[1.]Mayowa Stephen DALERO, [2.]Nicholas Akhaze MUSA

A BRIEF OVERVIEW ON ASSESSMENTS OF WIND ENERGY RESOURCE POTENTIALS IN NIGERIA

[1-2.]Mechanical Engineering Department, Federal University of Technology, Minna, NIGERIA

Abstract: For the development of rural parts in the developing countries, there is a need for energy to meet the small-scale power requirement. Villages and small living groups in these countries are found in locations far from the grid and the connection of these villages to the grid is not economical. The use of diesel fuel is costly as it is to be transported from the towns that may be far from those consumers' areas. Hence the need to invest resources in the extensive research of renewable sources of energy, such as wind. Whilst developed countries around the world have expanded their production capacity in wind energy technology (WET), developing countries still grapple with serious energy needs. The objective of this paper is to capture an updated all-inclusive perspective on wind energy potential, its current application and development in Nigeria based on studies from various sources. The development of wind energy is in its early stage and its application is almost negligible presently. This paper has identified some of the major challenges that need to be addressed for the development of wind energy in Nigeria. To promote the development and application of wind energy, government and private participations are required.
Keywords: Nigeria, renewable energy, wind, wind power capacity, windmill

1. INTRODUCTION

Wind is generated when convection currents caused by the sun's rays create global air circulation across the Earth's surface. When solar radiation hits the Earth and its surface temperature is raised, heat is reflected on the surrounding air. Warm air rises while cool air comes down. The cycle keeps repeated: the cool air gets heated up as it reaches the Earth's surface, rises back to the atmosphere; the raised warm air also gets cooled down and drops down to the Earth. This cycle continues for as long as the solar system remains in existence.

Wind is caused by the differential heat between the land and the water. It is caused by the flow of air from high pressure to low pressure. The Earth rotates, so that the wind flows mostly around the high and low-pressure areas, but the air does not flow directly from high to low pressure, it is rather deflected to the right in the Northern Hemisphere; to the left in the Southern Hemisphere.

The effect of the Earth rotating underneath the wind is important for very large and long-lived pressure systems. But, in case of small, short-lived systems, such as in the cold outflow of a thunderstorm, the wind flows directly from high pressure to low pressure. Stronger winds are developed when the "pressure gradient" gets stronger as a result of the closeness of high and low-pressure areas.

Mountain-to-valley breezes are local winds also caused by heat variations. Wind speed increases as winds transverse mountain ridges and ridge tops; such places also have more frequent winds. While mountain wind is usually stronger at night, valley wind is stronger during the day. Wind generally seems to be calm in the morning and stronger in the afternoon. It has been discovered also that winds are stronger near the shores of big lakes and along coasts because of unobstructed paths and sea-to-land breezes. Wind speed also varies with height above the ground.

Nigeria, as a sub-Saharan nation, also has abundance of wind because of its topography, the mountainous regions of the North and the offshore areas in the south have been identified as good sites for wind harvest.

2. GLOBAL SCENARIO ON WIND POWER CAPACITY AND PRODUCTION

The continued growth and expansion of the wind power industry in the face of a global recession and financial crisis is a testament to the inherent attractiveness of the technology. Overall, the wind industry finished up 2016 in good shape, with solid prospects for 2017 and beyond (Fried, Qiao, Sawyer, & Shukla, 2017). Despite some uncertainties in the market due to the US election results in November 2016, the market enjoyed the longest period of policy stability ever in the critical US market (Global Wind energy Council, 2017).

In 2016 new investment in clean energy fell to USD 287.5bn (EUR 267.8bn), 18% lower than the record investment of USD 348.5bn (EUR 324.6bn) in 2015 (Fried, Qiao, Sawyer, & Shukla, 2016). According to Bloomberg new energy finance (BNEF), Asia-Pacific and China alone accounted for USD 135bn (EUR 125.7bn) or almost 47% of the total global investments in clean energy during 2016. The new global total at the end of 2016 was 486.8 GW, representing cumulative market growth of more than 12 percent. The 23.4 GW in new installations figure in China powered this growth in large part; overall, the global wind power industry installed 54.6 GW in 2016, Fig. 1. While still robust, the 2016 market did not meet the expectations they had set for it early last year, primarily because China 'only' installed 23 GW in 2016, but also due to smaller than expected markets in Brazil, Mexico, Canada, and Africa – South Africa in particular. However, most of these issues are cyclical and the markets were expected to recover in 2017 (Fried, 2018).

China, the largest overall market for wind power since 2009, retained the top spot in 2016. Installations in Asia once again led global markets, with Europe in the second spot, and North America closing the gap with Europe, in third place.

Europe installed 12.5 GW of gross additional wind capacity in 2016. This was 3% less than the new installations in 2015. With a total installed capacity of 153.7 GW, wind energy now overtakes coal as the second largest form of power generation capacity in Europe (Ivan Pineda & Tardieu, 2017).

According to Pineda and Tardieu (2017), 12.5 GW of new wind power capacity was installed and grid-connected in the EU during 2016, a decrease of 3% compared to 2015 annual installations. 10,923 MW were installed onshore, and 1,567 MW were installed offshore. Wind power installed more than any other form of power generation in Europe in 2016. Wind power accounted for 51% of total power capacity installations.

Wind power additions continued at a rapid pace in 2016, with 8,203 MW of new capacity added in the United States and $13.0 billion invested. Supported by favourable tax policy and other drivers, cumulative wind power capacity grew by 11%, bringing the total to 82,143 MW (Wiser et al., 2016). According to Wiser, *et* al, (2016), wind power represented the third-largest source of U.S. electric-generating capacity additions in 2016, behind solar and natural gas. Wind power constituted 27% of all capacity additions in 2016.

2017 was not a spectacular year in terms of global installations, overall, 52.5 GW (Figure 1) of new wind power was installed across the globe in 2017, a slight decrease on the 2016 market of 54.6 GW, bringing total installed capacity up to 539 GW, Figure 2.

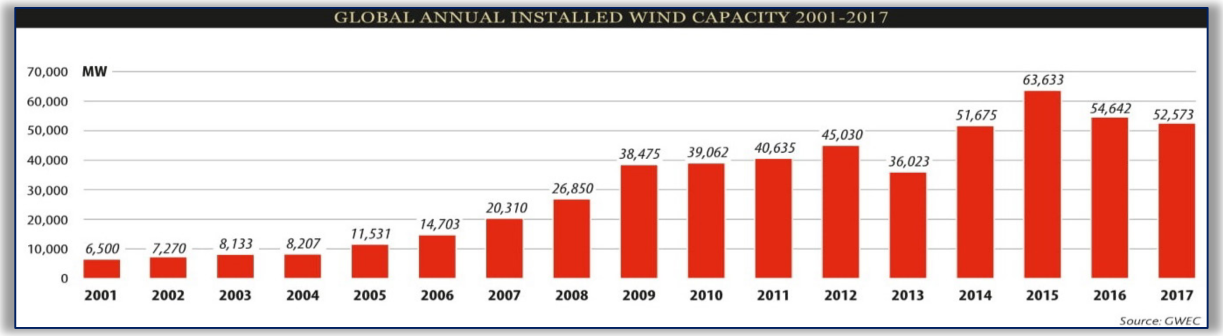

Figure 1: Global Annual Installed Wind Capacity during the period 2001 to 2017
Source: Global Wind Energy Council (2018)

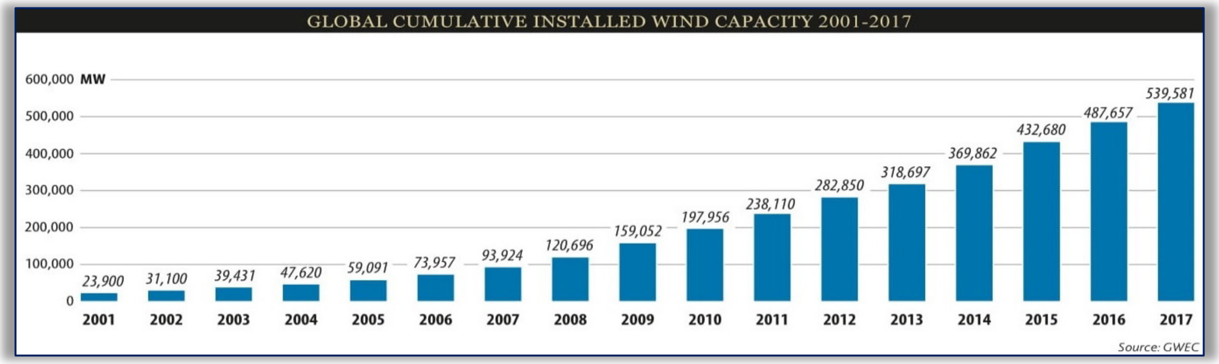

Figure 2: Global Cumulative Installed Wind Capacity during the period 2001 to 2017
Source: Global Wind Energy Council (2018)

China, the driver of global market growth for most of the last decade, installed 19.7 GW in 2017, more than twice as much as any other market, even though it represents a decrease of 2016's 23GW. India had a record year, breaking the 4GW barrier for the first time in 2017 (Fried, Qiao, & Sawyer, 2018). Europe installed 16.8 GW (15.6 GW in the EU) of gross additional wind power capacity in 2017, marking a record year on annual installations. With a total net installed capacity of 168.7 GW, wind energy remains the second largest form of power generation capacity in Europe, closely approaching gas installations (Pineda et al., 2018).

The U.S. wind industry installed 357 MW of wind capacity during the second quarter of 2017, bringing total installed capacity in the year to 2,357 MW (AWEA, 2017). As of the second quarter of 2017, AWEA (2017) stated that there were 14,004 MW under construction and 11,815 MW in advanced development, giving a combined 25,819 MW of wind capacity.

3. REVIEW OF ASSESSMENTS OF WIND ENERGY RESOURCE POTENTIAL IN NIGERIA

With respect to assessment of wind energy potential in Nigeria, several preliminary studies have been conducted during the last few years. Various initiatives by governments and researchers were carried out, and it was found that Nigeria is blessed with enormous opportunities for harnessing wind for various applications. Ajayi, (2008) stated that the far northern states, the mountainous regions and different places in the central and south-eastern states and also the offshore areas were identified as good areas for wind harvest. Adaramola et al., (2012) investigated the wind speed and energy potential in three selected locations in the southeastern part of Nigeria and showed that the annual mean wind speed at a height of 10m for Enugu, Owerri and Onitsha are 5.42, 3.36 and 3.59m/s, respectively, while the annual mean power densities are 96.98, 23.23 and 28.34 W/m2, respectively. The annual values of the wind speed carrying maximum energy for these locations are respectively 6.48, 4.33 and 3.90m/s.

Another investigation carried out at five different stations in the southwest showed that the wind speed measured at a height of 10 m ranged from 1.3 to 13.2m/s while the modal wind speed ranges from 3.0 to 5.9 m/s. 83.6% of the data were found to be greater than 3.0 m/s. The average monthly wind speed ranged from 2.72 to 7.72 m/s (Nze-Esiaga & Okogbue, 2014). Nze-Esiaga & Okogbue, (2014) further asserted that seasonally, average wind speeds ranged between 3.47 to 6.55 m/s for dry (October to March) and 3.83 to 6.94 m/s for wet (April to September). The annual mean power densities for the five cities of Abeokuta, Akure, Ibadan, Ikeja and Oshogbo are 65.09, 145.07, 176.96, 387.07 and 87.34W/m^2 respectively.

Okoro, et al., (2015) worked on the prospects of wind energy in Nigeria using 4 years of wind data from seven cities (Enugu, Jos, Ikeja, Abuja, Warri, Sokoto and Calabar). The annual wind speed at 10 m above the ground varied from 2.3 to 3.4 m/s for sites along the coastal areas and 3.0 – 3.9 m/s for high land areas and semi-arid regions. It was also reported that monthly average wind power was 50.1 W/m2 and Sokoto is capable of a power potential as high as 97 MWh/yr. Table 1 shows data of wind energy resources mapping for ten (10) sites in Nigeria collected from on ground measurement carried out between May 2004 and May 2005 by Lahmeyer International (Agbetuyi et al., 2012). It can be seen from the table that the sites are potential wind farm areas. This is because most wind turbines start generating electricity at wind speeds of around 3-4 meters per second (m/s) (The British Wind Energy Association, 2005).

Table 1. Showing ranking of the wind speed at various measurement stations

Site ID	Site Name	Measured mean wind speed at 30m height (m/s)
Sok 01	Sokoto/Badaga	5.4
Jos 01	Jos Airport/Kassa 5.2	5.2
Gem 01	Gembu/Mambila plateau	5.0
Pan 01	South part of Jos Plateau/Pankshin Hotel	5.0
Kan 01	Kano/ Funtua	4.9
Mai 01	Maiduguri/mainok	4.7
Lag 01	Lagos/ Lekki Beach	4.7
Enu 01	Enugu/Ninth mile corner	4.6
Gum 01	Gumel/Garki	4.1
Ibi 01	Ibi metrological station	3.6

Source: Lahmeyer International Consultants (2005) as stated by Agbetuyi et al., (2012)

Table 2. Showing wind energy density estimates at 25m height.

S/N	Station	Mean wind speed at 25m Level (m/s)	Monthly mean Wind Energy (kWh)	Annual Wind Energy (kWh)	Annual Wind Energy from a Wind Energy Turbine (kWh)	
					10m Blade Diameter	25m Blade Diameter
1	Benin City	2.135	2.32	27.86	2,187.81	13,673.78
2	Calabar	1.702	1.12	13.42	1,053.69	6,587.53
3	Enugu	3.372	7.83	93.91	7,375.75	46,097.96
4	Ibadan	2.620	4.15	49.78	3,,909.79	24,436.19
5	Ilorin	2.078	1.23	14.73	1,157.06	7,230.57
6	Jos	4.430	16.05	192.64	15,129.60	94,559.98
7	Kaduna	3.605	9.91	188.88	9,36.81	58,355.08
8	Kano	3.516	8.57	102.86	8,078.61	50,491.28
9	Lagos(Ikeja)	2.671	4.36	52.32	4,099.78	25,682.52
10	Lokoja	2.235	2.60	31.21	4,451.23	15,320.17
11	Maiduguri	3.486	8.42	101.01	7,933.61	49,583.17
12	Minna	1.589	1.05	12.60	989.60	6,185.01
13	Makurdi	2.689	4.44	53.27	4,183.51	26,148.85
14	Nguru	4.259	14.48	173.74	13,645.19	85,284.42
15	Oshogbo	1.625	1.07	12.81	1,006.60	6,288.09
16	P.H.	2.640	4.17	49.98	3,925.48	24,533.88
17	Potiskum	3.636	9.44	113.25	8,894.35	55,591.46
18	Sokoto	4.476	16.47	197.68	15,525.75	97,035.94
19	Warri	2.027	2.02	24.20	1,.900.66	11,879.15
20	Yelwa	3.360	7.76	93.13	7,314.88	45,714.59
21	Yola	1.824	1.45	17.34	1,361.88	8,511.75
22	Zaria	2.891	5.32	63.88	5,017.26	31,357.02
	Total		**134.23**	**1,680.5**	**120,078.9**	**790,548.39**

Source: www.renewablenigeria.org / Agbetuyi et al., (2012)

Table 2 shows the wind energy density estimate at 25m height. It can also be seen from the table that Sokoto and Jos have the annual wind energy from wind turbine (kWh) of 97,035.94 and 94,559.98 respectively (Mutlu, 2010). Based on wind speeds, it was recommended that these potential wind farm areas should be connected to the grid at distribution level. Generally, wind speed in the southern and northern Nigeria ranges from 1.4 to 3.0 m/s and 4.0 to 5.12 m/s respectively.

4. CURRENT WIND POWER PROJECTS IN NIGERIA

Wind power is one of the untapped renewable energy resources in Nigeria despite its abundance in different parts of the country. Although, windmills were used in Nigeria in the mid-1960s, in Sokoto and Garo over 20 homes and schools had used them to pump water, but all have been abandoned (Saddik et al., 2012). From the review, only four existing projects are found in the whole country as shown in Table 3.

Table 3. Showing the existing Wind Power Projects in Nigeria

S/N	Location	Year	Capacity	Status
1	Sayya, Gidan-Gada, Sokoto	1988	5kW/h	Working
2	Dan-Jawa Village, Sokoto	N.A	0.75kW/h	Working
3	Katsina, Katsina State	2012	10kW/h	Under Construction
4	Energy Research Center, Benin	N.A	1kW/h	Working

Key: N.A: Not available. Source: Saddik et al., (2012)

Katsina Wind Project is a 10MW wind electricity project from the Katsina Wind Farm in Lambar Rimi community, it was to be commissioned in March 2018 (Sunday & Shimnon, 2018). The project started as a pilot scheme in 2010 and has taken eight years, apparently six years behind schedule, yet uncompleted. The project consists of 37 units of wind turbine, each with a generating capacity of 275kW and a height of 55metres. Only 15 units are fully installed and connected to grid, the remaining 17 units are in various stages of completion, they are expected to be commissioned at the end of the year. If this timeline is achieved, the plant will become the second renewable energy source injected into the national grid after the 1.2MW on-grid solar plant at the Lower Usuma Dam in the Federal Capital Territory (Sunday & Shimnon, 2018).

5. CHALLENGES AND RECOMMENDATIONS OF WIND ENERGY DEVELOPMENT IN NIGERIA

Over the past few decades, various wind generator projects have been neglected in the country due to increasing popularity and low price of crude oil. However, in recent times, there have been were several attempts to restructure those windmills due to high price of Petroleum products.

Some of factors that led to the failure in the development of wind WET are:

Reluctance of government to encourage wind technologies. The country lacks robust policy framework of legal and regulatory mechanisms that can encourage the development of wind energy technology (WET), attract foreign and indigenous investors and set standards for wind farm creation and management. Considering that potential investors will always look out for governments which demonstrate commitment to WET development and what opportunities have been put in place to enhance marketability within the country before investing their resources. It is recommended that the government put in place policy documents which will incorporate the following: favourable regulated feed-in tariff for electricity from wind and other renewables, subsidies and remuneration rates for wind energy investors, right to connect renewable generation to the national electricity grid, legal obligations for electric utilities to purchase wind energy and promotion of private individuals, farmers and cooperatives to own wind turbine installations.

Lack of proper assessment of wind energy potentials. Until recently, the research on WET was so insignificant. Available data have not also been adequately employed to develop physical models that would translate the huge resources of wind to power. With this, prospective investors may lack reliable and useful information about overall picture of Nigeria's wind energy potential when seeking investment opportunities since there is a lack of comprehensive assessments on the potential of wind resource in Nigeria due to inadequate wind measurements. These issues are complicated by the lack of adequate funding of researches. It is recommended that, researches on wind resource assessment for the nation to cover onshore and offshore areas and development of low cost materials for wind turbines and other renewable energy technology applications should begin. Government and private investors should also fund researches.

Inadequate human capacity. The country lacks skilled personnel who can carry out complete wind power projects: conducting wind resources assessments, preparing investment reports, etc., basic technical and maintenance services, operation and management after installation of wind energy conversion systems (WECS). There needs to be a more elaborate awareness on the potentials of WET to encourage citizens to take up career in the field. Professionals should also engage in trainings and retraining to improve their skills and keep abreast of innovation in the industry. Wind energy resources should be included in the renewable energy resources development programme of Nigeria. The Nation's energy centres should be encouraged through funding to stimulate research efforts on WECS and manufacture.

Lack of feasibility studies on wind energy utilization. The Federal Government is targeting the generation of 30 per cent of Nigeria's electricity from renewable energy sources by year 2030 when the national grid would have hit 30,000MW. But, at present only 4.5MW of wind energy and 1.2MW of solar are connected to the grid (Sunday & Shimnon, 2018). With the present electric energy generation capacity, this target appears unrealistic. Government should come up with more realistic plan to solve the nation's energy deficit.

Inadequate wind data base to be used as the bases for designing and building different prototypes that need be considered in reducing locally manufactured windmills. There is no available offshore wind mapping. The government can build a station anemometer (wind measuring station) to collect statistics and analyse comprehensive wind data which Nigerian Meteorological Agency (NIMET) should monitor. NIMET should also be better funded to carry out sufficient mapping with adequate record keeping; all data should be available on their website and in reports which should be uploaded online.

6. CONCLUSIONS

The study was focused on the potentials for WET development in Nigeria. From the literatures reviewed, it was discovered that mean wind speed regimes in the north and south lie between 4.0–7.5m/s and 3.0–3.5m/s respectively at 10m above the ground. With these wind regimes, it can be deduced that there is an extensive prospect within the country for power generation through wind. However, for this potential to be effectively harnessed, challenges hindering WET advancement must be tackled. Some of the challenges are reluctance of government to encourage wind technologies, lack of adequate funding, lack of proper assessment of wind energy potentials, inadequate human capacity and lack of feasibility studies on wind energy.

The following limitations are associated with wind power development and solutions:

- In terms of initial capital cost, wind power is expensive to implement. Government must be prepared to invest hugely in the development.
- Good wind sites are often located in remote locations, far from cities where the electricity is needed. Transmission lines should be built to bring the electricity from the wind farm to the city.

Government should ensure level playing fields for the independent power producers and other genuine investors in the power business Government should also integrate WET into rural development plan and provide needed funds for sustainable research and development.

References

[1] Agbetuyi, A. F., Akinbulire, T. ., Abdulkareem, A., & Awosope, C. O. Wind Energy Potential in Nigeria. International Electrical Engineering Journal, 3(1), 595–601. 2012.

[2] Ajayi, O. O. Assessment of utilization of wind energy resources in Nigeria. Energy Policy, 37, 750–753. 2008. https://doi.org/10.1016/j.enpol.2008.10.020

[3] Argaw, N., Foster, R., & Ellis, A. Renewable Energy for Water Pumping Applications in Rural Areas. Las Cruces, New Mexico: National Renewable Energy Laboratory. 2003.

[4] AWEA. U.S. Wind Industry 2nd Quarter 2017 Market Report. American Wind Energy Association. 2017.

[5] Fried, L. Global Wind Statistics 2017. 1040 Brussels, Belgium: Global Wind Energy Council. 2018.

[6] Fried, L., Qiao, L., & Sawyer, S. GLOBAL WIND REPORT-Annual Market Update 2017. 1040 Brussels, Belgium: Global Wind Energy Council. 2018.

[7] Fried, L., Qiao, L., Sawyer, S., & Shukla, S. Global Wind Report 2015 | Gwec. Wind energy technology. 1040 Brussels, Belgium: Global Wind energy Council. 2016.

[8] Fried, L., Qiao, L., Sawyer, S., & Shukla, S. Global Wind Report 2016. Wind energy technology. 1040 Brussels, Belgium: Global Wind Energy Council. 2017.

[9] Global Wind energy Council. Global Wind Power Update Revision 2017. Tokyo: Global Wind energy Council. 2017.

[10] Lahmeyer (International) Consultants. Report on Nigeria wind power mapping projects, Federal Ministry of Science and Technology. 2005.

[11] Mutlu, O. S. Evaluating the impacts of wind farms on power system operation. Journal of Naval Science and Engineering, 6(2), 166–185. 2010.

[12] Nze-Esiaga, N., & Okogbue, E. C. Assessment of Wind Energy Potential as a Power Generation Source in Five Locations of South Western Nigeria. Journal of Power and Energy Engineering, 2, 1–13. 2014. https://doi.org/10.4236/jpee.2014.25001

[13] Okoro, O. I., Chikuni, E., & Govender, P. Prospects of Wind Energy in Nigeria. ResearchGate, (April). 2007.

[14] Oyedepo, S. O., Adaramola, M. S., & Paul, S. S. Analysis of wind speed data and wind energy potential in three selected locations in south-east Nigeria. International Journal of Energy and Environmental Engineering, 3(7), 1–11. 2012.

[15] Pineda, I., & Tardieu, P. Wind in power 2016 European Statistics. Wind Europe. 1040 Brussels, Belgium. 2017. https://doi.org/10.1007/s10854-007-9177-9

[16] Pineda, I., Tardieu, P., & Miró, L. Wind in power 2017- Combined Onshore and Offshore Wind Energy Statistics. 1040 Brussels, Belgium: Wind Europe. 2018.
[17] Saddik, A. I., Tijjani, N. 'u, & Alhassan, B. Wind Power: An Untapped Renewable Energy Resource in Nigeria. International Journal of Scientific & Engineering Research, 3(9). 2012.
[18] Sunday, S. E., & Shimnon, P. C. Grid to get 10mw from Katsina wind farm 8 years after. Daily Trust Newspaper, Nigeria. 2018, March 13.
[19] The British Wind Energy Association. Wind Turbine Technology. Berners Road, London N1 0PW: BWEA. 2005.
[20] Wiser, R., Bolinger, M., Barbose, G., Darghouth, N., Hoen, B., Mills, A., Tegen, S. 2016 Wind Technologies Market Report. U.S. Department of Energy. Oak Ridge, TN 37831-0062: U.S. Department of Energy. 2016.

ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665