CURRENT STATUS OF RESEARCH AND DEVELOPMENT ACTIVITIES ON EFFICIENT COOKSTOVES IN NIGERIA

Roseline Kela, Ahmad Tijjani and Kaisan M. Usman
Energy Commission of Nigeria
Plot 701c, Central Business District, P.M.B 358, Garki, Abuja Nigeria

ABSTRACT

Fuelwood and charcoal constitute about 60% of total primary energy consumption in Nigeria. To procure fuelwood, many hectares of forest are continuously lost thereby aggravating desert encroachment in some parts of the country. Despite the attendant environmental and health implications, merchandising in fuelwood and charcoal has emerged as one of the most lucrative businesses in the country due to the unending demand, the available option to reverse the ugly trend is a two-prong approach of reducing fuelwood consumption rate through the promotion of efficient cookstoves and systematic phasing out the use of fuelwood for cooking. Several research and development (R&D) aimed at achieving these two options are on-going at different institutions across the country. Consequently, proto-types have been developed and were found to be more efficient than the existing traditional means of fuelwood use in Nigeria. This paper highlights the current R&D activities, pilot projects and challenges in the area of efficient cookstoves development in Nigeria.

Keywords: current status; research and development; cookstoves, fuelwood, charcoal

1.0 INTRODUCTION

Energy is the mainstay of Nigeria's economic growth and development. It plays a significant role in the nation's international diplomacy, serves as a tradable commodity for earning the national income which is used to support government development programmes. It also serves as an input into the production of goods and services in the nation's industry, transport, agriculture, health and education sectors, as well as an instrument for politics, security and diplomacy [1]. Energy consumption in Nigeria is categorized based on the end-users into three groups, the residential, commercial and industrial sectors. Whilst most of the households in the urban and semi urban areas have access to modern energy supply, majority of the rural areas depends mainly on fuelwood for both domestic and commercial energy needs [2]. According to Udo et al. [3], in most countries, the industrial sector constitutes the largest consumers of energy followed by residential and then commercial sectors. In Nigeria, however, it has been established that residential sector consumes the highest amount of energy among the other sectors [1]. Nigeria has one of the lowest net electricity generation per capita rates in the world. Electricity generation falls short of demand, resulting in load shedding, blackouts, and a reliance on private generators [2].

Roughly 20 million households in Nigeria cook with fuelwood[4]. Nigeria has been documented to have one of the largest and most sophisticated fuelwood markets in the world, delivering firewood from dry savannah-land clearings to a network of urban retail outlets [4]. However, very few efficient improved cookstoves are available to Nigerian consumers making the country among those with the high number of deaths resulting from smoke fuels with estimated 95,000 Nigerians dying annually from problems arising from toxic smoke from rudimentary cook-stoves [4].

It is reported that as at 1981, Nigeria had 13,071,464 hectares of forest distributed across different parts of the country [5]. In the process of procuring fuelwood, however, many hectares of forest and natural vegetation in Nigeria are lost, thereby aggravating desert encroachment in some areas. Accordingly, fuelwood and charcoal are found to constitute about 40 % of total primary energy consumption in Nigeria. The annual national demand is estimated to be 39 million tonnes out of which about 95% is consumed in the household for cooking and cottage industrial activities such as processing cassava, and oil seeds, which are closely related to household activities [5]. The pattern of fuelwood and charcoal consumption for the period 1981 – 2006 is shown in tables 1 and 2.

The nature of fuelwood utilization for energy production in Nigeria is also a cause of concern. Most of the stoves being used are archaic; they produce excessive smoke and have high thermal inefficiency thereby consuming much more fuelwood than necessary for a particular activity. The inefficient stoves also cause devastating damage to the general health of the users and others within the immediate environment made up of mostly women and children.

In an effort to reduce the negative impact of the fuelwood utilization, Nigerian researchers have identified a two-prong approach of reducing fuelwood consumption rate through the promotion of efficient cookstoves and systematic phasing out the use of fuelwood for energy. Consequently, research and academic institutions in Nigeria have launched several R&D programmes that have developed various types of efficient cookstoves that have proven to be more efficient than the traditional stoves.

This paper discusses the current status of the R&D activities for the production of efficient cookstoves in Nigeria, the identified challenges of the activities and recommendations for improvement.

2.0 CONVENTIONAL COOKSTOVES IN NIGERIA

Despite the difficulties of procuring fuelwood and the attendant loss of resources, the present mode of fuelwood utilization in Nigeria is grossly inefficient. The fuelwood cooking is mainly done through the traditional 3-stone stove (as shown in figs 1 & 2) and other similar inefficient means leading to severe waste of energy and attendant health problems owing to excessive smoke. In an effort to reduce the waste and minimize the associated problems, researchers in Nigeria have developed various types of efficient wood-burning and charcoal stoves to replace the inefficient stoves.

Fig. 1: Locally fabricated open-stoves

Fig. 2: Inefficient fuelwood stoves

3.0 THE CURRENT STATUS OF RESEARCH AND DEVELOPMENT IN ENERGY EFFICIENT COOK STOVES IN NIGERIA

Nigerian researchers have developed various types of efficient fuelwoodcookstoves that have proven to be more efficient than the traditional stoves. The efficient fuelwoodcookstoves uses less quantity of fuelwood and possesses higher thermal efficiency than the traditional stoves.

The energy efficient cook stoves include but not limited to the solar cook stoves, biogas cook stoves, improved wood stoves, improved sawdust stoves, improved coal and/or charcoal stoves, briquette stoves, improved kerosene stoves and low power consuming electric stoves.

3.1 RESEARCH AND DEVELOPMENT IN SOLAR COOK STOVES

Research and development (R&D) activities in solar thermal for household cooking and heating have been recorded by the research centres of Energy Commission of Nigeria, the academia as well as private institutions in Nigeria.

Nigeria lies in the tropics and is endowed with abundant sunshine all the year round. The daily average sunshine hour in the southern region is about 8 hours during dry season and about 4 hours during the rainy season. While greater values of daily sunshine hours are obtainable in the northern region of the country, with an average of about 10 hours during dry season and 6 hours during the rainy Season [6].

Nigeria has been graded by the Solar Cookers International (SCI) as the 5th out of the 25 countries with greatest potential benefits from solar cooking (Table. 3). The heat energy produced by the sun is enormous and can go beyond 1000 W/m^2 [7] which corresponds to half the power of an electric kettle. It only takes 10 – 15 minutes to boil water on a solar cooker, and it's free, as long as the sun shines.

Some Nigerian institutions and research centres have conducted a number of research and development activities in different types of solar cookers. As part of the R & D efforts in solar cooking in Nigeria, Dahiru et al [8] reported the performance of a concentrating solar energy cooker with mirrors glued on the inside wall of the parabolic concentrator (Fig.2) as reflective material with reflectivity of over 80%. The cooker was evaluated by undertaking water boiling and rice cooking tests. The results obtained were compared to those obtained using a traditional fuelwood stove; the solar cooker was found to have boiled the water and cooked rice at the rates of 3.7g/min and 1.66g/min respectively with 41% efficiency.

Bello et al, [9] reports the performance and of a Solar Box Cooker at Ilorin. The results of the investigation illustrated that a maximum temperature of 88^{0}C was attained for the water boiling tests and suggest that the constructed solar cooker would take between one-and-half hours and two-and half hours to cook such commonly eaten foods like egg and rice in this tropical station. The average collector efficiency of the

Fig. 3: Parabolic Solar Cooker

solar box cooker has been estimated to be 47.56%

In June 2010, the students of the Department of physics and Industrial Physics at Evan Enwerem University in Owerri, Nigeria designed a parabolic solar cookers and solar box cookers.

Fig. 4: Box type solar cookers

3.2 RESEARCH AND DEVELOPMENT IN BIOMASS COOKSTOVES

There is a huge potential for the use of biomass as an energy source in Nigeria. Biomass refers to energy derivable from sources of plant origin such as trees, grasses, agricultural crops and their derivatives, as well as animal wastes [1]. As an energy source, biomass may be employed as solid fuel, or transformed by means of diversified technologies to liquid or gaseous state for the production of electric power, heat or fuel for motive power. Biomass resources are regarded as renewable as they are naturally occurring and when appropriately administered, may be harnessed without significant depletion.

Fuelwood and charcoal use by the households are by far the largest single demand on forests and woodlands. The commonly used medium of consumption is the traditional three-stone stove with efficiencies as low as 15% or even less Figs. 1 & 2). While it would be difficult, if not impossible to immediately stop the use of fuelwood for cooking in Nigeria, efficient wood-burning and charcoal stoves could be deployed as short term measures with to reduce the amount trees that are felled to supply fuelwood. The potentials of fuel wood and other biomass are summarized in Table 2.

Many versions of efficient wood-burning and charcoal stoves have been developed by research centres of the ECN. They are in form of Clay-based, metallic, or insulated cook stoves of various sizes that conserve the amount of fuelwood consumed by up to 50%. They lead to faster cooking and with the attachment of chimneys, they allow for organized exit of smoke which consequently reduces smoke inhalation. (Figs. 5 – 11).

Fig. 5: Double-pot improved stove by SERC, Sokoto

Fig. 6: Clay-based improved stove by SERC, Sokoto

Fig. 7: Clay based and Saw dust Stoves by SERC, Sokoto

Fig. 8: Double & single -pot energy saving stove by SERC, Sokoto

Fig. 9: One-pot improved stoves by SERC

Fig. 10: Metal Efficient Stove by NCERD, Nsukka

Fig. 11: Metal Efficient Stove by NCERD, Nsukka

3.3 RESEARCH AND DEVELOPMENT IN ELECTRIC STOVES IN NIGERIA

Locally fabricated electric cook stoves are found in Nigeria, they are mostly used by households and in students' hostels in the universities, colleges and polytechnics. They are highly inefficient in terms of electric power consumptions but they are fast in cooking and time saving in action because they produce very high heat energy sufficient enough to cook beans in less than an hour. As part of their power consumption characteristics, they are mostly associated with causing power break down in the cut out and distribution boxes of the users connections.

3.4 RESEARCH AND DEVELOPMENT IN BIOGAS STOVES IN NIGERIA

Biogas digesters, which are capable of producing biogas that could be used for domestic and industrial uses, have also been developed by many researchers in Nigeria. In Nigeria, the various research centres of Energy Commission of Nigeria and other institutions have developed pilot biogas plants that were found to be viable for domestic gas supply. in different locations across the country. Some of the projects are shown in Figs. 12, 13 & 14

Fig. 12, 13 & 14: Biogas Digester Pilot Plant and portable floating type developed by NCERD, Nsukka and SERC Sokoto respectively

4.0 CHALLENGES OF RESEARCH AND DEVELOPMENT IN NIGERIA

In Nigeria, research and development is faced with numerous challenges which if overcome, will make the research and developmentatmosphere more conducive, attractive and will bring in more professionals to the lifeline. Some of the challenges of research and developmentin Nigeria include:

1. Infrastructural Constraints: Although Nigeria is the world 9th largest country with proven results of natural gas; there are presently insufficient infrastructures to deploy the gas to the general populace for cooking.

2. Technological Constraints: Even though the products of the research and development activities are proven to be more efficient than the traditional stoves, their efficiencies are still low when compared to those produced in the developed countries, e.g. Save 80 fuelwood stove that saves up to 80% of fuelwood used for cooking.

5.0 CONCLUSION

Households are the leading Nigerian energy consuming sector, and most of these energies are being wasted unnecessarily in cooking, heating and other domestic activities. Whilst the current research and development activities have assisted in reducing the impact, but a lot more has to be done especially in the areas of funding to support the on-going energy saving campaigns in Nigeria's household sector. Some of the recommended strategies to be adopted are as follows:

1. Capacity Development: Development of training programmes and technical courses in entrepreneurship and managerial skills for researchers;
2. The existing Research and Development centres and technology development institutions should be adequately strengthened in terms of tools and equipment to ensure expertise in the area of improved cook stoves;

3 There are limited public funds available for the deployment and continuous improvement of R&D results. Also, the level of private sector participation in the R&D in Nigeria is almost zero.

4. There is inadequate public awareness on energy efficiency technologies and their benefits, both economically and environmentally in the country. This makes it difficult for the people to procure more efficient devices which could be more expensive at the initial stage but saves a lot in operational cost.

5. Preparation of standards and codes of practices, maintenance manuals, life cycle costing and cost- benefit analyses. There is need for the Standards Organisation of Nigeria to develop a relevant standard for the different types of cook stoves developed or imported into the country. Priority should be given to the area of energy efficiency and conservation during the drafting or the said standards.

Table 1: Energy Consumption by Sector – Fuelwood ('000 tonnes)

Year	Manufacturing	Household	Services	Total
1981	602.60	11449.32	5498.38	17550.29
1982	702.27	13343.08	5502.16	19547.51
1983	807.12	15335.36	5629.53	21772.02
1984	903.90	17174.02	6171.76	24249.67
1985	1054.33	20032.27	5922.69	27009.29
1986	1216.83	23119.71	5746.40	30082.94
1987	1401.33	26625.30	5479.75	33506.38
1988	1616.84	30720.02	4982.54	37319.41
1989	1850.27	35155.09	4561.00	41566.36
1990	2024.13	38458.50	5813.97	46296.61
1991	2296.61	43635.61	5632.94	51565.16
1992	2599.60	49392.48	5441.20	57433.28
1993	2935.49	55774.30	5259.39	63969.18
1994	3302.34	62744.43	5202.11	71248.88
1995	3711.54	70519.23	5126.23	79357.00
1996	4167.96	79191.18	5024.87	88384.00
1997	4677.84	88878.88	4885.38	98442.10
1998	5247.46	99701.69	4695.66	109644.81
1999	5879.00	111701.08	4542.31	122122.39
2000	6579.85	125017.11	4422.96	136019.92
2001	7366.72	139967.67	4164.60	151498.98
2002	8253.05	156807.98	3678.54	168739.57
2003	9216.45	175112.64	3613.03	187942.13
2004	10325.81	196190.33	2813.81	209329.95
2005	11530.95	219088.01	2532.74	233151.69
2006	12872.22	244572.21	2239.92	259684.36

Source: Nigerian Energy Balance, Energy Commission of Nigeria 2011

Table 2: Energy Consumption by Sector – Charcoal ('000 tonnes)

Year	Manu-facturing	Household	Services	Total
1981	8.57	2.90	136.98	148.45
1982	9.68	6.63	149.53	165.84
1983	6.83	32.28	146.15	185.27
1984	6.06	67.59	133.31	206.97
1985	7.27	85.03	138.92	231.21
1986	6.99	108.13	143.18	258.30
1987	7.34	131.07	150.15	288.55
1988	8.28	148.94	165.13	322.36
1989	8.42	171.31	180.39	360.12
1990	6.79	254.00	141.51	402.30
1991	7.43	295.94	146.06	449.43
1992	7.10	343.77	151.21	502.08
1993	6.83	397.62	156.44	560.89
1994	6.74	461.70	158.16	626.60
1995	6.39	533.11	160.50	700.00
1996	6.45	611.81	163.74	782.00
1997	6.47	698.72	168.41	873.61
1998	6.03	794.70	175.22	975.94
1999	6.23	902.90	181.13	1090.27
2000	6.45	1025.51	186.02	1217.98
2001	6.90	1156.20	197.56	1360.66
2002	7.60	1288.79	223.67	1520.05
2003	8.03	1462.37	227.72	1698.12
2004	8.98	1595.66	292.40	1897.04
2005	9.84	1784.57	324.85	2119.26
2006	10.77	1989.44	367.32	2367.52

Source: Nigerian Energy Balance, Energy Commission of Nigeria 2011

Table 3: 25 Countries with the Greatest Potential Benefits from Solar Cookers in Descending Order

COUNTRY	POSITION	Annual Insulation 2=best 1=good (NASA)	% forest/ wood-lands (UNFAO data)	Est. fuel scarcity 2 = >1/2 pop., 1=< 1/2 pop. (SCI est.)	Est. population 2020 (in millions) (UN data	Est. % pop. with Both sun & fuel scarcity	Est. no. of people with both sun & fuel scarcity 2020 (in millions
India	1st	1.2	21	2	1312	12	154.3
China	2nd	1	16	2	1402	7	98.1
Pakistan	3rd	1.5	4	2	227	20	45.2
Ethiopia	4th	1.5	5	2	105	23	24.2
Nigeria	**5th**	**0.5**	**19**	**1**	**177**	**7**	**12.4**
South Africa	6th	2	7	1	44	20	11.0
Brazil	7th	0.75	67	1	210	4	8.4
Uganda	8th	1	26	2	47	16	7.5
Tanzania	9th	1	45	1	50	15	
Afghanistan	10th	1	2	2	40	17	
Sudan	11th	2	30	1	93	15	
Nepal	12th	1	33	2	35	17	
Kenya	13th	1	32	1	39	15	
Somalia	14th	2	13	2	18	27	
Niger	15th	2	2	1	22	22	
Mozambique	16th	2	40	1	24	16	
Burkina Faso	17th	0.5	27	1	21	16	
Haiti	18th	2	6	2	10	31	
Madagascar	19th	1	22	1	27	11	
Malawi	20th	1	34	2	17	16	
Zimbabwe	21st	2	58	2	13	20	
Sri Lanka	22nd	1	35	1	21	11	
Eretria	23rd	2	14	2	7	27	
Dominican Republic	24th	2	28	1.5	11	15	1.7
Zambia	25th	1	54	1	14	8	1.1

Source: Solar Cookers International (SCI), 2004

Table 1: Renewable Energy Sources and Capacities In Nigeria

ENERGY SOURCE	CAPACITY
Large Hydro	11,250MW
Small Hydro	3500MW
Fuel Wood	13,071,464 hectares (forest land 1981)
Animal Waste	61 million tonnes / yr
Crop Residue	83 million tonnes /yr
Solar Radiation	3.5 – 7.0 KWh/M^2-day
Wind	2-4 m/s (annual average)

Source:Renewable Energy Masterplan, Energy Commission of Nigeria 2012

Table 3 Products of Research and Development on Energy Efficient Cookstoves in Nigerian Institution

S/N	RESEARCH INSTITUTES/ CENTRES	TYPE OF EFFICIENT COOKSTOVE	YR OF DEVT	PERFORMANCE (% efficiency)
1	**Sokoto Energy Research Centre (SERC) Usmanu DanFodiyo University, Sokoto, Nigeria**	Single and double box type solar cookers	2006	47.56
		Parabolic solar Cooker	2006	41
		Clay based Improved woodstove	2003	25
		Biogas Digesters	1998	40
2	**National Center f Energy Research and Devt NCREI University of Nigeria, Nsukka**	Metal based Efficient woodstove	2011	50
		Charcoal stove	2005	30
		Sawdust Stove	2005	30
		Biogas Digesters	2001	40
3	**Developmental Associations for Renewable Energ (DARE) Kaduna Nigeria (CDM project)**	Stainless Steel Efficient Woodstove (Save 80: Developed in Germany, assembled in Nigeria)	2010	80

Source: Compendium of Research and Development Result, Energy Commission of Nigeria 2011

REFERENCES

[1] Sambo A. S. "Strategic Developments in renewable Energy in Nigeria" International Association for Energy Economics, Third Quarter ,pp 15-19(2009),

[2] Sambo A. S. "Renewable Energy Policy and Regulation In Nigeria" a Paper Presented at the International Renewable Energy Conference, 7th – 9th October, Rockview Hotel, Abuja, Nigeria (2008)

[3] Sambo, A. S. and Bala, E. J. Musa, U. (1991) "Design, Construction and Performance of a parabolic concentrator cooker" Nigerian Journal of Solar Energy, Vol.10,pp.19- 25.

[4] Energy Information Adminstration (EIA) United States of America (2014) http://www.eia.gov/countries/country-data.cfm

[5] Udo N. Ekpo, Chuku A. Chuku and Ekpeno L. Effiong, (2011), University of Uyo "The Dynamics of Electricity Demand and Consumption in Nigeria: Application of the Bounds Testing Approach" Current Research Journal of Economic Theory, pp 43-52, ISSN: 2042-4841, August (2011)

[6] International Centre for Energy, Environment and Development (ICEED) 2013 www.**iceednigeria.org**

[7] Nigerian Energy Balance, 2011: A publication of the Energy Commission of Nigeria

[8] Pelemo, D. A., Fassi, M. K., Owolabi, S. A., and Shaniyi, J. A (2002) "Effective utilization of solar energy for cooking" Nigerian Journal of Engineering Management Vol. 3, No. 1, pp 13 – 18

[9] Petri, K. Solar (1995) "Cookers for use in Namibia; Faculty of Mechanical Engineering, Helsinki University of Technology, Namibia"

[10] Dahiru, D. Y.; Samaila, U.; and Habou, D. (2007) "Performance Evaluation of A concentrating Solar Cooker Under HeavyWeather Condition, Continental J. Engineering Sciences, Wilolud Online Journals Vol.1: pp36 – 44

[11] Bello, A. M. A., Makinde, V., and Sulu, H. T. (2010) "Performance Tests and Thermal Efficiency Evaluation of a Constructed Solar Box Cooker at a Guinea Savannah Station" (Ilorin, Nigeria), Journal of American Science; 6(2), pp 32-38 (ISSN: 1545-1003)

[12] Solar Cookers International (SCI), 25 Countries with the Greatest Potential Benefits from Solar Cookers, 28th October, 2014 www.solarcookingimagescountries.com