УДК 621.311.243 https://doi.org/10.36296/1819-8058.2024.2(77)21-31

STEADY ENERGY DEVELOPMENT IN ALGERIA: AN OVERVIEW

Received Apr. 02, 2024; accepted Jun. 21, 2024
Available online Jul. 01, 2024

Ostapchuk O.[1, 2], Tires I.[1]

Author for correspondence: Ostapchuk Oleksandr,
e-mail: o.ostapchuk@kpi.ua

[1] Dr. of Tech. Sciences, professor.
https://orcid.org/0000-0003-3397-2423

[2] Graduate Student
https://orcid.org/0000-0003-2604-141X

[1] National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine

[2] Institute of Renewable Energy of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

Under the goals of the Paris Agreement aimed at addressing climate change, the construction of sustainable energy systems is emphasized. Using the example of the Republic of Algeria, this article ana-lyzes the stated objective of achieving the necessary potential for the development of systems with re-newable energy sources, the current state, and the possibilities of the energy system, as well as the dy-namics of distributed generation facilities. Factors influencing the development of generation systems are identified, including the country's geographical location, availability of specific natural resources, and the development of energy infrastructure.
A path to achieving climate neutrality is proposed through the exploration of internal reserves, such as enhancing the energy efficiency of the most widespread consumers of electricity. The research focus-es on the factors influencing the development of generation systems based on renewable energy sources. The methods employed include analysis and synthesis of the existing situation in the field of electricity supply system development.
The study aims to identify factors for achieving the goals of the energy transition in the Republic of Algeria. The results of the study include determining pathways for the development of energy systems to construct sustainable energy.

Keywords: *renewable energy sources, sustainable development, electric power engineering, greenhouse gases, solar and wind energy, distribution networks, energy systems, photovoltaic stations.*

СТАЛИЙ РОЗВИТОК ЕНЕРГЕТИКИ АЛЖИРУ: ОГЛЯД

Отримано 02 квіт. 2024 р.; рекомендовано до публікації 21 чер. 2024 р.
Доступно онлайн 01 лип. 2024 р.

Остапчук О. В.[1,2], Тірес І.[1]

Автор для кореспонденції: Остапчук Олександр,
e-mail: o.ostapchuk@kpi.ua

[1] д-р техн. наук, проф.
https://orcid.org/0000-0003-3397-2423

[2] аспірант
https://orcid.org/0000-0003-2604-141X

[1] Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», м. Київ, Україна

[2] Інститут відновлюваної енергетики НАН України, м. Київ, Україна

Відповідно до завдань Паризької угоди, які направлені на вирішення проблеми зміни клімату є побудова систем сталої енергетики. На прикладі Республіки Алжир аналізується заявлена мета щодо досягнення необхідного потенціалу розвитку систем з відновлюваними джерелами енергії, поточний стан та можливості енергетичної системи і динаміка розвитку об’єктів розподіле-ної генерації. Встановлено фактори впливу на розвиток систем генерації, до яких належать географічне положення країни, забезпечення природними ресурсами окремого виду та розвиток енергетичної інфраструктури. Запропоновано шлях досягнення кліматичної нейтральності через пошук внутрішніх резервів шляхом підвищення енергетичної ефективності найбільш роз-повсюджених споживачів електричної енергії. Об’єктом дослідження є фактори впливу на роз-виток систем генерації на основі відновлюваних джерел енергії. Методи дослідження – аналіз та синтез існуючої ситуації у сфері розвитку систем забезпечення електричною енергією. Метою роботи є визначення факторів щодо досягнення цілей *енергетичного переходу республіки Ал-жир. Результатом виконаної роботи є визначення шляхів розвитку енергосистем для побудови сталої енергетики.*

Ключові слова: *відновлювані джерела енергії, сталий розвиток, електроенергетика, парникові гази, сонячна енергетика, вітроенеретика, розподільні мережі, енергосистема, фотоелектрич-ні станції.*

Abbreviations:

GG – greenhouse gases

RES – renewable energy sources

PV – solar energy

WPP – wind power plant

CCP – combined-cycle plant

PV – solar power plant

TPP – thermal power plant

GTPP – gas thermal power plant

HPP – hydropower plant

PP – power plant

Introduction. One of the global challenges today is the noticeable climate change on the planet, which led to the adoption of the Paris Agreement on climate change, which recognizes the impact of climate change on the further state of human and environmental development. The document provides for ensuring the widest possible cooperation of all signatory countries in order to effectively respond to the global problem of GG emissions. The main condition of the Agreement is to reduce the rate of increase in average temperature below 2°C compared to pre-industrial levels and to make maximum efforts to limit temperature rise to 1.5 °C [2]. An unofficial decision of the same Agreement is to provide financial support of $100 billion to developing countries. This measure is primarily aimed at increasing the interest of these countries, changing their energy policies, creating new jobs, etc. One example of work towards an energy transition and the challenges it faces is the experience of the People's Democratic Republic of Algeria (Algeria), which in 2011 chose the path of building sustainable energy. The country's leadership set an ambitious goal – to reduce greenhouse gas emissions by 7% by 2030 through its own capabilities, with further expansion to 22% with external support. The result of this activity was the creation of the Ministry of Environment and Renewable Energy Sources (2017) and the establishment of a plan to achieve 22 GW of installed capacity of renewable energy facilities by 2030 [3]. Under the updated Renewable Energy Development Program adopted in 2020, the share of RES is planned to increase to 16 GW, including 15 GW connected to the grid and 1 GW off-grid (by 2035), with an interim target of 4 GW connected to the grid and 500 MW off-grid by the end of 2024 [4-5].

Problem Statement. Based on the text of the above programs, the increase in the share of RES will be achieved through solar photovoltaic and thermal energy, cogeneration, biomass, geothermal and wind energy, and involves the development of a long-term strategy for certain economy sectors to determine their prospects. Particular attention should be addressed to ensuring the sustainability of the system, i.e., the possibility of its harmonious development without impact on the environment. The prioritization of development is influenced by a significant number of various factors, such as: the structure of electricity consumers, the geographical location of the country, the energy potential of resources, etc. The aim of the study is to determine the possibilities for achieving the goals of the energy transition of the Republic of Algeria and the factors that will contribute to the implementation of the approved program or, conversely, hinder its development.

Methods. The article used comparative, expert and statistical analysis of data presented in scientific papers, materials of international analytical agencies and organizations dedicated to studying the country's energy potential, problems of energy systems development, etc.; synthesis of the results was obtained.

Main content. The Republic of Algeria is located in North Africa between 35° and 38° north latitude and 8° and 12° east longitude, has a total area of 2.381 million km², and is the largest country on the continent and ranks 10th in the world by land area [6] (Fig. 1). The entire territory is divided into three geographical zones: the north (the Tell region), the high plateaus, and the Sahara Desert. About 87% of the area is under the Sahara Desert, which explains why 90% of the population is concentrated in the northern part of the country.

As for the energy potential, this country has significant reserves of fossil fuels (oil and natural gas) and has been a member of OPEC+ since its origination [7]. This circumstance significantly affects the structure of the country's energy sector. According to the latest data published by the Ministry of Energy and Coal at the end of 2017, the country's energy sector consisted of approximately 97% from energy obtained from fossil fuels, particularly natural gas [8] (Fig. 2).

The largest electricity production operator is the state-owned company Sonelgaz-Electricity Production, which provides maintenance and operation of its PPs, with an installed capacity of over 18 GW, with the prospect of increasing to 23 GW (planned for 2030). The company uses four main types of generation with different capacities: steam and gas turbines, hydraulic plants, and combined-cycle facilities. As of 2022, the company has 59 power plants on its balance sheet, namely [9]:

– 5 thermal power plants (TPPs), 14 generators;
– 30 gas-fired thermal power plants (GTPPs), 83 generators;
– 14 mobile gas turbine plants (GTPs), 50 generators;
– 2 combined-cycle power plants (14 generators);
– 4 hydropower plants (HPPs).

a) b)

Fig. 1. Geographical location on the continent (a) and topographic map of Algeria (b)

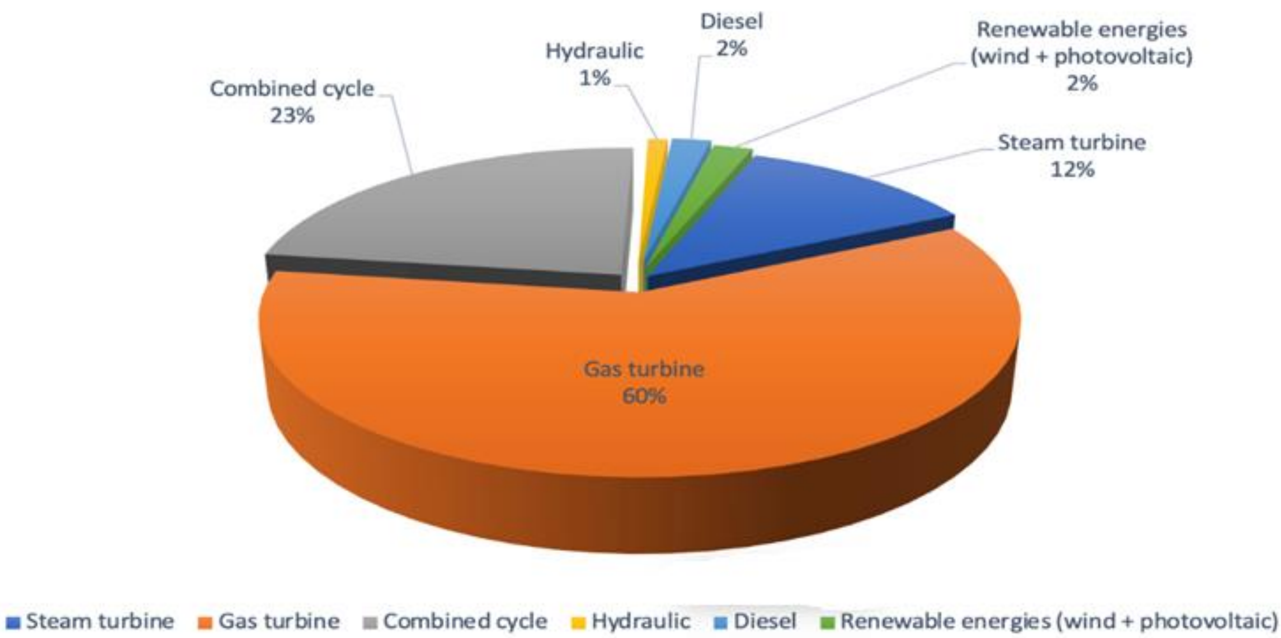


Fig. 2. Share of electricity production by types in 2017

In addition to these facilities, the company operates the Hassi Berkine gas turbines (4x110 MW). As a result, in the structure of installed capacity by type of generation, the share of gas turbines (55%), combined-cycle plants (29%), and steam turbines (11%) prevails. The remaining 5% is distributed among other production facilities (diesel plants, hydraulic power plants, and renewable energy systems). The dynamics of the company's energy sources development is shown in Table 1.

Table 1. Rate of change 2018/2019 %

PRODUCTION	**Steam turbine**	849,5 GWh	+7,0%
	Gas turbine	3 673,2 GWh	-11,2%
	Combined cycle	3 866,4 GWh	+32,9%
	Hydraulic	17,1 GWh	-
	Diesel	83,7 GWh	-19,4%
	Photovoltaic	52,4 GWh	+1,3%
	Wind	0,2 GWh	-34,2%

By reviewing the company's strategic plans, conclusion can be made that the goal is to build and launch an additional 4 GW of combined-cycle capacity by the end of 2021 was only partially realized through the launch of the Bellara combined-cycle plant (with a capacity of 1.4 GW) and the plant in Naama (with a capacity of 1.2 GW).

Analyzing the location map of the specified objects on the territory of the country [9], it is possible to conclude that the vast majority of generating capacities of various types (gas, hydraulic, wind, etc.) are concentrated in the north of the country, other regions have mainly diesel power plants at their disposal, which have the most negative impact on the environment.

The map showing the location of these facilities on the territory is given in Fig. 3 [9]. Based on statistical data provided by the EIA agency, from 2011 to 2020 the total installed capacity of the energy system (Fig. 3a) and the level of electricity consumption in Algeria (Fig. 3b) almost doubled [10].

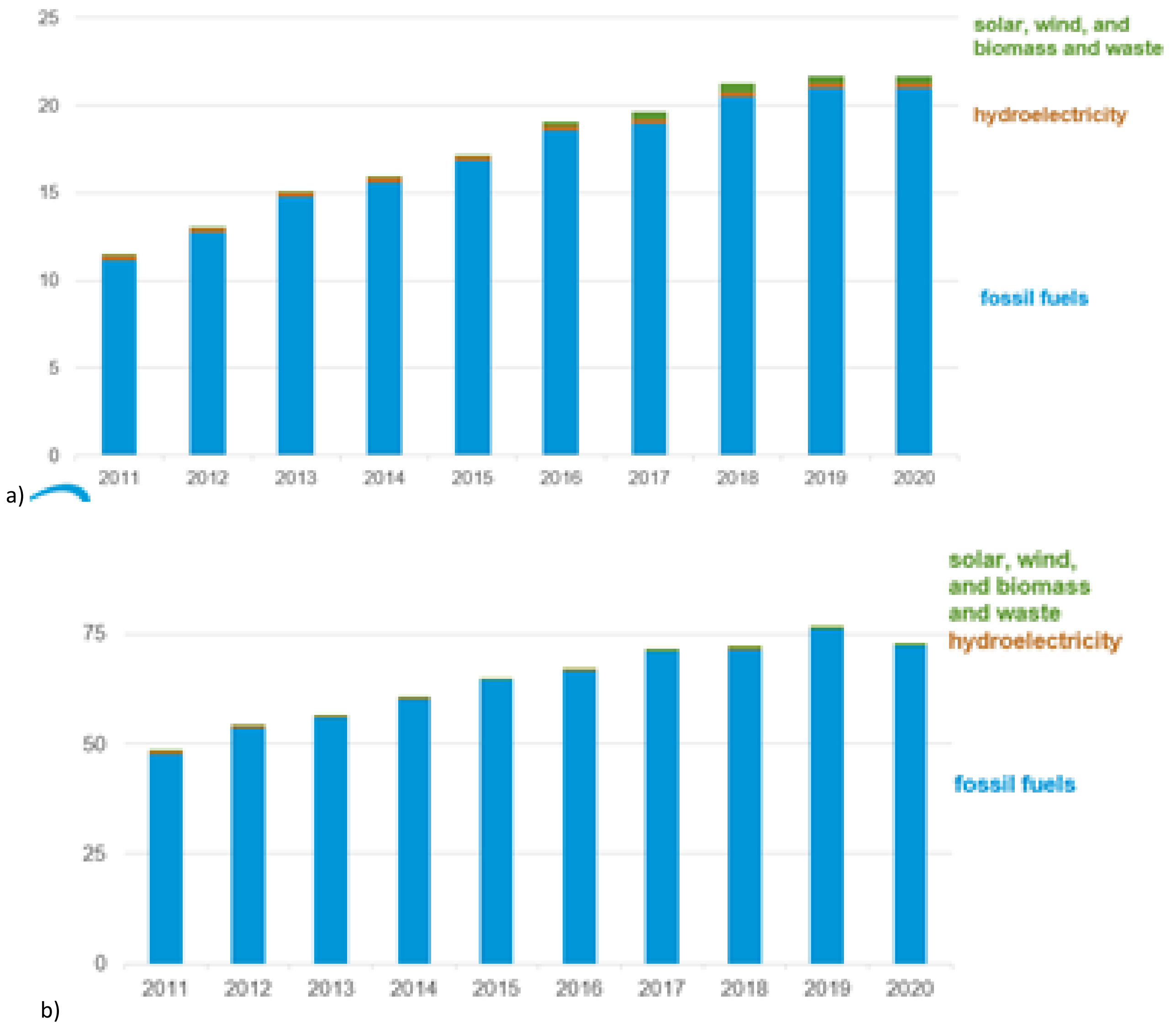


Fig. 3. Installed capacity (a) and energy production (b) of Algeria's energy system for 2011-2020

Despite a certain decline associated with COVID-19 quarantine restrictions, the trend of increasing electricity consumption in the energy system continued its overall growth in recent years (Fig. 4).

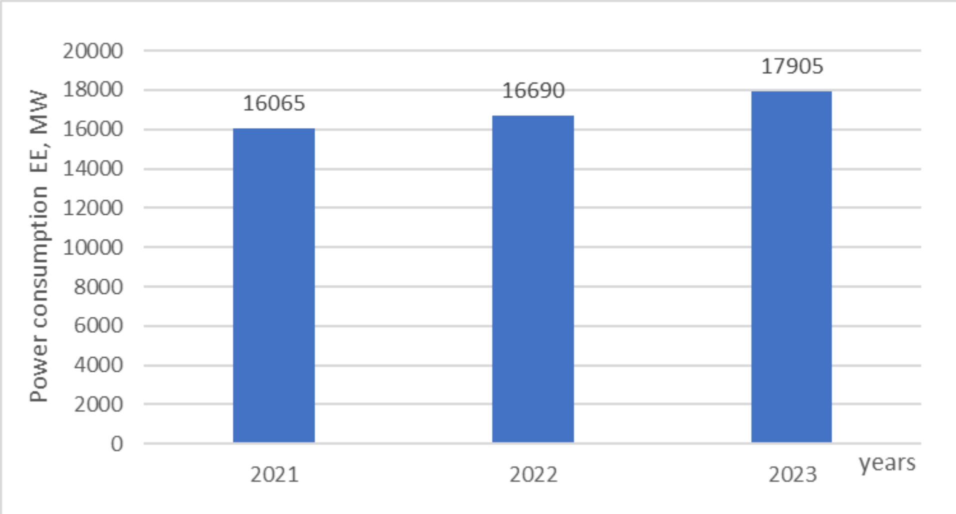


Fig. 4. Electricity consumption in the energy system

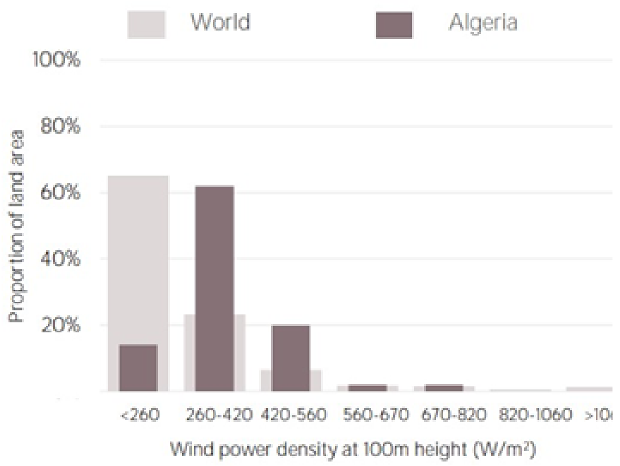
From the data presented, it can be concluded that the increase in the consumption level occurs at a rate of 1 GW per year, and the record is 17.9 GW, recorded on July 10, 2023. Securing of further growing of consumption level can only be achieved by creating a certain reserve of generating capacity. The sustainable way to increase the generation level and considering the country's commitments is to overcome the existing generation deficit precisely through renewable energy sources. According to government estimates, the renewable energy targets should provide 15 GW of electrical capacity with a growth rate of 1 GW per year until 2035 [8]. To implement such ambitious goals, it is necessary to understand the existing potential and prospects for the development of renewable energy. The analysis of the potential of renewable energy sources has been carried out by individual researchers, as well as special agencies and companies, in recent years [3, 11-17]. In the northern part of the country, where relatively heavy rainfall occurs during the year, there are 13 hydroelectric power plants, the main characteristics of which are given in Table 2.

Table 2. Main characteristics of HPP

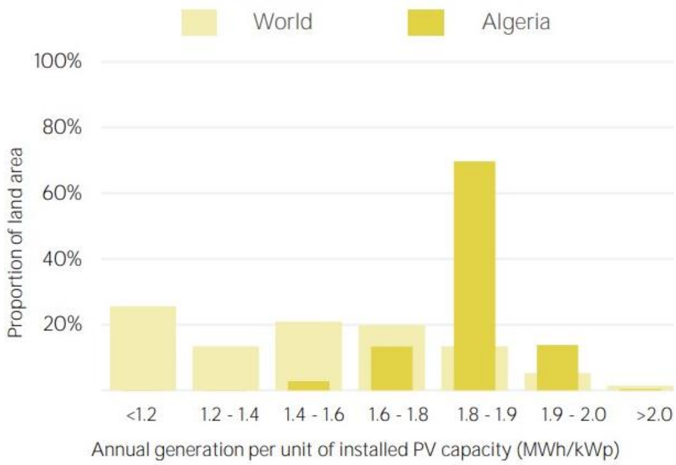
№	**Hydropower Plant**	**Capacity (MW)**
1	Draguina (Bejaia)	71,5
2	Ighil emda (Bejaia)	24
3	Mansoria (Bejaia)	100
4	Erraguene (Jijel)	16
5	Souk el djemaa (Relizane)	8,085
6	Tizi meden (Tizi ouzou)	4,458
7	Ighzenchebel (Algiers)	2,712
8	Ghrib (Ain defla)	7
9	Gouriet (Bejaia)	6,425
10	Bouhanifia (Mascar)	5,7
11	Oued fodda (Chlet)	15,6
12	Beni behdel (Tlemcen)	3,5
13	Tessala (Algiers)	4,228
TOTAL		269,208

Due to the relatively long Mediterranean coastline, the country has a rather high potential for wind energy (Fig. 5a), but the potential for solar energy is truly impressive (Fig. 5b), which is related to the country's location in the so-called "sun belt".

For the development of wind energy, the government planned to build seven WPP by 2021, but to date, only one has been built and put into operation. It has a total capacity of 10.2 MW and consists of 12 turbines with a unit capacity of 850 kW (built in 2014 in the south of the country) [18-20]. Despite the fact that by 2030 the task was set to build other WPP with a total capacity of 5 GW, today there is no information about the implementation of these plans. The situation is slightly better with the construction and commissioning of SPP. Their list, year of construction and main technical characteristics are given in Table 3 [16].



a)



b)

Fig. 5. Potential of wind (a) and solar (b) energy in Algeria and the world

Table 3. List of SPP and main technical parameters

№	Site	Region	Area Project (km²)	Instaled Capacity (MW)	Commissioning Date
1	El Hadjira	Ouargla	0,6	30	2017
2	Oued Nechou PV	Ghardaia	0,05	1,1	2014
3	Tindouf	Tindouf	0,18	0,9	2015
4	Djanet	Illizi	0,06	0,3	2015
5	Tamanrasset	Tamanrasset	0,26	13	2015
6	Aoulef		0,1	0,5	2016
7	Zaouiate Kounta		0,12	0,6	2016
8	Reggane		0,1	0,5	2016
9	Timimoune		0,18	0,9	2016
10	In Salah	Adrar	0,1	0,5	2016
11	Kaberten (PV)		0,06	0,3	2015
12	Adrar		0,4	20	2015

Based on the structure of RES (Fig. 6), a significant advantage is provided to the solar generation, both at present and in the future perspective [8, 21, 22].

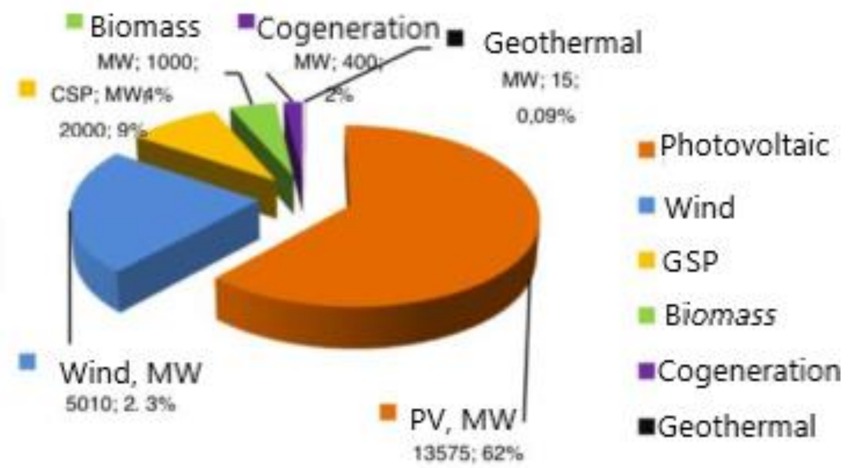
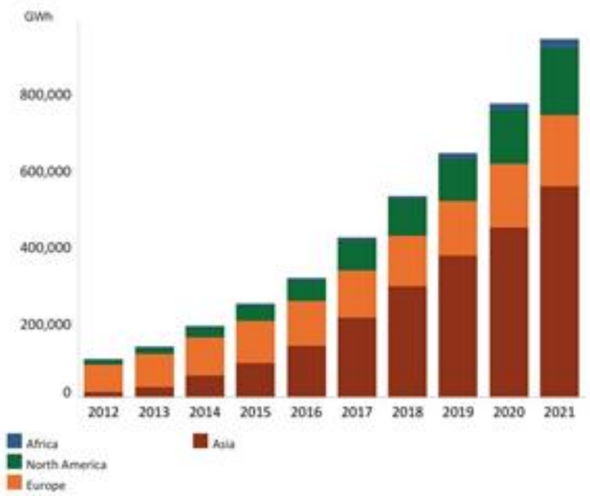
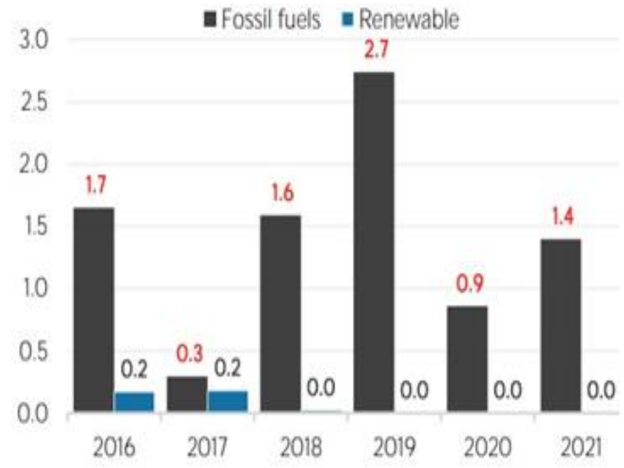


Fig. 6. Share of electricity production by type of renewable energy source (according to the industry development program until 2030)

But despite the rather significant potential of RES, the dynamics of introducing new facilities both in African countries (Fig. 7a) and in Algeria (Fig. 7b) in recent years is not quite significant [23].



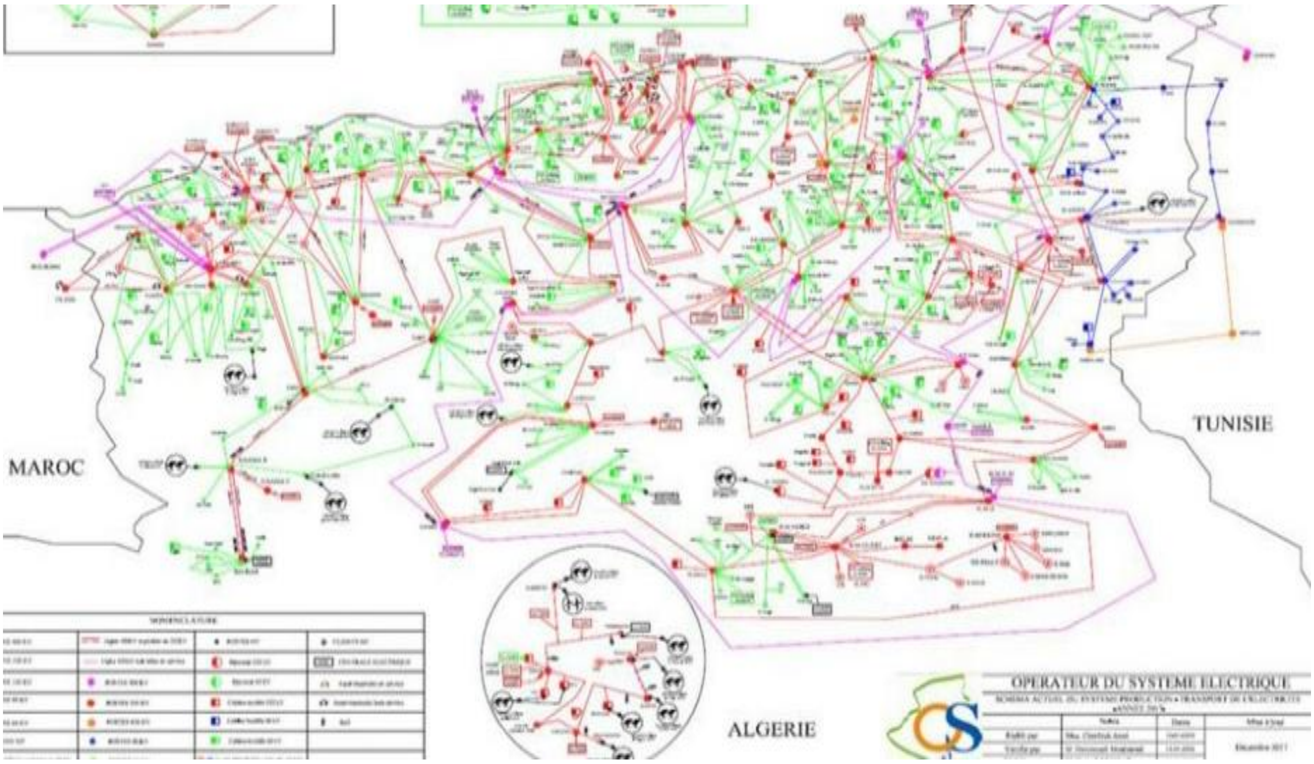
a)



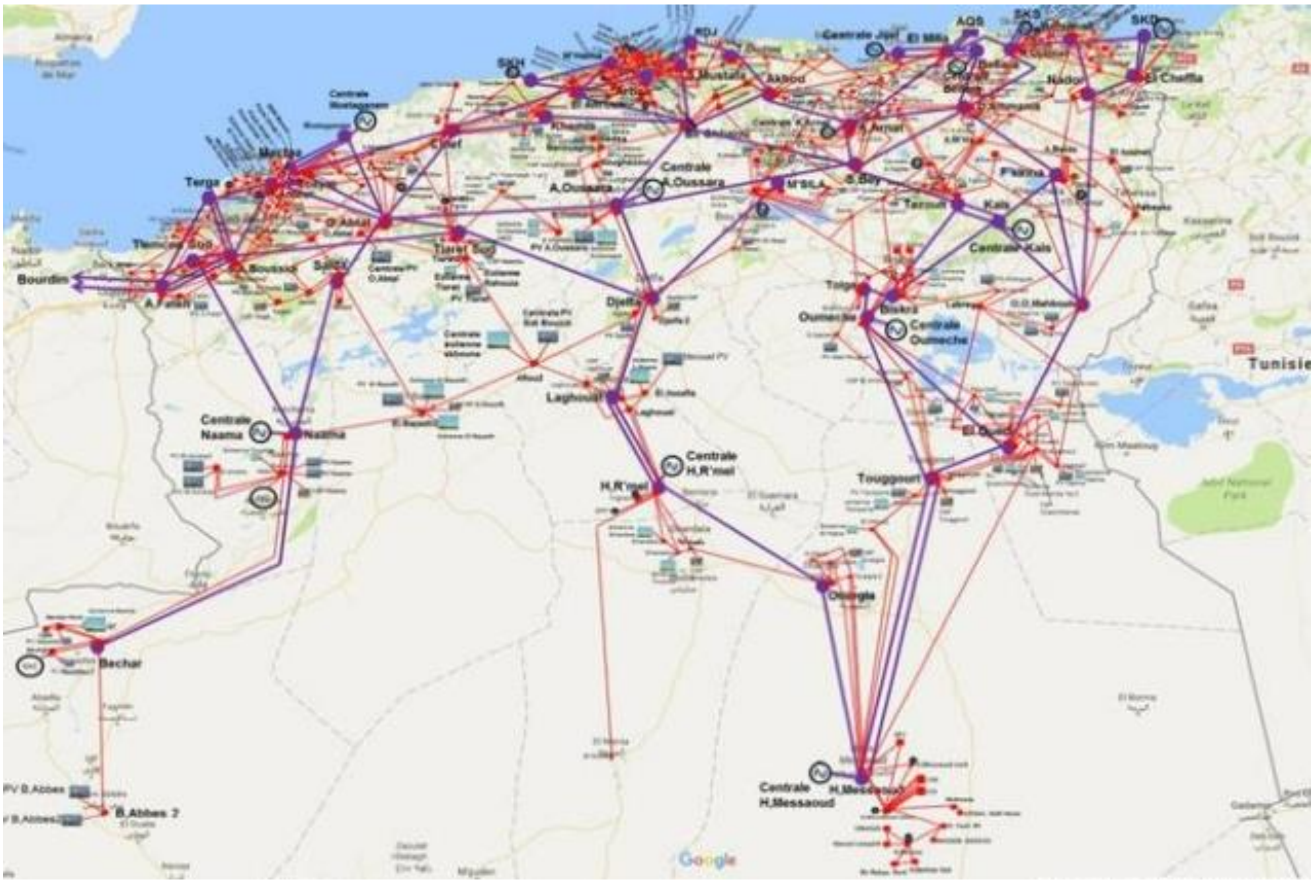
b)

Fig. 7. Dynamics of renewable energy use in African countries (a) and Algeria (b)

Based on this dynamics, the government's plan to achieve a 37% share of installed capacity and 27% of electricity production from RES in the country's energy balance by 2030 is quite unrealistic and far from successful implementation. To achieve this goal in a relatively short time and overcome the current situation (the total capacity of renewable energy facilities in 2020 was less than 1 GW), Algeria is seeking to attract foreign investment in energy projects [24]. Thus, in December 2021, a bid was announced for the installation of 1 GW of solar photovoltaic capacity, divided into 11 facilities with capacities ranging from 50 to 300 MW. However, the deadline for submitting proposals has been postponed, and the estimated start date for the implementation of these contracts is the end of 2024 or the beginning of 2025 [25]. Currently, the second phase (2021–2030) is being implemented, with the task of building transmission lines that will connect the industrially developed regions of the northern part of the country with new facilities in the Sahara Desert (Adrar, In-Salah, Timimoun, and Beshaar). According to the government position, that this development of energy infrastructure will facilitate the construction of new generating capacities. If we compare the map of electrical grids as of 2017 (Fig. 8a) with the plans for their development by 2030 (Fig. 8b), such changes can be noticed.



a)



b)

Fig. 8. Electrical grid map for 2017 (a), prospects for its development by 2030 (b)

A lot of attention is paid to issues related to the creation of energy infrastructure in sparsely populated and remote areas. Thus, in works [26-28], options for building autonomous systems using solar generation and electrical energy storage systems are considered, and their feasibility and economic efficiency are justified. It is understandable that the government's task is to create a favorable infrastructure for the implementation of powerful investment projects. However, according to the authors of this study, the capabilities of existing networks and developed regions are greatly underestimated. If we take statistical data on the efficiency of existing electrical systems, according to the World Bank, the level of electricity losses in the electrical networks of Algeria during 2007–2012 ranged from 18% to 21%, which is very high compared to developed European countries, where losses are at a level of no more than 4% - 8% [29]. The quality indicators of electrical energy in many regions of the country also leave much to be desired since the transmission capacity of the lines is very low [30]. It is a well-known fact that the maximum line losses correspond to the period of maximum load. Moreover, as seasonal consumption measurements show according to the Commission on Renewable Energy and Energy Efficiency (Fig. 9), the highest peak in consumption is recorded in summer and exceeds similar indicators in other seasons by about 1.5 times [31].

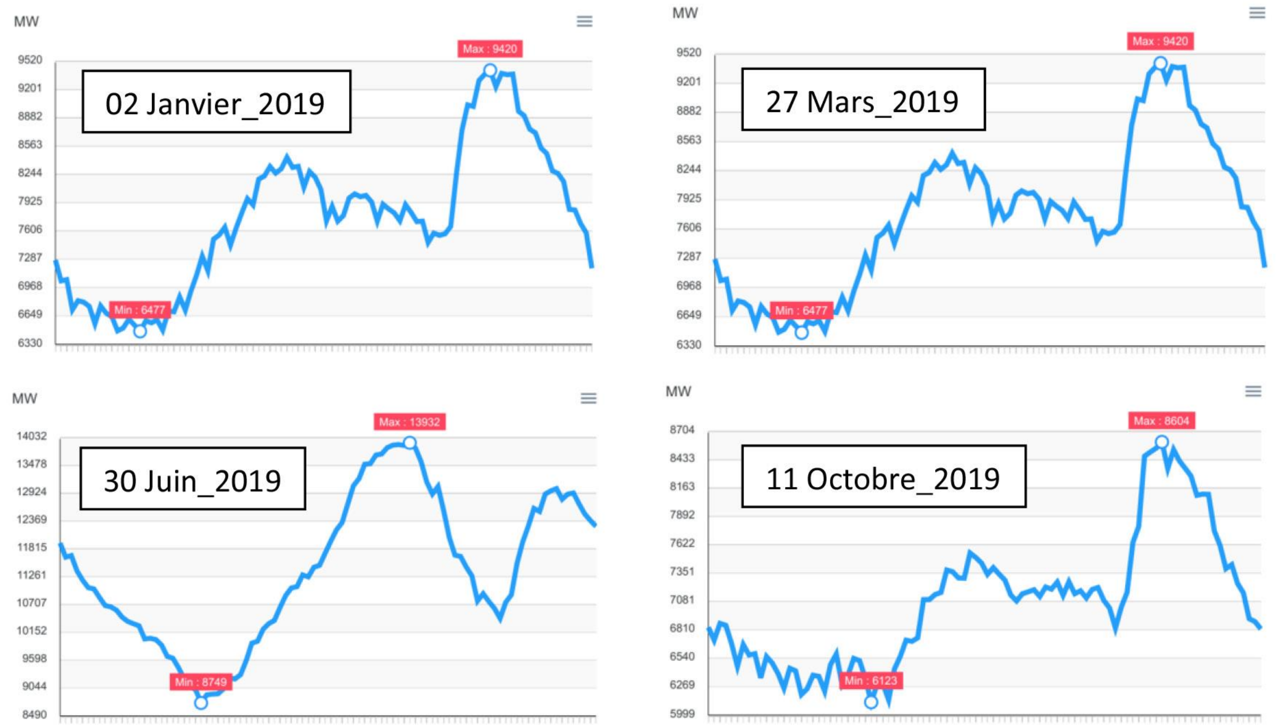


Fig. 9. Seasonal electricity consumption graphs

Reducing the level of consumption, and consequently, electricity losses, can be achieved both through wider implementation of energy-efficient solutions (installation of energy-saving equipment, thermal modernization of buildings, introduction of special tariffs during peak consumption hours) and the use of energy source diversification (use of distributed solar generation systems, autonomous water heating systems, heat pumps, and geothermal sources). Evaluating the effectiveness of the proposed measures will allow to recommend them for a specific region, considering its specifics. The planned measures will not only improve the quality of electrical energy but will also contribute to reducing transmission line losses and provide an impetus for the development of renewable energy systems, as they do not require significant capital expenditures.

Conclusions. The need and goal to increase the share of RES in developing countries does not always correspond with the actual situation there. The example of the Republic of Algeria shows that a favorable geographical location and the availability of appropriate natural resources are not decisive factors for achieving the declared goals in building sustainable energy. The tasks set by the country's leadership at the beginning of the transition program implementation are still far from being realized and have a certain dependence on external factors. The aim of the conducted research was to determine the overall energy potential of the country and to raise awareness about finding internal reserves to achieve the declared goals of the energy transition.

REFERENCES

1 Sutter J. D., Berlinger J. Final draft of climate deal formally accepted in Paris, Cable News Network. 2015. № 3. P. 3.

2 Paryzka uhoda, Ofitsiinyi vebportal parlamentu Ukrainy. [Online]. 2024. URL: https://zakon.rada.gov.ua/go/995_l61 (ukr)

3 Zahraoui Y., Basir Khan M. R., Alhamrouni I., Mekhilef S., and Ahmed M. Current status, scenario, and prospective of renewable energy in Algeria: A review», Energies, 2021, v. 14. P. 1–28. doi: 10.3390/en14092354.

4 Renewable Energy Development Program. [Online]. URL: https://algeriainvest.com/storage/uploads/discover_algeria/documents/1639628020Renewable%20Energy.pdf

5 Parekh C. Algeria Renewable Energy National Plan. [Online]. 2023. doi: 10.13140/RG.2.2.12417.84324.

6 Renewable Energy in Algeria. [Online]. URL: https://encyclopedia.pub/entry/10582

7 Claes D. H., Garavini G. Handbook of OPEC and the global energy order: past, present and future challenges. London, Routledge international handbooks, 2020. 351 p. URL: https://www.routledge.com/Handbook-of-OPEC-and-the-Global-Energy-Order-Past-Present-and-Future-Challenges/Claes-Garavini/p/book/9781032400761

8 Ministère de l'Énergie Algérie. [Online]. URL: https://www.energy.gov.dz/?rubrique=electricite-et-gaz

9 Algeria Electricity Production: National Sonelgas (Economic Indicators). [Online]. URL: https://www.ceicdata.com/en/algeria/electricity-production-annual/electricity-production-national-sonelgas

10 International - U.S. Energy Information Administration (EIA). [Online]. URL: https://www.eia.gov/international/analysis/country/DZA

11 Bouraiou A.et al. Status of renewable energy potential and utilization in Algeria, Journal of Cleaner Production, 2020, v. 246. 58 p. doi: 10.1016/j.jclepro.2019.119011.

12 IRENA. Energy-Profiles. Algeria. [Online]. URL: https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Statistical_Profiles/Africa/Algeria_Africa_RE_SP.pdf

13 Belward A. et al. Renewable Energies in Africa - Current Knowledge. EUR 25108 EN. Luxembourg: Publications Office of the European Union; 2011. 62 p. URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC67752, doi: 10.2788/1881.

14 Guezgouz M., Jurasz J., Chouai M., Bloomfield H., and Bekkouche B. Assessment of solar and wind energy complementarity in Algeria. Energy Conversion and Management, v. 238. P. 114–170. doi: 10.1016/j.enconman.2021.114170.

15 Mokrani O. B. E. K, Dida M., and Settou B. Promotion of Solar Energies in Southern Algeria Strategies and Perspectives. The Handbook of Environmental Chemistry, Berlin, Heidelberg: Springer Berlin Heidelberg, 2023. P. 1–18. doi: 10.1007/698_2023_1008.

16 Himri Y.et al. Overview of the Role of Energy Resources in Algeria's Energy Transition, Energies, 2022, v. 15. P. 1–26. doi: 10.3390/en15134731.

17 Bentouba S., Slimani A., and Boucherit M.S. Le pompage photovoltaïque: un outil de développement des régions du sud d'Algérie, Revue des Energies Renouvelables CER 07, 2007. P. 109–112. [Online] URL: https://www.researchgate.net/publication/228771020_Le_pompage_photovoltaique_un_outil_de_developpement_des_regions_du_sud_d%27Algerie

18 Abdeslame D., Merzouk N. K., Mekhtoub S., Abbas M. and Dehmas M. Estimation of power generation capacities of a wind farms installed in windy sites in Algerian high plateaus, Renewable Energy, v. 103. P. 630–640. doi: 10.1016/j.renene.2016.10.075.

19 Algeria's first wind farm completed. [Online]. URL: https://www.windpowermonthly.com/article/1221141/algerias-first-wind-farm-completed?utm_source=website&utm_medium=social

20 Mederreg D. et al. Assessment of the Resources of Wind Energy in Various Regions of Algeria, International Journal of Sustainable Development and Planning (IJSDP), 2021, v. 16, № 4. P. 641–650. doi: 10.18280/ijsdp.160404.

21 Fares T., Djeddi A., Nouioua N. Solar energy in Algeria between exploitation policies and export potential, Proceedings - 2019 1st International Conference on Sustainable Renewable Energy Systems and Applications, ICSRESA 2019 (December 04-05, 2019). doi: 10.1109/ICSRESA49121.2019.9182306.

22 Bailek N. et al. Developing a new model for predicting global solar radiation on a horizontal surface located in Southwest Region of Algeria, NRIAG Journal of Astronomy and Geophysics, 2020, v. 9, № 1. P. 341–349, doi: 10.1080/20909977.2020.1746892.

23 Statistical Review of World Energy 2023, BP Energy Outlook, 2023, v. 72. P. 8–20.

24 Bouznit M., Pablo-Romero M. d. P., and Sánchez-Braza A. Measures to Promote Renewable Energy for Electricity Generation in Algeria, Sustainability, 2020, v. 12, №. 4. P. 1–17. doi: 10.3390/su12041468.

25 Algeria - solar 1,000 MW: call for tenders. [Online]. URL: https://loucif.law/algerie-solar-1000-mw-appel-doffres-a-investisseurs

26 Fodhil F., Hamidat A., and Nadjemi O. Potential, optimization and sensitivity analysis of photovoltaic-diesel-battery hybrid energy system for rural electrification in

Algeria, Energy, 2019, v. 169. P. 613–624, doi: 10.1016/j.energy.2018.12.049.

27 Bharatee A., Ray P. K., and Ghosh A. A. Power Management Scheme for Grid-connected PV Integrated with Hybrid Energy Storage System, Journal of Modern Power Systems and Clean Energy, 2022, v. 10, № 4. P. 954–963. doi: 10.35833/MPCE.2021.000023.

28 Souria D. and Mouhoubi A. Optimization of Electrical Energy Generation Systems in the Mini-grids of Southern Algeria, International journal of economic performance, v. 06, № 01. P. 118–131.

29 Maammeur H., Hamidat A., Loukarfi L., Missoum M., Abdeladim K. and Nacer T. Performance investigation of grid-connected PV systems for family farms: case study of North-West of Algeria, Renewable and Sustainable Energy Reviews, 2017, v. 78, P. 1208–1220. doi: 10.1016/j.rser.2017.05.004.

30 Mouheb M., Malek A., and Loukarfi L. Contribution of solar energy for the correction of the voltage drop recorded on a LV power grid in Algeria, Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 2020, v. 42, № 20. P. 2485–2500, doi: 10.1080/15567036.2019.1607948.

31 Transition Energétique en Algérie: Leçons, Etat des Lieux et Perspectives pour un Développement Accéléré des Energies Renouvelables», CEREFE (2020), 2020, [Online]. URL: ttps://www.cerefe.gov.dz/wp-content/uploads/2022/02/Rapport_CEREFE_TE-2020-4.pdf