool (WAPP), Southern African Power Pool (SAPP), Western Power Corridor (WESTCOR) and Eastern Africa Power Pool (EAPP). They can not only secure the electricity supply, but also they may lead to grid extension, in the long run.

< Good and bad practices >

Despite their humanistic policy to supply electricity to poor people, Tanzania over-subsidized the cost, and at the end of the day bankrupted. Therefore, rural electrification policy should carefully design the structure to keep it sustainable.

On the other hand, African countries can bring in prepaid card system to ensure their bill collecting, reduce staff cost. Not only the Republic of South Africa but also Tanzania and Zambia are using this breakthrough technology.

Equally important, utilities which invest in maintenance are showing high performance of availability factor. If this is not the case, power facilities can only bring out less than hald of their full function.

==

All in all, these studies clearly show that mineral rich nations have relatively higher access to electricity, but as most of them lack energy policy for rural electrification, the villages do not benefit from grid electricity. The inland or East countries are suffering from lower electrification rates, but good policy might make improvements.

5. Conclusion

5-1 The conclusion of energy production and consumption in Africa

- Presently, Northern African countries and the Republic of South Africa are producing and consuming most of the energy (oil, gas, coal and electricity) in Africa.
- For power generation, the main source for Northern African countries and oil rich countries is fossil fuel. By contrast, developing countries mostly depend on hydro or diesel
- International fuel transportation for power generation is not popular in Africa.
- On the other hand, international transmission of electricity is expanding.

5-2 The conclusion of sustainable offgrid energy technology

- African bottom billions are not satisfied with just a small solar, what they need is GRID ELECTRICITY, or if not, SUSTAINABLE, RELIABLE and AFFORDABLE off-grid electricity.
- The author found proven cases of renewable energy business models in Africa, but the problem of capital funding lingers on. Many successful cases are subsidized or granted.
- Solar energy is proved to give great impact for bottom billions, but it not affordable, and can only be of assistance for light electrical equipment.
- Wind energy is most abundant at Northern and Southern Africa, where energy access is already high. And as the feasibility study requires long time and high expense, it is difficult to find really cost effective sites for wind power in Sub Saharan Africa.
- Biogas, Multifunctional Platform, and micro hydro can supply reliable and sustainable electricity.

The features of rural energy can be summarized as follows;

Table 14 Analysis of features with offgrird energy technologies for Africa

Technology	Relia bility	Affordability		Site	To make sustainable
		Plant cost	Fuel cost		
Solar	×	△ or × (Expensive)	◎ (Free)	◎ (Anywhere)	Power storage technology
Wind	×	△ or× (Expensive)	◎ (Free)	× (Few)	
Biogas	◎	× (Expensive)	◎ (Free)	○ (Many)	Policy
MFP	◎	○Affordable	× (Expensive)	◎ (Anywhere)	Policy
Micro Hydro	◎	×× (Very Expensive)	◎ (Free)	×× (Very few)	Policy

We can find in table 14 that reliable and renewable energy sources (biogas and micro hydro power plant) are not affordable, so they need support of policy. MFP is affordable (while not granted), but requires approval from local governments and the UNDP, and they have to pay for expensive diesel.

Solar and wind are too volatile, so they need battery (Solar and wind is too unstable, so they are better to be just added on grid). However, the present power storage technology is not only so efficient, but also requires replacement for every few years. We should be aware that solar and wind are not even popular in most prosperous countries, so they promote feed in tariff (FIT) policies. In short, **the day when sustainable solar or wind system comes affordable to the African bottom billion, might come only more than 10 years after the price becomes well moderate for people in developed countries**.

The **battery technology still relies on the voltaic pile**, which was **developed on year 1800**, more than 200 years ago. Therefore, **we should not wait for a breakthrough technology**, but it is **better to design good energy policy**.

A good policy, or business / financial scheme might deliver small solar or small wind plants in the village or houses in some day. **The day when a small solar or wind power comes is a really great moment, but it is not the goal**. The power is so weak, and although no fuel cost is needed, they still have to pay for battery, to make it sustainable.

5-3 The conclusion of grouping

- North Africa has almost 100 percent access to electricity.
- South Africa and Ghana completed good rural electrification policy, so they have high access in the rural area.
- Western African countries have generally more than 20 percent of access, but most of rural area is still not connected.
- Eastern and inland Africa has very low access to electricity. They need good policies, and enough fund to improve.

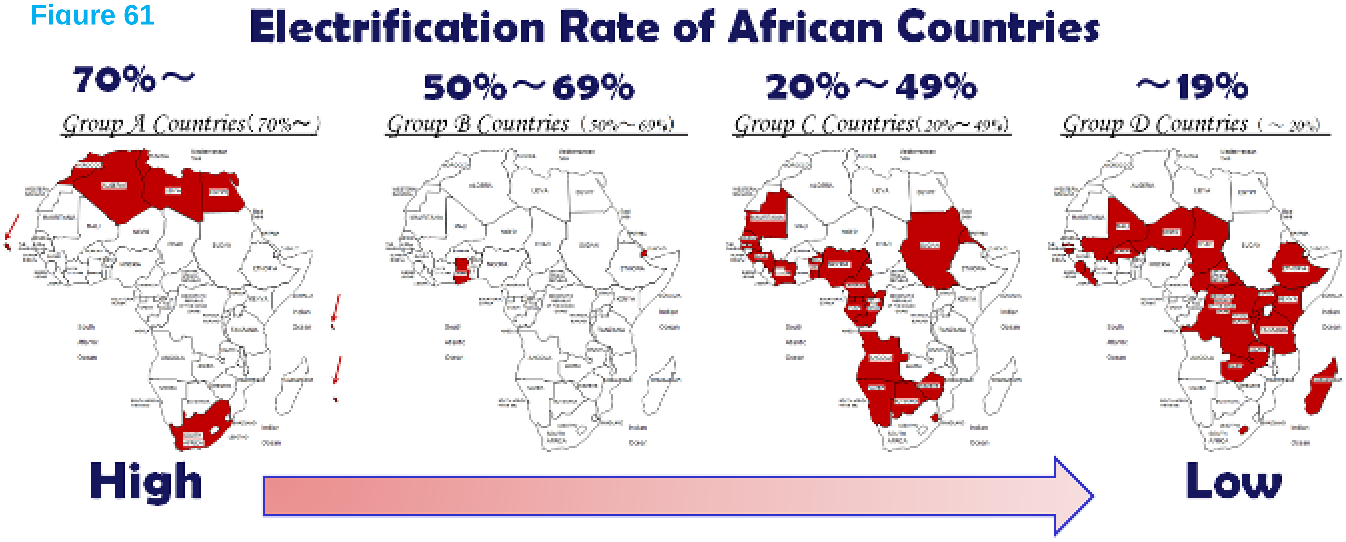
Table 15　Electrification of African regions in summary

Country Group	Electrification Rate	Oil production	Natural Gas production	GDP/capita
Average of Group A	80%	64	38	6,321
Average of Group B	52%	4	0	1,092
Average of Group C	33%	298	193	3,562
Average of Group D	10%	7	14	548

Here we can say that THERE IS A CLEAR TENDENCY FOR RURAL

ELECTRIFICATION IN AFRICA, North and south is good, West comes next. East and Central Africa has generally low access to electricity. Ghana and Djibouti are exceptions, because of ambitious energy policy (Ghana) and strategic location (Djibouti).

Figure 61

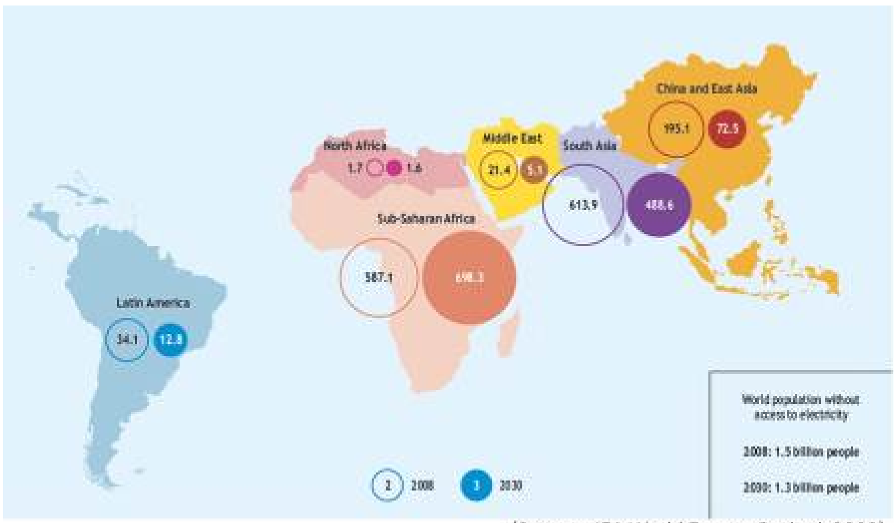


Th

5-4 The future of African Energy prospected by IEA

The International Energy Agency (IEA) projected that in Africa, more than any other regions still have no access to energy in 2030[49]. It should be remarked that the lifestyle of African people who cook by biomass and fetch water from far sources far away, are very similar to their ancestors who lived there some hundred ago, except that the 21st century Africans communicate with mobile phones, and they carry water by plastic tanks or buckets. Therefore, the scenario that the lifestyle of African bottom billion remains unchanged for another 30 years, is VERY LIKELY. ***Can we agree for it? And how can it be improved?***

Figure 62 The number of people without access to electricity



(Source : IEA World Energy Outlook 2009)

[49] "World Energy Outlook 2009" International Energy Agency http://www.worldenergyoutlook.org/docs/weo2009/WEO2009_es_japanese.pdf

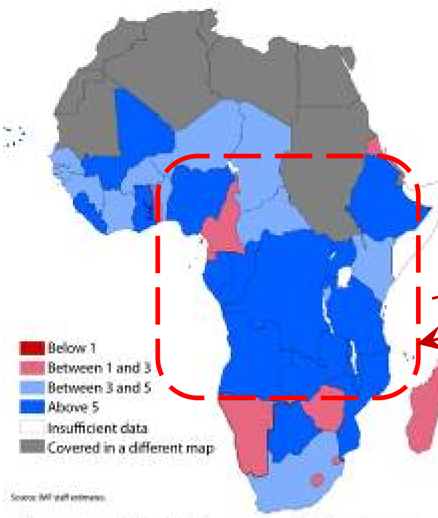
5-5 The conclusion of this Thesis

The IEA says most of the African remain the same at 2030. However, we can find one answer on mobile phones. Who in the world projected the day so many poor Africans use mobile phones? Now we can say it is even one of the infrastructures in Africa. For example, as we found in the case of prepaid charging system in Tanzania, rural electrification combined with mobile phone may work.

With regard to the capital funding, we can find great chances in micro finance or leasing. And one promising trend in Africa is the energy business entrepreneurs of university students[50]. Students have the knowledge of technology can learn business methods at the university, or exchange experiences. Policy should support them.

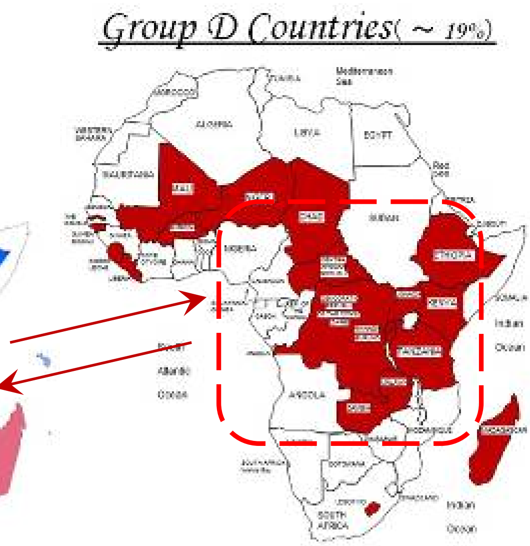
Finally, we have some hope when we look at the recent economic growth in Africa. The high-growing economies are most equal to the energy poor countries, so when these countries conduct well-suited energy policy so that they can extend the grid, subsidize biogas, MFP or micro hydro plants, replacement of solar batteries, or support small energy businesses, the future projected by the IMF can be changed.

Figure 63 GDP growth of African countries



Source : World Economic Outlook Database April 2010 - IMF

Figure 53 Countries with electricity access less than 19%



Here, it is feasible to conclude that aspiring energy policy can do deliver sustainable energy to African bottom billions, as we saw in the cases of Ghana, South Africa, Uganda and Ethiopia. Equally important, however mineral resources can be produced, rural people have to live without sustainable energy, as we found on West African countries.

[50] Renewable Energy for Rural Areas in Africa, Apr, 2008, Abeeku Brew-Hammond and Francis Kemasuor