From energy poverty to sustainable development: the socioeconomic impact of rural electrification in Morocco

Mohammed Benchrifa[1], *Khaoula* Benchrifa[2] *Aziza* Lamchaimach[3] and *Jamal* Mabrouki[3].

[1]Improvement and Valuation of Plant Resources, Faculty of Sciences, Ibn Tofaïl University-KENITRA-University Campus, Kenitra 14000, Morocco
[2]Sidi Mohammed Ben Abdellah University, Morocco
[3]Laboratory of Spectroscopy, Molecular Modeling, Materials, Nanomaterial, Water and Environment, CERNE2D, Faculty of Science, Mohammed V University in Rabat, Avenue Ibn Battouta, PO Box 1014, Agdal,Rabat, Morocco

Abstract. Energy is a fundamental pillar of economic and social development, but dependence on fossil fuels poses major environmental and social challenges, particularly in rural areas of developing countries. Rural electrification is therefore an essential lever for sustainable development, promoting social equity and improving living conditions. In Morocco, rural electrification has become a national priority through the Rural Electrification Program. Thanks to this program, the rate of access to electricity has risen from 18% in 1995 to nearly 99.86% in 2022. This policy has had significant socio-economic impacts, including the creation of income-generating activities, improvements in education and health, and a reduction in rural exodus. Rural electrification in Morocco thus appears to be a strategic tool for reducing territorial inequalities and promoting sustainable development.

1 Introduction

All human activities, particularly those that contribute to economic and social development, rely on energy, because the development of a society translates into the increasing satisfaction of a number of needs: food, education, housing, leisure, health, transportation, etc. All these activities require different net consumption levels and final energy consumption in various forms (fuel, electricity, etc.). However, although energy is an essential component of the development process, a large part of its resources come from fossil fuels, which have limited reserves and are therefore exhaustible. Environmental and health problems related to its use are multiplying, so access to modern energy services is essential. These challenges are exacerbated by population growth, price instability, geopolitical tensions over energy supplies, and the inequalities and poverty that still affect a significant portion of the world's population.

According to the International Energy Agency (IEA), more than 1.2 million people around the world were without electricity in 2011 [1]. Almost all of them live in developing countries. The region most affected by lack of access to electricity is Africa, particularly sub-

Saharan Africa, where the electrification rate does not exceed 32%. These figures are even more alarming when we look at electrification rates in rural areas. According to the IEA, only 65.1% of rural areas in developing countries had access to electricity in 2011, compared to a rural electrification rate of 99.7% in member countries of the Organization for Economic Cooperation and Development (OECD) [2].

Today's rural world faces several sustainable development challenges. Broadly speaking, this type of development includes the pursuit of equity and social justice while meeting the needs of current and future generations. Sustainable development aims to integrate concerns about prevention and respect for the natural environment, as well as concerns about social justice (distribution of resources, equity in employment, social investment, etc.) into decision-making processes related to development choices. etc.). Currently, the environment is poorly taken into account and undervalued by economic growth, which does not consider the long-term and intergenerational effects of economic activity.

For Morocco, rural electrification is a priority, aimed at improving the quality of life of populations and promoting economic development in these often-neglected regions. Thanks to innovative initiatives and strategic investments, the country is making progress toward its goal of bringing electricity to all rural communities by 2030 [3]. This rural electrification is not limited to providing electricity, but also aims to transform communities and open up new opportunities for a brighter and more sustainable future for all Moroccans. The objective of this article is to present Morocco's efforts and strategies for the total electrification of rural areas and to assess the socio-economic impact of this electrification on the target population.

2 Background

The impact of rural electrification is often assessed at the country or regional level. Much work has been done on rural electrification in Africa. Examples include Dinkelman's (2011) work in South Africa, which assessed the impact of rural electrification on employment, and Davis's (1998) [4] work, which identified the effects of access to electricity on households' fuel choices. The main interest of South Africa in this research is the evolution of access to electricity in rural areas following the transition to democracy in the early 1990s and the end of apartheid, which had created significant inequalities in access to infrastructure. Furthermore, the final report produced by the Beninese Agency for Rural Electrification and Energy Management (ABERME) in 2019 on the simplified environmental and social impact assessment of lot 3: 34 rural localities showed that the implementation of this project had positive impacts on the environment and society, namely improved public and domestic lighting, the development of income-generating activities requiring energy, improved conditions for learners and therefore increased school performance, improved quality of existing public and private services in the localities, the creation of temporary and permanent jobs (welding, vulcanization, hairdressing, catering, etc.).

Furthermore, in the report produced by Souleymane CISSE and Kouamé Marius SOSSOU in 2016 in Senegal on the Impact of the Rural Electrification Program on Food Security in Senegal [5] , the authors show that rural electrification has contributed positively to reducing food insecurity in rural areas by promoting access to basic social services, increasing the level of agricultural consumption and production, improving household eating habits, and reducing their level of poverty. In addition, Kan Arsène KOUADIO revealed in his report entitled The Challenges of rural electrification in Côte d'Ivoire, published in 2021[6], that electrification has helped to curb rural exodus in electrified localities compared to non-electrified localities, and that rural populations are turning to solar photovoltaic technologies as a solution for electrification. These individual solutions are undeniably successful in Côte d'Ivoire, particularly in rural areas. It should also be noted that these individual solutions are

an alternative to counter the lack of access to electricity in areas not served by the national electricity grid. These new solutions contribute to improving the living conditions of populations through electrification in areas far from the electricity grid. Indeed, economic activities in electrified villages are better developed and differ from those in non-electrified areas. Thus, thanks to electrification in rural areas, new household appliances (refrigerators, fans, etc.), electrical equipment for agricultural processing, agricultural packaging facilities, cold storage facilities, and running water supply networks are appearing.

In Asia, several studies have examined the issue of rural electrification. Examples include the work of Khandker, Barnes, and Samad (2009) [7] and Khandker et al. (2009) [8], who analyzed the impacts of rural electrification on well-being using data from Bangladesh and Vietnam. Based on surveys conducted between 2002 and 2005, the authors found that connection to the electricity grid had positive impacts, particularly on household income and expenditure, and a remarkable improvement in the population's level of education. Furthermore, a study conducted by Bhattacharyya (2006) [9] in India asserts that rural electrification alone is unlikely to solve the problem of energy access due to the low penetration of electricity in the energy mix of poor households. More recently, however, van de Walle et al. (2013) [10] have highlighted the positive effects of rural electrification on consumption and income, as well as on girls' school enrolment.

3 Morocco's rural electrification strategies

Morocco has launched an ambitious National Rural Electrification Program aimed at providing access to electricity to all rural communities in the country by 2030 [11]. This program is based on an integrated approach, combining the extension of traditional electricity grids with decentralized solutions such as mini-grids and domestic solar systems. Through public-private partnerships and innovative financing, this program aims to transform the energy landscape in rural areas and offer new opportunities for development.

As part of this program, considerable efforts are being made to extend electricity grids to the most remote areas of the country. Massive investments are being made in the construction of power lines and substations, gradually connecting isolated villages to the national grid. This expansion of electrical infrastructure creates a solid foundation for the socioeconomic development of rural areas by providing access to essential services such as education, healthcare, and communications. In addition to extending traditional electrical grids, Morocco is also focusing on decentralized solutions and renewable energy to electrify rural areas. Solar and wind mini-grids are being deployed in remote areas, providing a reliable and affordable source of electricity to communities not served by the main grid. In addition, programs to install solar home kits are being implemented, enabling rural households to access electricity for their daily needs.

Electricity access rates have risen from 18% in 1995 to 99.86% in 2022 (Fig 1), according to the latest figures from the National Office for Electricity and Drinking Water (ONEE).

This progress reflects the success of the Comprehensive Rural Electrification Program, a national initiative launched in 1996 that has extended access to electricity to almost the entire country [12].

The program has impacted 13 million Moroccans, marking a significant advance in socio-economic inclusion and regional development.

With a total investment of nearly MAD 25.3 billion (approximately $2.5 billion), the Rural Electrification Program has connected 41922 villages to the electricity grid, electrifying 2.16 million households. In 2023 alone, the program expanded its reach to an additional 198 villages, bringing electricity to approximately 24000 people in rural areas [13].

Beyond traditional electrical connections, the Rural Electrification Program has also integrated renewable solutions for isolated regions. Between 1998 and 2018, more than 70

000 households were equipped with solar kits through collaborations with the National Initiative for Human Development (INDH) and other community projects [14].
This sustainable approach aligns with Morocco's broader goals of advancing renewable energy and achieving environmental objectives [15].
ONEE's efforts have also facilitated the development of substantial infrastructure. This includes the installation of more than 51 000 kilometers of medium-voltage lines, 136 600 kilometers of low-voltage lines, and 25 700 transformer stations [16].

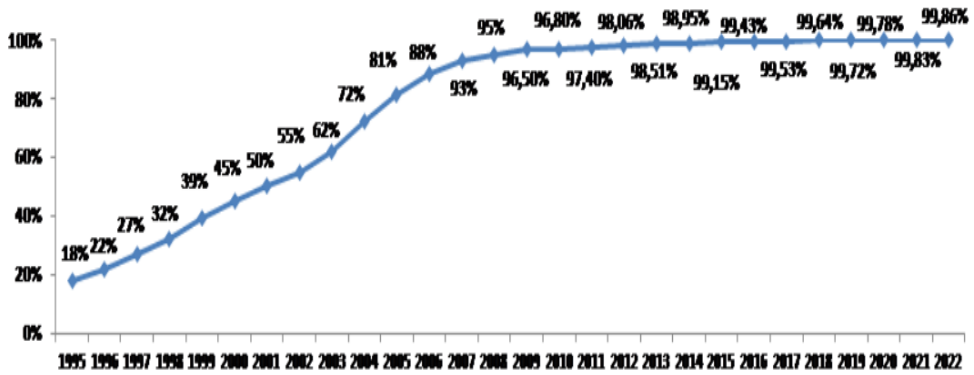

Fig. 1. Evaluation of rural electrification in Morocco.

4 Main Socio-Economic Impacts of Rural Electrification in Morocco

The challenges of the National Rural Electrification Program, now successful in providing previously excluded areas with basic infrastructure, have enabled the deployment of a vast infrastructure in rural areas, thus providing immense opportunities for development and the creation of income- and job-generating projects, while also contributing to a significant reduction in the urban-rural divide.
In this sense, although this structuring project places a heavy burden on ONEE in terms of ensuring the daily operation and maintenance of increasingly extensive electricity networks characterized by difficulties of access on the one hand, and on the other hand, the management of customers in scattered and increasingly isolated areas. It has significantly improved the daily lives of rural populations and promoted income-generating activities.
Various impact studies carried out by ONEE to accompany the implementation of the National Rural Electrification Program have shown that rural electrification is not neutral and has significant economic and social impacts.
Economically, electrification has an overall positive impact on improving household incomes and developing income-generating activities, particularly those requiring the use of productive electrical appliances. For traditional craft activities (tapestry, sewing, etc.), the impact is particularly noticeable in terms of longer working hours (a 25% increase in night-time working hours), which improves productivity levels.
The number of businesses has grown significantly with the arrival of electricity, allowing opening hours to be extended from 6 a.m. to 10 p.m. to accommodate nighttime work, and the rate of refrigerator ownership is 60% compared to 15% among those without electricity.

In agriculture, the impact has been felt in the modernization of cattle farming, the creation of milk collection centers and dairy cooperatives, and the introduction of new crops, leading to a transformation of the local economic structure. Forty-three percent of villages with an electric pumping system have introduced new crops (vegetables or fruit).
On a social level, electrification has significantly improved the level of comfort in households through the impressive spread of comfort equipment such as TVs, satellite dishes, refrigerators, and communication equipment, including widespread mobile phone penetration. The massive spread of audiovisual communication media thanks to electrification provides an opportunity to reach a wider rural audience through educational programs. Furthermore, a profound transformation in the consumption patterns and lifestyles of Morocco's rural populations is expected in the coming years, thanks to urban models transmitted by television.
Among other benefits, electrification has helped to mitigate and slow down the rural exodus of household members. In several villages, electrification has even led to the return of emigrants to the village after its electrification.
The positive impact is also evident in improved school enrolment rates for children, particularly girls. There has been an increase in the age at which girls leave school and an improvement in their enrolment rates.
The electrification of health clinics is an asset that has strengthened healthcare services in rural areas by providing opportunities to use more sophisticated medical equipment and extend medical services into the evening. The majority of electrified villages consider that insecurity has decreased since electrification. This is linked to the existence of functional public lighting.

5 Conclusion:

As we have seen throughout this study, electricity has real effects and helps to meet several human needs in rural populations. However, as the literature has already taught us, the effects of electrification depend on the context and pre-existing inequalities. In this sense, access to the resource does not represent a major change. However, even if inequalities remain largely unchanged, electricity still offers great potential.
The widespread implementation of the National Rural Electrification Program has enabled the Kingdom to provide rural areas with essential infrastructure, opening up new opportunities for development and employment. This has helped to significantly reduce the gap between urban and rural areas and significantly improve the daily lives of rural populations.
Through these initiatives, Morocco continues to strengthen its commitment to sustainable development and improving living conditions in rural areas, thereby helping to reduce inequalities between urban and rural regions.

References

[1] Liu, J., Jain, V., Sharma, P., Ali, S. A., Shabbir, M. S., & Ramos-Meza, C. S. (2022). The role of Sustainable Development Goals to eradicate the multidimensional energy poverty and improve social Wellbeing's. Energy Strategy Reviews, 42, 100885.
[2] Bencheikh, I., Mabrouki, J., Azoulay, K., Moufti, A., & El Hajjaji, S. (2019, April). Predictive analytics and optimization of wastewater treatment efficiency using statistic approach. In International Conference on Big Data and Networks Technologies (pp. 310-319). Cham: Springer International Publishing.

[3] A. Awan, F. Bilgili, Energy poverty trends and determinants in Pakistan: Empirical evidence from eight waves of HIES 1998–2019. Renewable and Sustainable Energy Reviews,2022, 158, 112157.
[4] DAVIS, Donald R. Technology, unemployment, and relative wages in a global economy. *European Economic Review*, 1998, vol. 42, no 9, p. 1613-1633.
[5] CISSE, Souleymane et SOSSOU, Kouamé Marius. Impact du Programme d'électrification rurale sur la sécurité alimentaire au Sénégal.
[6] KOUADIO, Kan Arsène. *Les enjeux de l'électrification en milieu rural de la Côte d'Ivoire*. 2021. Thèse de doctorat. Université de Lorraine.
[7] KHANDKER, Shahidur R., BARNES, Douglas F., et SAMAD, Hussain A. The welfare impacts of rural electrification in Bangladesh. *The Energy Journal*, 2012, vol. 33, no 1, p. 187-206.
[8] KHANDKER, Shahidur R., BARNES, Douglas F., SAMAD, Hussain A., *et al.* Welfare impacts of rural electrification: evidence from Vietnam. *World Bank Policy Research Working Paper*, 2009, no 5057.
[9] BHATTACHARYYA, Dipak Kumar. *Research methodology*. Excel Books India, 2006.
[10] VAN DE WALLE, Dominique P., RAVALLION, Martin, MENDIRATTA, Vibhuti, *et al.* Long-term impacts of household electrification in rural India. *World Bank Policy Research Working Paper*, 2013, no 6527.
[11] Ghizlane, F., Mabrouki, J., Ghrissi, F., & Azrour, M. (2022). Proposal for a high-resolution particulate matter (PM10 and PM2. 5) capture system, comparable with hybrid system-based internet of things: case of quarries in the western rif, Morocco. Pollution, 8(1), 169-180.
[12]BENNOUNA, Amin. Energie au Maroc, quoi de neuf en 2022?. *EcoAct: Paris, France*, 2022, p. 2-7.
[13]BENCHRIFA, Mohammed, TADILI, Rachid, IDRISSI, Ahmed, et al. Development of New Models for the Estimation of Hourly Components of Solar Radiation: Tests, Comparisons, and Application for the Generation of a Solar Database in Morocco. International Journal of Photoenergy, 2021, vol. 2021.
[14]K. Batool, Z. Y. Zhao, M. Irfan, J.Żywiołek, Assessing the role of sustainable strategies in alleviating energy poverty: an environmental sustainability paradigm. Environmental Science and Pollution Research, 2023, 30(25), 67109-67130.
[15] MABROUKI, Jamal, AZOULAY, Karima, BENCHEIKH, Imane, *et al.* Optimizing electrocoagulation parameters for enhanced leachate remediation. *Journal of Dispersion Science and Technology*, 2025, p. 1-17.
[16] Y. Wang, Z. Wang, J. Shuai, C.Shuai, Can digitalization alleviate multidimensional energy poverty in rural China? Designing a policy framework for achieving the sustainable development goals. Sustainable Production and Consumption,2023, 39, 466-479.