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DYNAMICS OF ACCESS TO ELECTRICITY AND EXPECTED DEMAND IN ELECTRICITY UNDER FULL ELECTRIFICATION IN SENEGAL

***Abstract.** The research was devoted to the analysis of the dynamics of access to electricity to evaluate the expected annual demand in electricity under full electrification in Senegal. During the last decade, the moderately positive dynamics of the population's access to electricity were observed but the problem of access remains unresolved for most of the rural and remote regions. The expected annual demand in electricity for populations, which today stay without access to electricity, was evaluated by two methods. In the first method, the statistical data of average annual electricity consumption per capita were used. The second method was grounded on theoretically estimated annual electricity consumption for a household with minimal living standards. The most trustable value of expected annual demand was obtained by the first method. In the case on-grid connection the expected annual demand can be partially covered by a reduction of losses in transmission and distribution networks. In other cases, for populations in rural and remote areas, demand can be satisfied by renewable energy through connection consumers to mini-grids or standalone systems.*

***Key words:** electrification, access to electricity, dynamics of electricity access, dynamic of population without access to electricity, demand in electricity.*

Introduction

The economic growth observed in recent years in developing countries of Sub-Saharan Africa increased the electricity demand. In Senegal, economic growth accelerated since 2014 and in 2018 reached 6.7%. For further sustainable economy and social development, covering rising demand in electricity, becomes a crucial issue for this country. Senegal has a significant potential for generating green electricity with renewable energy sources like solar, wind, and hydro. The Senegal electricity market design can also be considered as sufficient background for involving renewable generation in the market environment. Nevertheless, the National Electricity Company of Senegal (SENELEC) is granted the monopoly of wholesale buying and transport, there exist many opportunities for the private sector in production, distribution, and sale of electricity. The development of renewable energy is supported in Senegal by government policy and has a necessary regulatory framework. Among the main national decrees for implementation of the Renewable Energy Law are the Act No. 2010-21 on the framework law on renewable energy and the Decree No. 2011-2013 on conditions of electricity purchase and pricing produced by power plants from renewable energy sources, and the conditions of their connection to the grid [1-5].

Thus, by the combination of existing capacities of conventional power plants with potentials of renewable generation the problem with growing requests in electricity would be solved. However, among the main obstacles regarding this problem is limited access to electricity. The necessity of expanding access to electricity is deepened by the fact that in the next 10 years Senegal's population will grow up by 6 million. The country's integrated plan on improving access to electricity requires significant investment and changes in the electricity sector. The least costly option for most of the population, which today does not have access to electricity, is to expand access to the national electricity networks. For the population living in small communities in rural or remote areas, decentralized solutions with on-grid and off-grid power systems are foreseen [6-8].

But for practical measures on implementation of the integrated plan in Senegal the dynamics of access to electricity for the total, the urban and the rural populations must be studied. It is also needed

to evaluate the expected electricity demand under full electrification of the urban, rural, and remote areas.

Goal and tasks of research

The goal of the research was to conduct the analysis of the dynamics of access to electricity in Senegal to evaluate the expected electricity demand under the full electrification of the country.

To achieve the goal the next tasks were defined.

1. To analyze dynamics of access to electricity in Senegal.
2. To estimate total, urban and rural populations without access to electricity.
3. To evaluate the expected annual electricity demand under full electrification of areas without access to electricity.

Results and discussion

Analysis of dynamics of access to electricity in Senegal. To study the dynamics of access to electricity in Senegal the database provided by [9] was used, where the last available data on access to electricity were given for 2018. Dynamics of access to electricity in Senegal were studied for the last two decades. In general, in 2009-2018 the moderately positive dynamics of access to electricity were observed in the country. However, expanding electricity access has remained a challenging issue. The results of the investigation are given in Fig. 1.

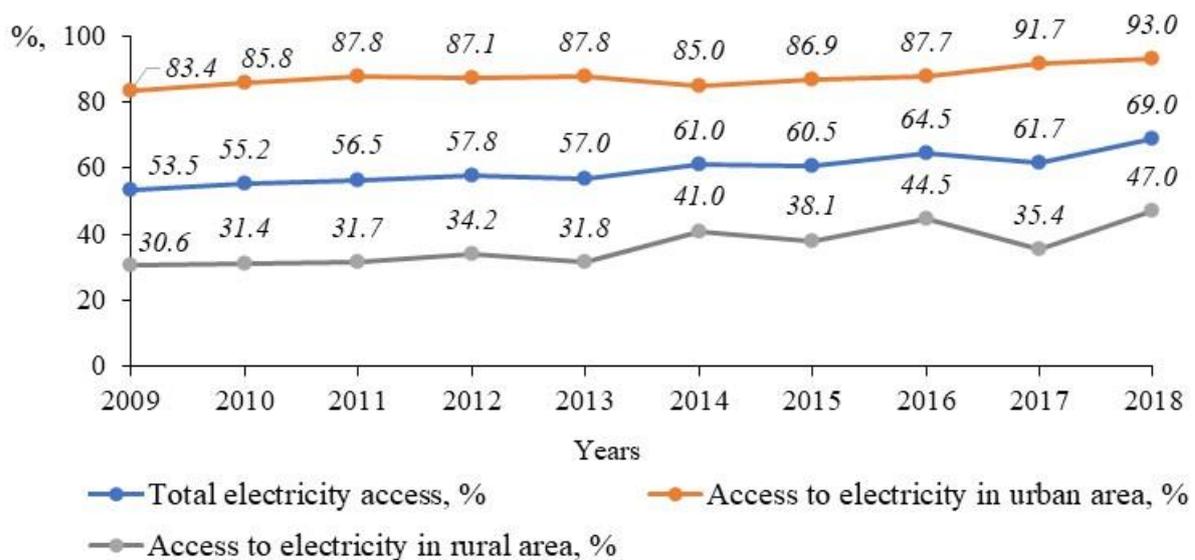


Figure 1 – Dynamics of access to electricity in Senegal, 2009-2018

As shown in Figure 1, during the decade the total access to electricity was increased by 15.5 %: the access to electricity in the urban areas was rose by 9.6 %, and in the rural areas - by 16.4 %. As a result, in 2018 the access in the urban areas reached 93 % and the level of total access rose to 69 %. But the problems of access to the infrastructure of electricity networks and service remains unresolved for most of the rural and remote regions, where the level of population access was only 47 %.

Estimation of total, urban and rural populations without access to electricity in Senegal.

There also were investigated the changes occurred in the number of the total population as well as the inhabitants in urban and rural areas without access to electricity. To provide this analysis the changes in the share of urban and total inhabitation in the total population of Senegal were studied for 2008-2018. To explore the changes in the pattern of the population a statistical database of the National Agency for Statistics and Demography [10] was used. The dynamics of changes in the number of populations without access to electricity are shown in Fig. 2.

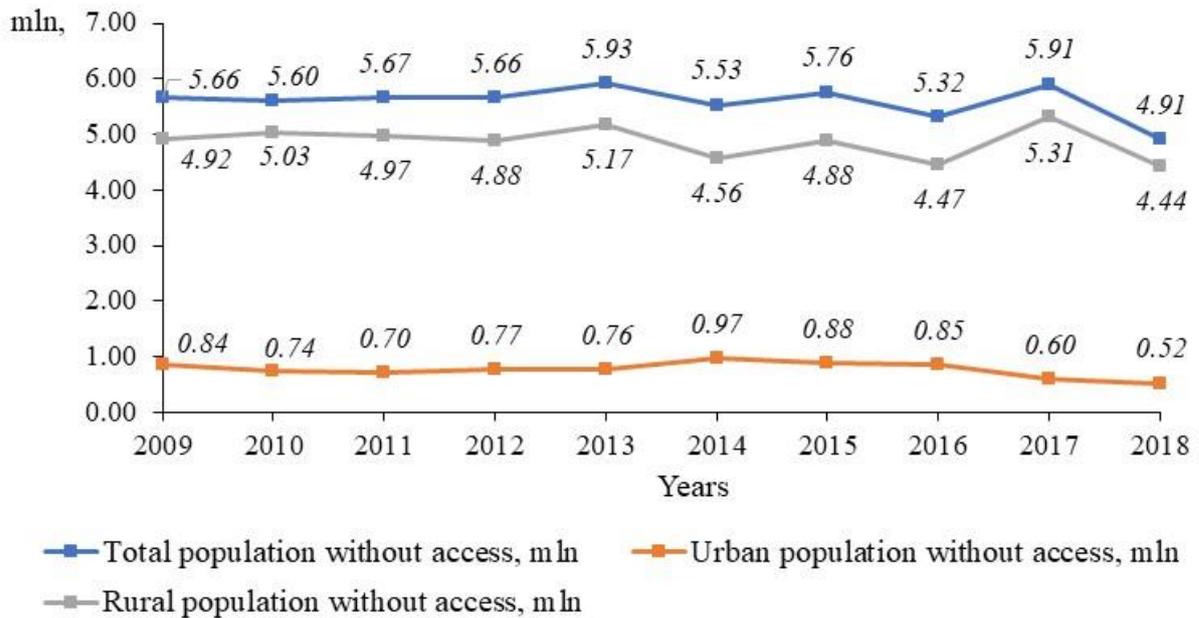


Figure 2 – Population without access to electricity in Senegal, 2009-2018

At the end of 2018, there were 4.91 million from 15.85 million total population of Senegal without access to electricity. Mostly because the access has remained on insufficient level for rural inhabitation. Although during a decade some moderate positive changes were observed. Compared to 2009, in 2018 the total population without access to electricity was decreased from 5.66 to 4.91 million; the urban population - from 0.84 to 0.52 million, and the rural population – from 4.92 to 4.44 million.

Evaluation expected electricity demand under full electrification in Senegal. The next task of the research was related to the evaluation of projected annual demand in electricity under full electrification of areas, which are today without access to electricity. There were a few different approaches used for solving this problem.

By the first method, the expected demand was estimated by multiplying the annual electricity consumption per capita and the number of populations in Senegal without access to electricity. To conduct the estimations the statistical data of average annual electricity consumption per capita were explored. According to [3], in 2014 in Africa it was equal to 483 kWh per person. This value was not found satisfactory enough for evaluation as it does not consider differences between developing countries in Africa. For this reason, the open statistical database of CIA was used [11]. According to this database, in 2016 the average annual electricity consumption per capita in Senegal was equal to 209 kWh per person. This value was taken for further calculation.

By the second method, the expected demand was estimated by multiplication of the annual electricity consumption per the household, necessary to satisfy the minimum living standards, and the number of households without access to electricity. This approach was grounded on the IEA methodology about the amount of annual electricity consumption per household [8]. By the IEA assumptions, the minimum demand for electricity should ensure the operation of the most necessary and typical home electrical appliances. The assumptions made by IEA the annual energy consumption of an average single household must cover needs the operation of one refrigerator, four lightbulbs operating five hours per day, a fan working 6 hours per day, a TV working 4 hours per day, and a mobile phone charger. For these minimum living standards, the energy consumption of a single household with standard electrical appliances was equal to 1250 kWh per year, and with efficient electrical appliances - 420 kWh per year.

In the frame of the second method, the number of households without access to electricity in

Senegal was defined by the division of the number of populations without access on the average household size (N). Information about the average household size in Senegal was varied between the sources. According to the United Nations comparative analysis of data for 2017 [12], the highest proportion of households as the number of members was observed in Senegal for $N = 8.3$. But by the World Bank Group evaluation [6], in 2018 the average household size in Senegal was even higher: $N = 9.9$. As these sources are the official ones, both values were used for calculations.

The evaluation of expected annual electricity demand under full electrification of areas that today are without access to electricity was defined by both methods. The results are given in Table 1. By the first method the Case 1 was calculated, and the Cases 2 and 3 - by the second method. For the Case 1 the expected annual demand in electricity was calculated for average annual electricity consumption per capita 209 kWh; for the Case 2 - for average annual electricity consumption per household with standard electrical appliances 1250 kWh, and for the Case 3 - for average annual electricity consumption per household with efficient electrical appliances 420 kWh. Cases 2 and 3 were also calculated for various values of N .

Table 1 - Expected annual demand in electricity under full electrification in Senegal

Population without access to electricity, million		Expected annual electricity demand, billion kWh				
		Case 1	Case 2 (a): $N = 8.3$	Case 2 (b): $N = 9.9$	Case 3 (a): $N = 8.3$	Case 3 (b): $N = 9.9$
Total	4.91	1.03	0.74	0.62	0.25	0.21
Urban	0.52	0.11	0.08	0.07	0.03	0.02
Rural	4.44	0.93	0.67	0.56	0.22	0.19

The expected annual demand for the Case 1, obtained with real statistical data on average annual electricity consumption per capita, was higher than results in Cases 2(a), 2(b), 3(a) and 3(b), obtained using the annual electricity consumption, which theoretically was estimated by IEA for a household with minimal living standards. The difference between results for Cases 1 and 2 (a) was 1.4 times and for Cases 1 and 3 (b) - almost 5 times. The maximum expected level of electricity demand under full electrification was obtained by the first method and was about one billion kWh per year. The minimum expected level of electricity demand was obtained by the second method and was about 200 million kWh per year. The demand can be covered in different ways. As stated by [12] in 2016 the annual electricity production in Senegal reached 4.17 billion kWh, but the annual electricity consumption was 3.50 billion kWh per year. The difference of 0.87 billion kWh was caused by electricity losses in transmission and distribution networks. In the case on-grid connection the part of expected annual demand can be covered due to the reduction of losses in networks. The remaining demand can be covered by renewable energy in the case of mini-grids or standalone systems.

Conclusions

The moderately positive dynamics of access to electricity were observed in Senegal during 2009-2018. The total access rose to 69 %. Though the level of access for rural and remote regions was increased by 16.4 % it reached only 47 %, thus for these regions, the problem of access has stayed unresolved. The positive changes in access to electricity were also observed for the total population and for the population in urban and rural areas. In 2018 the total population without access to electricity was decreased. But from 15.85 million of the country's population, there were 4.91 million without access to electricity. The expected annual demand in electricity under the full electrification was evaluated by two methods. From the practical point of view, most trustable values of expected annual demand were obtained using the real statistical value on average annual electricity consumption per capita. Under full electrification, the expected annual demand in electricity was evaluated approximately one billion kWh per year. There were also given recommendations about

the ways to cover the expected electricity demand. In case on-grid connection it can be partially covered by a reduction of losses in transmission and distribution networks. For other populations in rural and remote areas, it can be satisfied mostly by renewable energy through connection to mini-grids or standalone systems.

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