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Review of strategies for sustainable energy in Morocco

Abstract: The present paper exposes how Morocco's population and economic expansion pose a challenge to its capacity to supply energy demand, especially given how the scarcity of fossil fuels and their high market price now and in the future develop and follow strategies to achieve the objectives of sustainable development. The effectiveness of this investment and the vast number of unexploited resources have led Morocco to aim for a new ambition of obtaining 52% of its energy demands from renewable sources, making it one of the world's leaders with regard to renewable energies. This paper analyzes the large specter of renewable energy sources and their potential in Morocco, including solar, hydroelectric, tidal, wave, and geothermal energy sources, then identifies the barriers halting its growth, going from storing and transmitting to financing, followed by the comparative costs and benefits approach.

It also assesses the country's strategy for sustainable development, highlighting its financing, and then expands the scope of the research to explore other potential applications of renewable energy in the Kingdom, such as desalination and transportation, followed by providing a list of guidelines

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and recommendations on how the country can bypass the obstacles stopping it from harnessing and using these precious resources, The feasibility of these solutions were judged through a survey by the population which showed a very promising result.

Keywords: sustainable development, energy efficiency, renewable energy sources,strategic investments, energy mix

Introduction

To meet their energy needs while preserving the environment, several countries have turned to renewable energy sources as a result of the growing global population and the threat of climate change. However, since many societies place a higher priority on providing for their people's fundamental necessities than lowering greenhouse gas emissions, there is a significant variation in the level of commitment to this goal among nations.

Despite this, Morocco, a developing country with a populace that is expanding with a flourishing industrial sector, has not only incorporated renewable energy in its energy mix but has also set a target to make it the main source by 2030. With the kingdom's significant investments in renewable energy, this ambitious target, which may be difficult for a developing nation, seems to be within reach, although it is uncertain if it will allow it to be able to achieve the goal of obtaining 52% of its energy from clean sources in the short term.

To assess Morocco's future energy requirements, several research investigations have been performed (Haouraji et al. 2020; Citroen et al. 2015) allowing the assessment of energy demand forecasts in contrast with available natural resources.

The country has so far focused on solar, wind and hydroelectric electricity, making it a pioneer in this area (Garcia and Leidreiter 2016), enabling it to reach 17.1% of the country's demand by renewable energy sources as of 2021 (excluding hydroelectricity) (ONEE 2021a). In fact, there are many obstacles to overcome, starting with reducing energy bills by decreasing wasted energy through energy-efficient strategies and specific policies inspired from successful projects performed by developed and developing countries.

To achieve the goal of transitioning to renewable energy as the primary source by 2030, the country has to focus on several other key factors. One of the most important is the expansion and improvement of its renewable energy capacity. This requires significant investment in research and development as well as the construction of new renewable energy facilities. It is also important to improve the transmission and distribution infrastructure to ensure that renewable energy can be reliability delivered to consumers.

The adoption of renewable energy in the kingdom may also be impacted by social and cultural variables besides the technological difficulties that must be addressed. For instance, some groups of the population can be hostile to change or might resist the idea of equipping the land

with the harnessing devices of renewable energy. To ensure the success of the shift to renewable energy.

In terms of finance, Morocco has secured significant funding for its renewable energy projects through a range of sources, such as the Moroccan Agency for Sustainable Energy (MASEN). This funding has helped to support the growth of the Kingdom's renewable energy sector and more will be essential to achieving the country's goals. Using innovative funding mechanisms like crowd funding could also secure important funds for this cause.

While there are several challenges to overcome, the Kingdom is far from an impasse, in fact, through this article we will witness the potential it holds and the recommendations to consider allowing it to flourish not only in its energy and economy sectors but also many others, such as the agriculture and transport sectors.

1. The current state of renewable energy in Morocco

The country is now heavily dependent on imported gas and oil to meet its energy needs, at high costs. Renewable energy not only has the potential to help the country meet its economic growth targets but also to help it combat climate change.

Morocco's renewable energy resources are diverse and include hydroelectric, solar and wind power. Due to the country's geographic advantage, solar and wind power are particularly promising in Morocco.

The Moroccan Agency for Sustainable Energy (MASEN) has been at the forefront of solar energy development in the country, with many large-scale solar power plants in operation or under construction. For example, the Noor complex in Ouarzazate is currently the largest concentrated solar power plant in the world, with a total capacity of 580 MW.

Wind energy is also a significant renewable resource in Morocco, with strong winds in the northern and coastal regions. The Moroccan Wind Energy Association (AMEE) has been instrumental in the development of the country's wind energy sector, with some large-scale wind farms in operation or under development. The same applies for hydroelectric power, with several hydroelectric dams in operation, including the Mohammed VI dam on the Oum Er-Rbia River.

While Morocco achieved significant progress in expanding its renewable energy capacity in recent years (ONEE 2022), there are still challenges to overcome in order to benefit more from the country's renewable energy potential. These challenges include the need for infrastructure investments, regulatory reforms, and the development of storage solutions to ensure the stability of the grid. Also, the high costs of renewable energy technologies remain a barrier for Morocco.

To address these challenges and push the development of renewable energy in the country, many of institutions and organizations have been dedicated to studying and developing new technologies and approaches focused on renewable energy in Morocco, like the National Centre

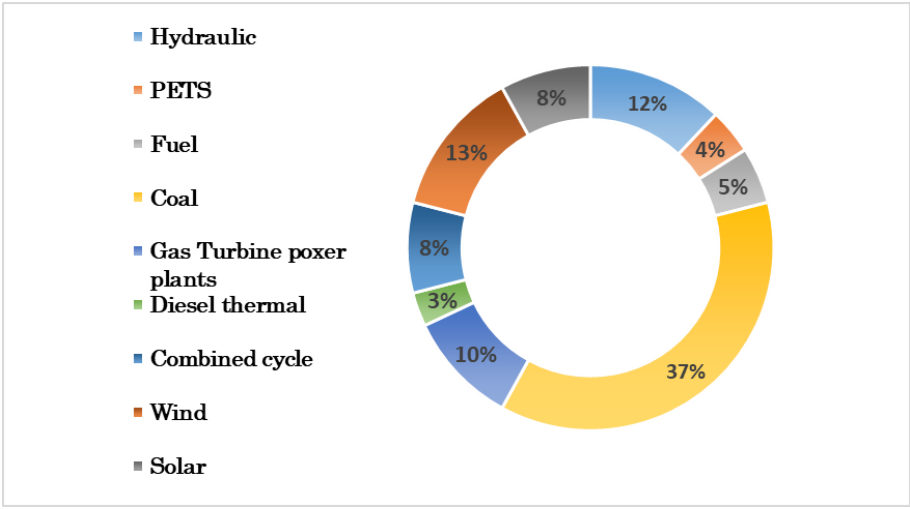


Fig. 1. Distribution of Moroccan electricity production by source in 2021 (ONEE 2022)

Rys. 1. Rozkład produkcji energii elektrycznej w Maroku według źródła w 2021 r.

for Energy, Science, and Nuclear Techniques (CNESTEN) and MASEN. These organizations are already involved in several research projects, including the development of advanced wind turbine designs, concentrated solar power plants, and the integration of renewable energy into the grid.

2. The potential of renewable energy resources

Morocco has many renewable energy resources, including solar, wind, and hydroelectric power. Solar energy is particularly promising in Morocco due to the country's high levels of solar radiation and its abundant desert regions. The Moroccan Solar Energy Association (AMES) estimates that Morocco has the potential to generate up to 5,000 MW of solar energy per year, enough to meet the country's entire electricity demand (Hanger et al. 2016). In fact, Morocco is already a leader in the use of solar energy in Africa, with several large-scale solar projects in operation, including the Noor solar complex in Ouarzazate, which is one of the largest solar power plants in the world.

Wind energy is no less important in Morocco, with strong winds in the northern and coastal regions. The Moroccan Wind Energy Association (AMEE) estimates that Morocco has promising potential to generate wind energy (El Hadrie et al. 2019). Morocco also has several hydroelectric dams in operation, including the Mohammed VI dam on the Oum Er-Rbia River.

In order not to waste its renewable energy potential, Morocco has implemented some initiatives and policies to promote the use of renewable energy. These include the adoption of a feed-in tariff system to encourage the development of renewable energy projects, the establishment of the Moroccan Renewable Energy Fund (MARF) to finance renewable energy and energy efficiency projects, and the development of a national renewable energy action plan to guide the deployment of RE strategy, also to establishing new institutions to support the development of new renewable energy technologies, like the Moroccan Center for Innovation and Solar Energy (MCISE).

2.1. Wind energy

Morocco has significant potential for wind energy, with strong winds in the northern and coastal regions, estimated at about 25,000 MW of wind energy per year (El Khchine et al. 2019). By 2021, Morocco reached a total installed wind-power capacity of about 1,500 MW (Captain -tide tool for tidal range database...).

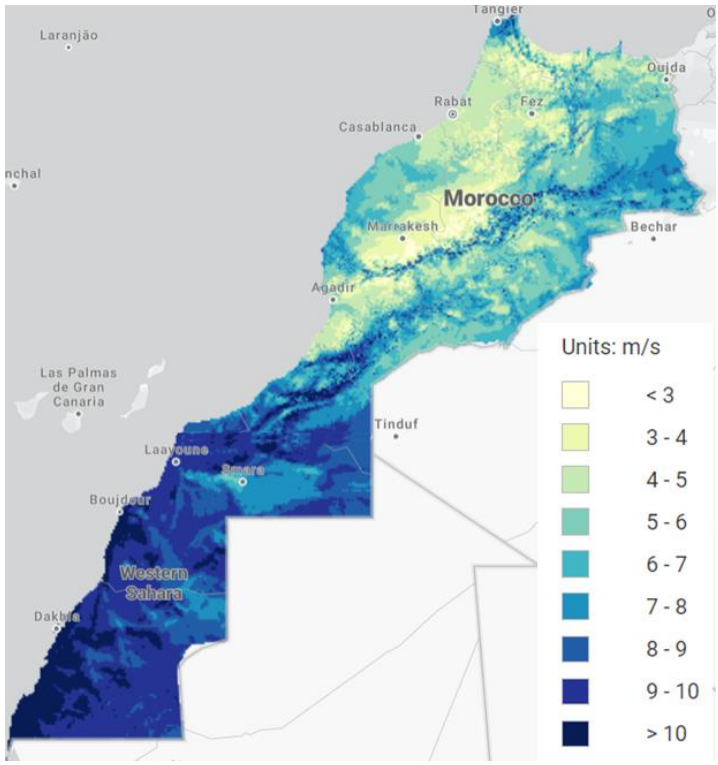


Fig. 2. Morocco's global wind energy speed (Re-explorer Geospatial...)

Rys. 2. Globalna prędkość energii wiatrowej w Maroku

The government has set a priority in its energy strategy to install 10,000 MW of wind power capacity by 2030 (Ministry of Energy... 2016).

To achieve these goals, especially since Morocco has the potential to generate up to 27% of its electricity from wind power (Moroccan Agency of Sustainable Energy).

Morocco already had 759 MW of installed wind capacity in 2019, making it the leading country in Africa with regard to wind capacity. It has secured one of the most suitable locations for large-scale wind utilities in Africa (Fig. 3). The most promising wind energy resources in Morocco are located on the Atlantic coast, where wind speeds can exceed 10 m/s. The south Atlantic region in particular holds significant potential for the development of wind energy projects (Fig. 2) particularly when combined with the desalination of seawater. The southern part of Morocco has a high demand for both energy and clean water, making the integration of these two resources a potentially attractive solution.

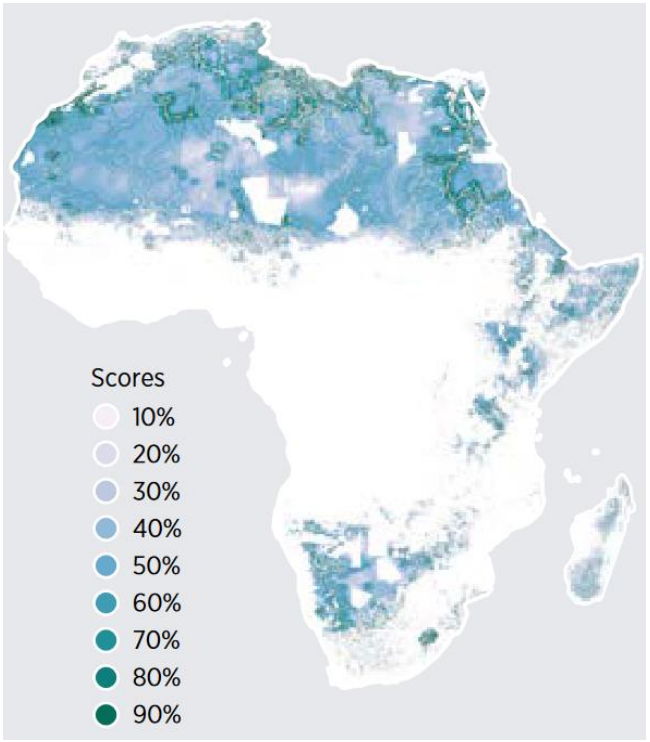


Fig. 3. Africa's most suitable areas for utility-scale wind (IRENA and AfDB 2022)

Rys. 3. Najbardziej odpowiednie obszary Afryki dla elektrowni wiatrowych na skalę przemysłową

Several wind projects have been also installed in Morocco, including the Boujdour wind farm (300 MW), the Tiskrad wind farm (100 MW) and the Jbel Lahdid wind farm (270 MW) (ONEE 2022).

The country should also explore the option of taking advantage of its offshore wind energy, notably in the Safi region where the potential of this resource is at its peak and the water depth is less than 50 m, making it very suitable to implement offshore wind turbines (Fig. 4).

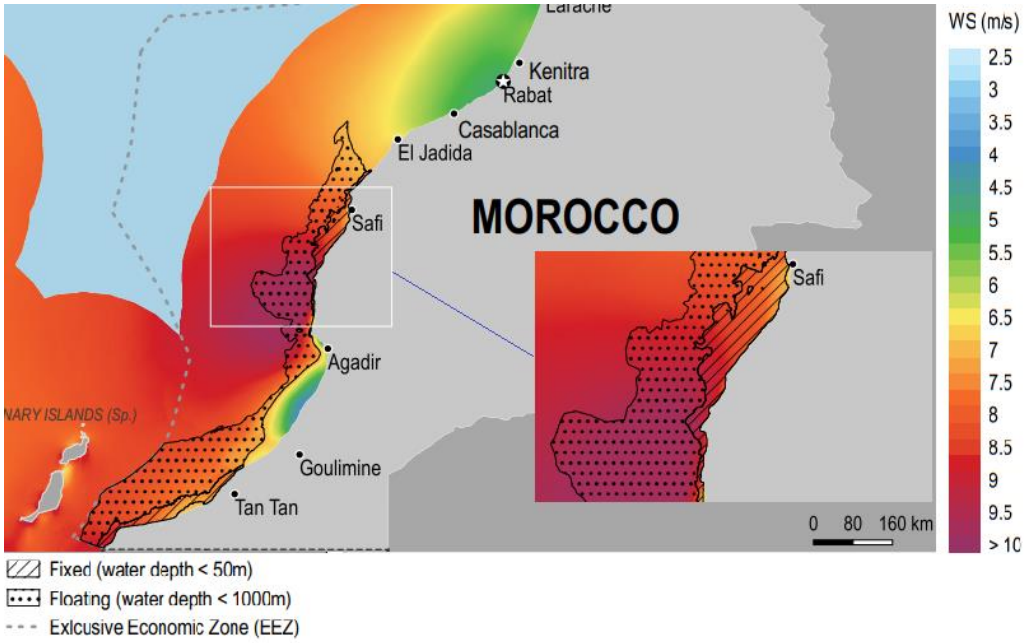


Fig. 4. Morocco's offshore wind suitable sites (Naimi et al. 2016)

Rys. 4. Morskie farmy wiatrowe w Maroku z odpowiednimi lokalizacjami

The hub heights of wind turbines used in Morocco generally ranged from 100 to 150 meters (Sierra et al. 2016). However, there are models of wind turbines of various sizes, with hub heights reaching up to 220 meters or more (Ahmed et al. 2019). Wind-turbine height is an important factor that can affect their efficiency (Smith et al. 2016).

Despite the projects completed in the development of wind energy in Morocco, challenges remain. For example, the high initial costs of construction and the maintenance of wind farms. It is necessary to improve the efficiency of wind turbines by increasing the heights of the hub Figures 5 and 6, to make wind power plants more profitable, and at the same time, more demanding in terms of investment and technicality.

Also, the geographical and environmental challenges of building wind projects in Morocco, such as the hilly terrain and lack of access to transmission infrastructure, can also make it difficult to commercialize wind power.

Continued investment and development of wind energy in Morocco is important in realizing this potential and contributing to the country's sustainable development, especially in the southern region where the potential of the wind is at its peak and there are not enough projects Figure 7.

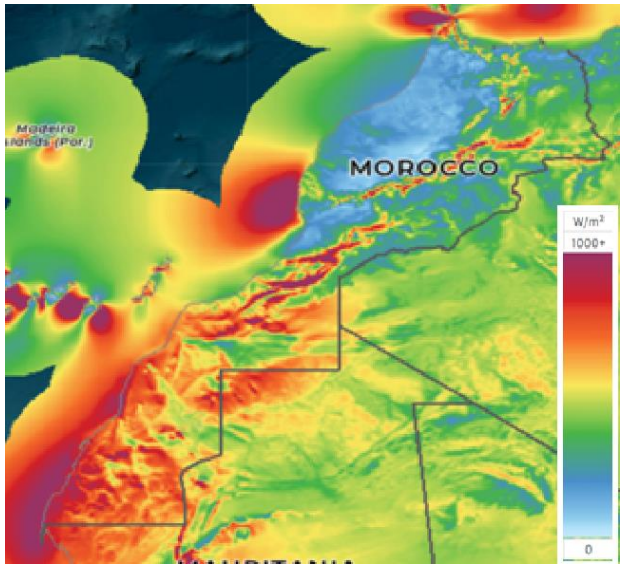


Fig. 5. Morocco's offshore wind energy potential at 100 m (Global Wind Atlas...)

Rys. 5. Potencjał morskiej energetyki wiatrowej Maroka w odległości 100 m

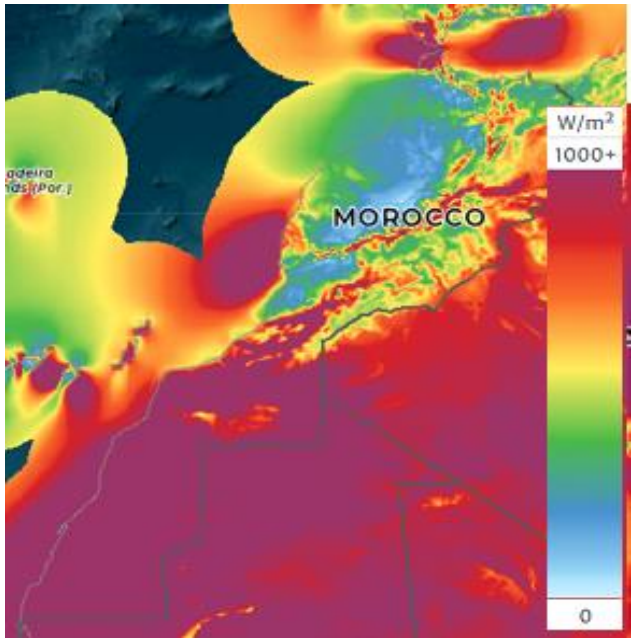


Fig. 6. Morocco's offshore wind energy potential at 200 m (Global Wind Atlas...)

Rys. 6. Potencjał morskiej energetyki wiatrowej Maroka w odległości 200 m

Fig. 7. Morocco's wind energy plants location (MASEN 2020)

Rys. 7. Lokalizacja elektrowni wiatrowych w Maroku

2.2. Solar energy

Morocco's solar energy potential is without doubt its strongest point, advantage to its high levels of solar radiation with an average of 6 to 7 kWh/m² per day, and around 85% of its territory covered by desert (Integrated Solar Energy...). This important solar potential has motivated the Moroccan government to invest in solar energy projects.

In 2009, Morocco launched the National Solar Plan to increase the contribution of solar energy to 14% of its electricity mix by 2020 and 52% by 2030 (Integrated Solar Energy...). The plan to achieve these goals included the development of very important large-scale solar projects, such as the Noor Solar Power Complex, which is the largest concentrated solar power plant in the world. The complex is in the region of Ouarzazate, in central Morocco, where the climatic conditions are at their fullest helpful potential (Figs. 8 and 9).

As of 2021, Morocco had already reached a total installed solar capacity of around 850 MW, according to the National Office of Electricity and Drinking Water (ONEE) (Captain-tide tool for tidal range database...). Following the success of the Noor Solar Power plant, notably the Nour 1

Solar Power Station (160 MW), the Nour 2 Solar Power Station (200 MW), and the Nour 3 Solar Power Station (150 MW) (Hanger et al. 2016), which contribute significantly to the kingdom's energy mix, other important similar projects are now ongoing, such as the Noor Tafilalt solar photovoltaic project (120 MW) consisting of three solar power plants in the regions of Zagora, Missour and Erfoud (ONEE 2021a).

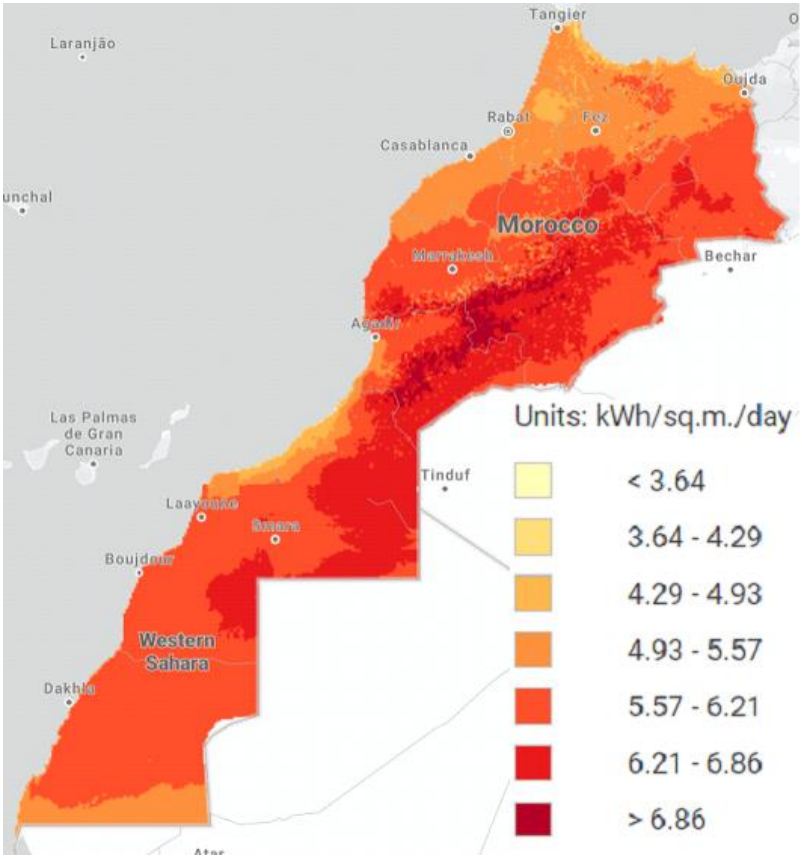


Fig. 8. Moroccan solar energy potential (Re-explorer Geospatial...)

Rys. 8. Potencjał energii słonecznej Maroka

2.3. Hydroelectric power

Hydroelectric power is a clean and renewable source of electricity playing a significant role in Morocco's energy mix. The kingdom's hydroelectric dams in operation, include the Mohammed VI dam on the Oum Er-Rbia river, with an installed capacity of 365 MW, the Al Massira dam (300 MW), the Al Wahda dam (135 MW), the Sidi Moktar dam (120 MW) and several

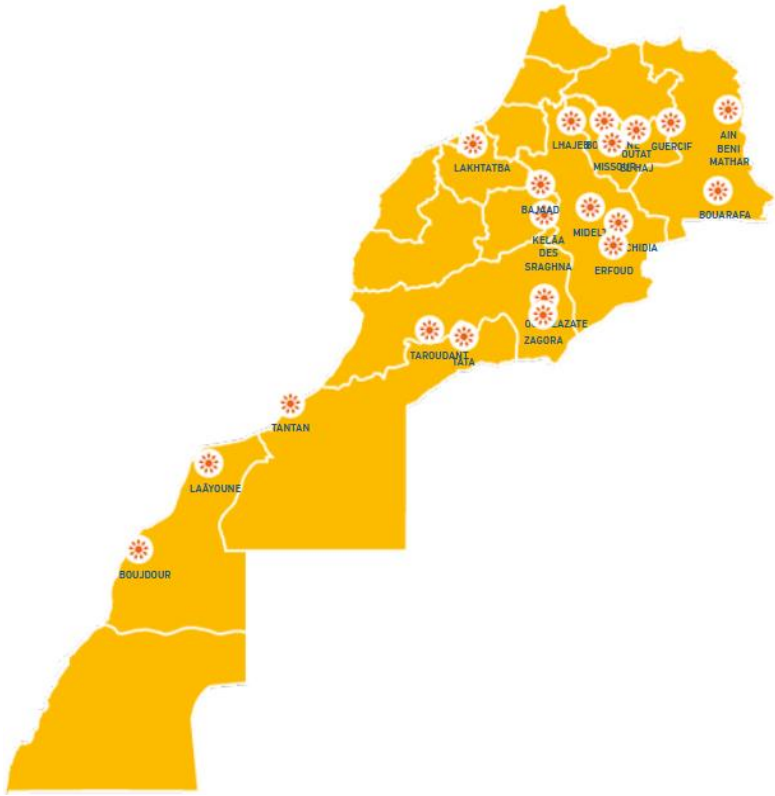


Fig. 9. Morocco's solar energy plants location (MASEN 2020)

Rys. 9. Lokalizacja elektrowni słonecznych w Maroku

more (Ministry of Energy, Mines, and Sustainable Development 2021). These dams located throughout the country, however, are now impacted by the potential droughts roaming over it in the past recent years (Fig. 10). However, this did not discourage the kingdom to change its policy; instead, it implemented some new hydroelectric dams and expanded the existing ones. Thanks to this strategy, as of 2021, Morocco achieved a total installed hydroelectric capacity of around 2000 MW (ONEE 2021b), and is still aiming for more, through new projects like Abdelmoumen STEP, the 2nd Energy Transfer Station by Pumping (STEP) in the kingdom, in the region of Agadir, with a capacity estimated at 350 MW and an overall cost of approximately 3.8 billion dirhams.

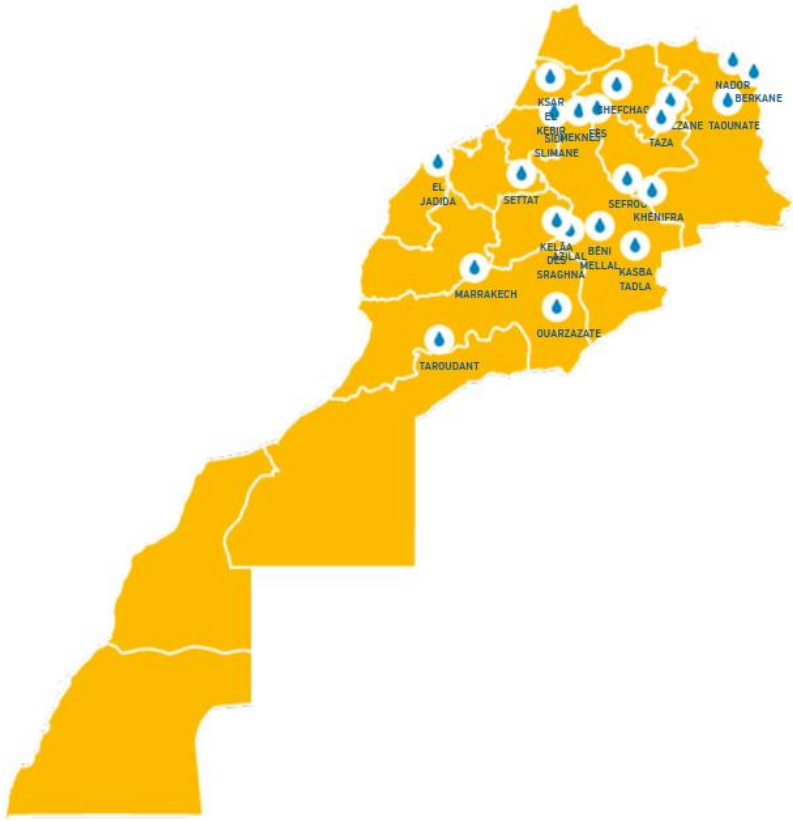


Fig. 10. Hydro power projects Map in Morocco (MASEN 2020)

Rys. 10. Lokalizacja elektrowni wodnych w Maroku

2.4. Tidal energy

Tidal energy is a clean and renewable source of electricity that is generated from tidal movements. It has a modest potential in Morocco since its tidal range is around 2 m (Captain-tide tool for tidal range database).

While Morocco's tidal energy is mostly unexploited, this is due to its relatively unfavourable geographical position (Fig. 11).

No location in Morocco has a profitable tidal range suitable for a tidal power plant, even Dakhla Bay on the Atlantic coast of Morocco has a tidal range of around two meters at best.

One of the other challenges facing the development of tidal energy in Morocco is the high upfront costs associated with building tidal energy facilities.

Overall, Morocco's tidal energy potential is too low to help the country meet its energy needs and reduce its reliance on fossil fuels.

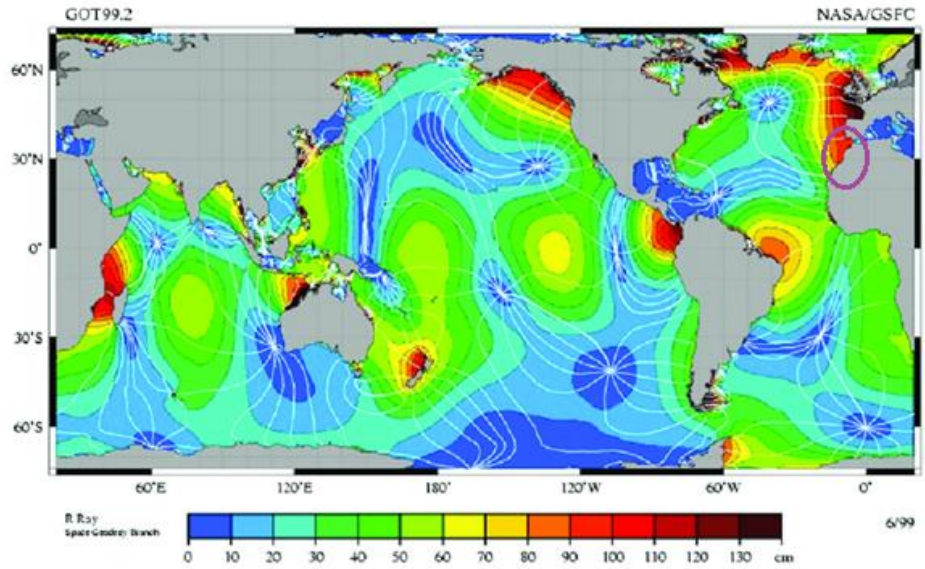


Fig. 11. Global tidal ranges (NASA—Goddard Space Flight Center 2015)

Rys. 11. Globalne zasięgi pływów

2.5. Wave energy

A study estimated the annual wave energy potential of Morocco to be around 262 MWh/m, which is about 20% of the country's current electricity consumption (Sierra et al. 2016).

The study, which was published in 2010, used wave data from several locations along the Moroccan coastline to estimate the wave energy resource. The results showed that the highest wave energy potential was found along the northwest coast of Morocco, in the region between Casablanca and Rabat, with the highest potential recorded as being in winter (Ozgener et al. 2004).

2.6. Biomass

Morocco has a diverse range of biomass resources, including agricultural waste, forestry waste, and energy crops. Agricultural waste includes materials such as straw, corn stalks, and olive pits, while forestry waste includes materials such as sawdust and wood chips.

One of the most promising forms of this source of energy in Morocco is olive pits. The country is one of the world's largest producers of olive oil, and the production of this oil generates a large amount of waste in the form of pits. These pits can be used to generate energy through combu-

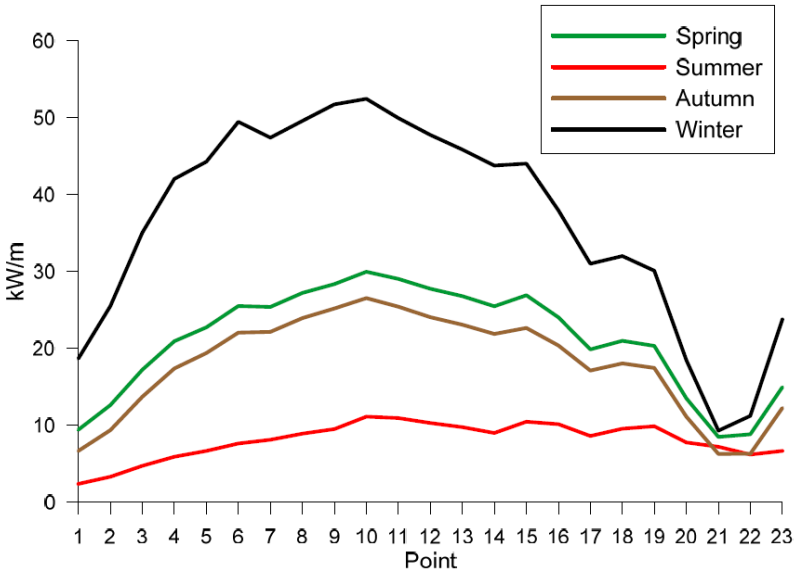


Fig. 12. Seasonal average values of the wave power per unit on Morocco's Coastline (Ozgener et al. 2004)

Rys. 12. Średnie sezonowe wartości mocy fal na jednostkę na wybrzeżu Maroka

stion or conversion into biofuels, in fact, this is estimated to produce about 2,828.11 GWh/year (World Bank Group... 2020).

With nine million hectares of forestry, the potential of biomass production in Morocco is considerable, notably in the rural part (Fig. 13).

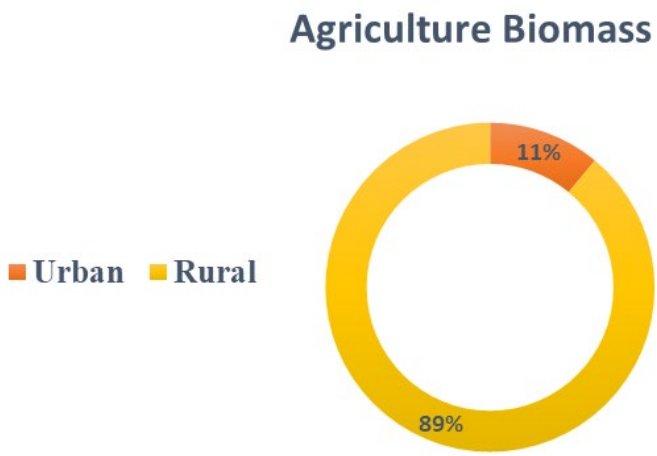


Fig. 13. Potential biomass production in Morocco (Mana et al. 2021)

Rys. 13. Potencjalna produkcja biomasy w Maroku

This potential lead the kingdom to join the International Bioenergy Platform (IBP) and the African Bioenergy Partnership (ABP) to boost the development and use of bioenergy. It is important to note that the full potential of the Moroccan biomass resources and their use for energy generation still requires further research and development, notably with regard to liquid biofuel and its application in transportation as a substitute for fossil resources, as well as microalga biomass which grow over twenty times faster than terrestrial crops and shows better benefits.

Other challenges that need to be addressed include the lack of appropriate technologies and the lack of infrastructure to collect and transport the resources.

2.7. Domestic waste

In addition to these resources, Morocco can explore the potential of domestic waste as renewable energy. A study conducted on the biomass collected from domestic waste in the region of Rabat revealed that the local discharge could produce the equivalent of 9.13 GWH electricity from methane due to household waste in Morocco containing about 70% of organic matter (Naimi et al. 2016), and the production of this resource keeps increasing every year (Fig. 14).

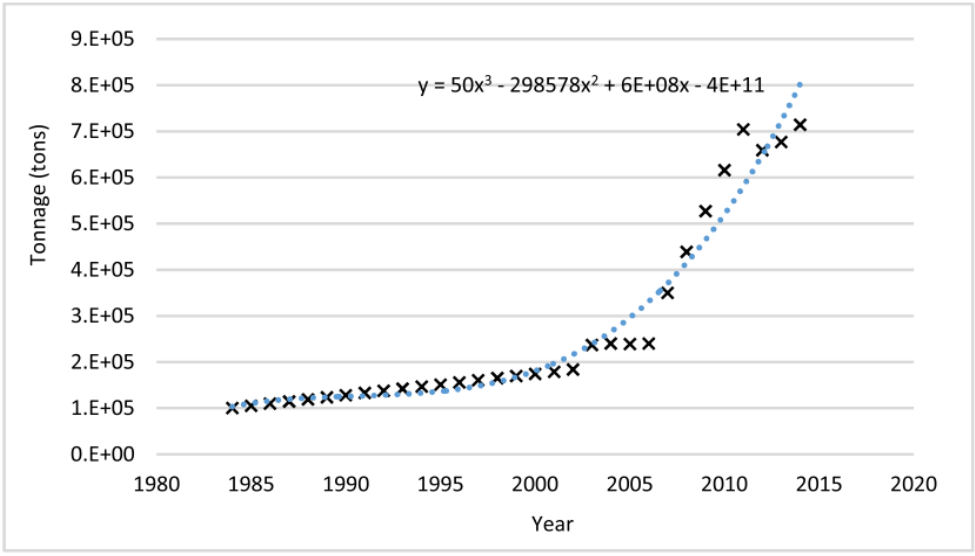


Fig. 14. Evolution of the waste tonnage in the region of Rabat (Naimi et al. 2016)

Rys. 14. Ewolucja tonażu odpadów w rejonie Rabatu

Many studies have been conducted on the subject, and while some of them revealed the difficulty for developing countries like Morocco to keep up with the waste generated by their growing population (Zikali et al. 2022), others have provided guidelines for the recycling of household solid waste to produce energy (Honcharuk et al. 2023). The kingdom can employ this valuable knowledge to succeed in developing this kind of energy in the future.

2.8. Geothermal energy

According to the Moroccan Agency for Sustainable Energy (MASEN), Morocco has a limited potential for geothermal energy which is generated by the heat from the earth and is typically found in areas with high volcanic or geothermal activity.

While Morocco does have some geothermal resources, these resources are not as significant as the country's solar, wind and hydroelectric resources.

While only a few studies have been performed on this subject, they have revealed that the northeastern region shows the most promising result (Fig. 15), notably at the region of Berkane

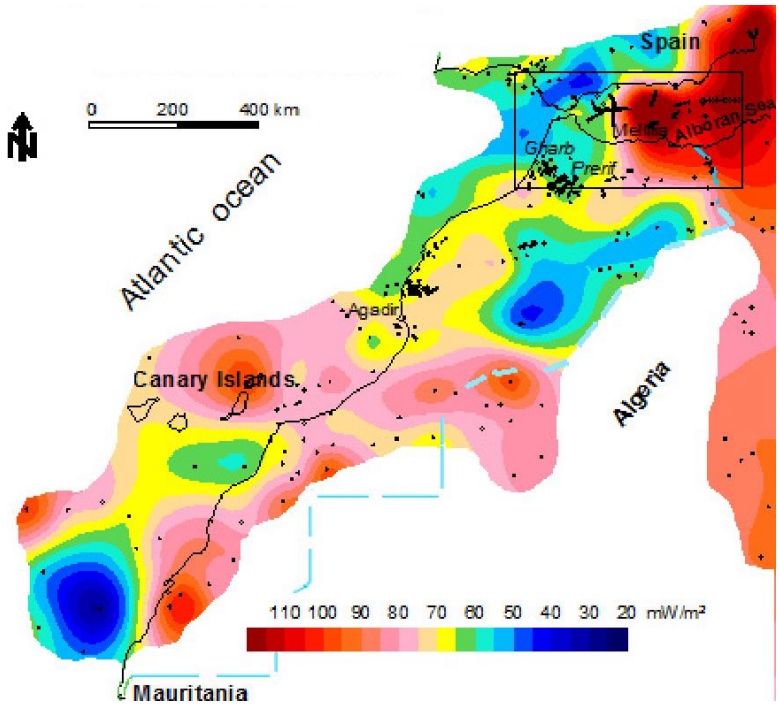


Fig. 15. Geothermal heat flow density map for Morocco (Correia et al. 2017)

Rys. 15. Mapa gęstości przepływu ciepła geotermalnego dla Maroka

where this energy potential is at its peak (Fig. 16), Morocco still doesn't have any exploitable geothermal projects.

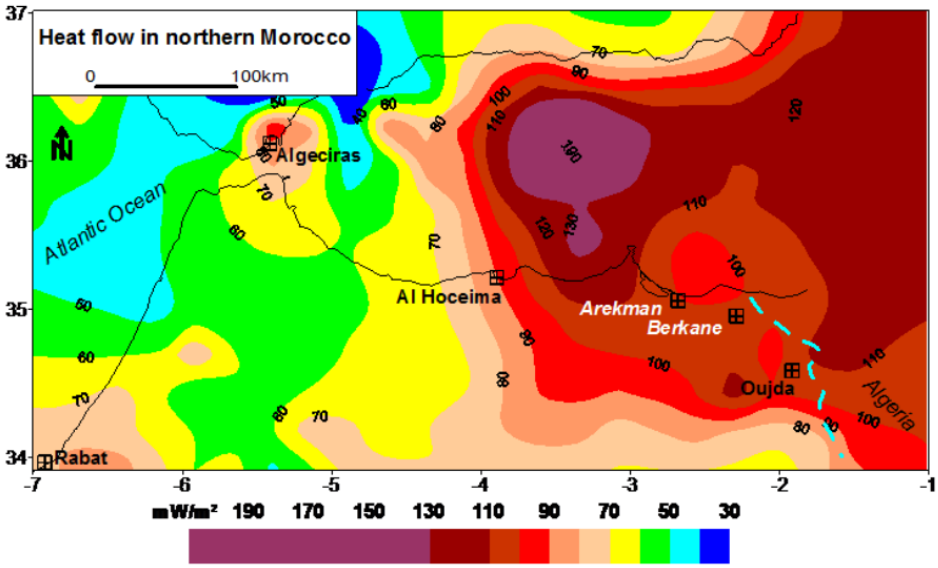


Fig. 16. Detailed geothermal heat flow density map for the region of Berkane (World Bank Group... 2020)

Rys. 16. Szczegółowa mapa gęstości przepływu ciepła geotermalnego dla rejonu Berkane

Much research has been conducted in order to explore the potential of geothermal energy in the Kingdom; one of the most advanced was performed on the Kariat Arekman Borehole, which showed that the temperature measured at 470 m reached 50°C (Fig. 16) and can generate about 9.5 GJ/m^2 (World Bank Group... 2020).

This promising discovery reveal that more research needs to be performed on this subject in order to assess the true potential of Morocco's geothermal energy.

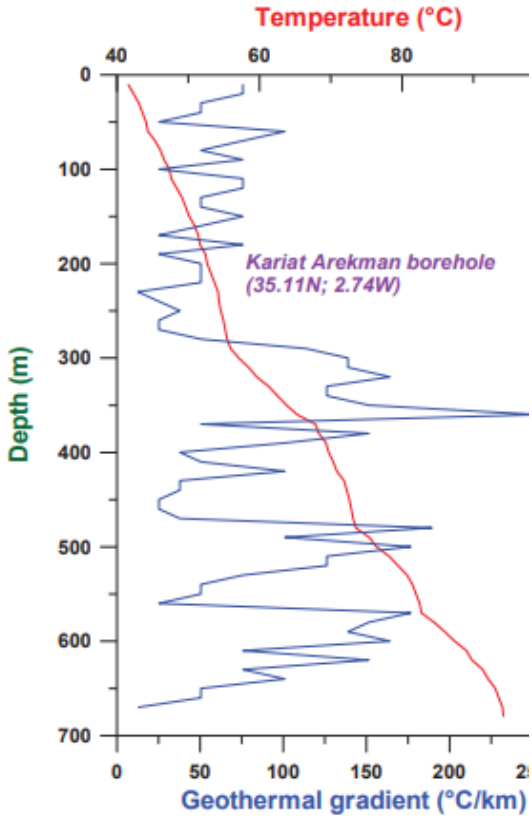


Fig. 17. Temperature Log of Kariat Arekman Borehole (World Bank Group... 2020)

Rys. 17. Rejestr temperatury w odwiercie Kariat Arekman

3. Forecast of future energy needs

The country is currently heavily dependent on imported fossil fuels, particularly oil and gas, which are expensive and vulnerable to price fluctuations. This was one of the main reasons that led Morocco to address these challenges by setting ambitious goals for investing in renewable energy.

The demand for electricity consumption in Morocco has increased at an annual average of 7% since 2002 (Šimelytė 2019). This is driven by many factors, including population growth, economic development, and urbanization witnessed in the past few decades.

It is expected that the electricity demand in Morocco will reach 62 TWh in 2025 (Hanger et al. 2016) which will make it even harder for the country to attain its aim of reaching 52% of the national electricity needs through renewable energy.

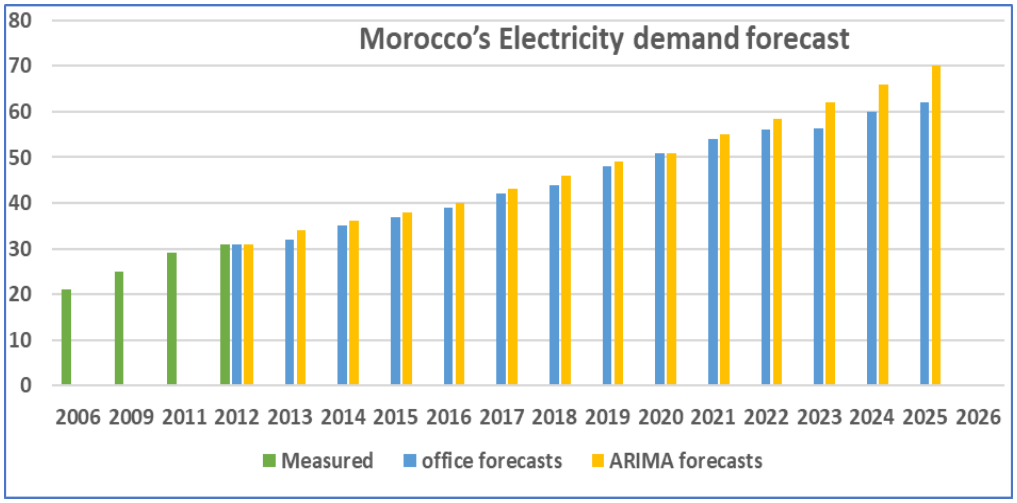


Fig. 18. Morocco's Electricity demand forecast [TWH] (Hanger et al. 2016)

Rys. 18. Prognoza zapotrzebowania na energię elektryczną w Maroku [TWH]

Other studies have also highlighted the significant growth in energy demand that Morocco is likely to experience in the coming years. For example, a report by the International Renewable Energy Agency (IRENA) projects that the country's total final energy consumption will reach 49 Mtoe (million tons of oil equivalents) in 2030, which is an increase of more than 50% from the 2015 level (IRENA 2016).

Population growth wasn't the only driver of this increase in energy demand, in fact, economic development, the expansion of industrial sectors, the electrification of almost all the rural regions, and the change of habits among citizens are now leaning more towards a civilized high energy-consuming lifestyle than traditional lifestyle. All of these factors have been significant with regard to energy consumption in Morocco.

The Kingdom's population is expected to reach 44 million by 2050 (United Nations.World Population Prospects 2019), and consequently, this growth will reflect a high demand for energy production to fulfil the needs of urbanization.

To meet its energy demand forecast, Morocco will need to consider a larger range of options, including the expansion of its domestic energy production, the development of new energy sources, and the improvement of energy efficiency.

4. The level of exploitation of these resources

The Moroccan Ministry of Energy Transition and Sustainable Development has announced that the country's national energy strategy, launched in 2009, has increased the country's electrical capacity from renewable energy sources to more than 4.1 gigawatts, representing approximately 38% of Morocco's total installed electrical capacity (The Ministry of Energy Transition 2022). The strategy included a range of solar, wind, and hydroelectric projects, with an investment of around fifty-five billion dirhams (approx. $5.5 billion) between 2009 and 2022. In 2018, Morocco had already achieved 34% renewable energy capacity, with around 1,770 MW from hydroelectricity, 1,220 MW from wind energy, and 711 MW from solar energy (Ameur et al. 2019).

The solar energy potential in Morocco is particularly high due to the country's high incident solar radiation of approximately 5.1 kWh/m^2/day and more than 3,200 hours of sunshine per year (Nait Mensour et al. 2019). Some solar plants like the NOOR 3 also have a thermal storage capacity of up to 8 hours and this way significantly contributing to Morocco's solar energy capacity (Relloso and Gutiérrez 2017).

The potential for wind energy in Morocco is estimated to be over 6,000 MW, particularly in the north of the country (Allouhi et al. 2017). As of 2021, Morocco had an installed wind capacity of approximately 1,500 MW, and the country has plans to increase it to 2,600 MW by 2030.

Hydropower is also an important source of renewable energy in Morocco, with an installed capacity of approximately 2,000 MW as of 2020, including 464 MW from PETS (STEP pumped energy transfer stations) (ONEE 2021a).

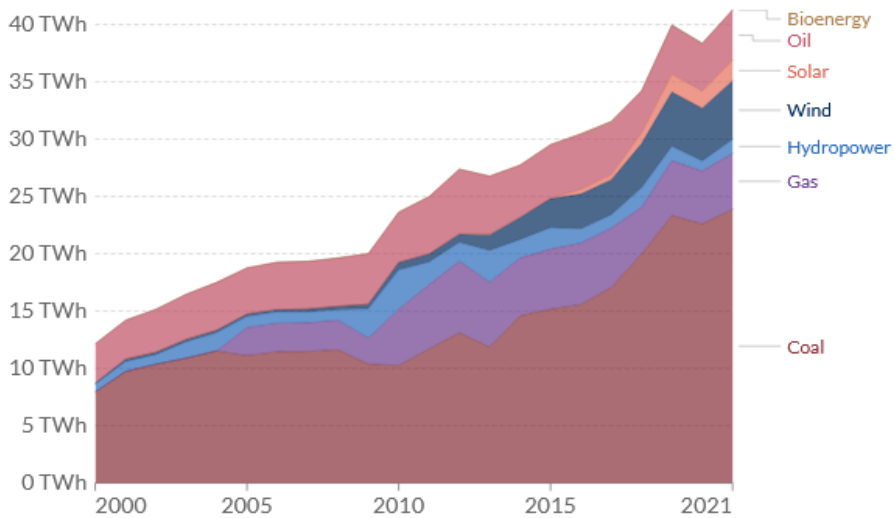


Fig. 19. Morocco's electricity production (Our World in Data based... 2022)

Rys. 19. Produkcja energii elektrycznej w Maroku

Although Morocco has significant biomass resources, the country currently only uses about 1% of this due to a lack of processing techniques (Kousksou et al. 2015).

More research about managing these resources needs to be performed in order to highlight the wasted potential of biomass energy.

5. The costs and benefits of different renewable energy

The costs of renewable energy technologies vary around the world, with several factors influencing the price of electricity generated from these sources. A comparison between renewable energy power costs in both the international market and in Morocco, using data from the International Renewable Energy Agency (IREA) and the Moroccan Ministry of Energy, Mines, and Sustainable Development, shows that the levelized cost of electricity (LCOE) for solar photovoltaic (PV) systems ranges from $0.06/kWh to $0.30/kWh in the international market. While in Morocco, solar power ranges from $0.06/kWh to $0.09/kWh, which is lower than the international average. This is due to many factors, such as favorable solar radiation conditions in Morocco and government policies supporting the adoption of solar power.

The same goes for wind power which ranges from $0.03/kWh to $0.15/kWh internationally but from $0.05/kWh to $0.08/kWh in Morocco. This lower cost is once again attributed to the kingdom's favorable wind resource conditions and the support for the expansion of the wind power industry.

As for hydroelectric power, the prices range from $0.03/kWh to $0.30/kWh in the global market, and from $0.03/kWh to $0.06/kWh in Morocco, followed by biomass, with a LCOE of around $0.16 /kWh (Mana et al. 2021).

Finally, the LCOE for geothermal power usually ranges from $0.05/kWh to $0.20/kWh, but no data is available for the local market since geothermal power is not a significant source of electricity in Morocco and is thus outside the scope of efficient renewable energy (IREA 2020).

The average cost of installing solar power systems ranges from $3,500 to $7,000 per kilowatt (kW) of installed capacity, depending on the location and the size of the system. While the average cost of maintaining a residential solar panel system ranges from $300 to $500 per year (DOE 2021).

In the case of wind energy, the cost of installing power systems ranges from $3,000 to $6,000 per kW of installed capacity and the average cost of maintaining a small wind turbine for residential use ranges from $300 to $1,000 per year.

Hydroelectric power systems on the other hand cost from $1,500 to $3,000 per kW of installed capacity and the average cost of maintaining a small hydroelectric power system ranges from $500 to $1,500 per year.

While the installation cost of a biomass power plant is around 3,755.7 $ per kW (Mana et al. 2021).

However, the average cost of installing geothermal power systems ranges from $2,000 to $4,000 per kW of installed capacity, estimated with an average cost of maintenance for a residential geothermal heat pump ranging from $500 to $1,000 per year.

According to the International Renewable Energy Agency (2020), the average cost of maintaining a tidal power plant ranges from $500 to $1,500 per year per kW of installed capacity. While the cost of installing it ranges from $2,000 to $6,000 per kilowatt (kW) of installed capacity (American Wind Energy Association 2021; IREA 2020).

Generally, it appears that the costs of renewable energy technologies are generally lower in Morocco compared to the international average. This is due to a combination of favorable conditions with regard to natural resources, lower human resources costs and supportive government policies. Further research and new technologies may contribute to decreasing these costs even more.

All this data highlights that Morocco should give priority to hydroelectric power and biomass followed by solar and wind energy for a cost-efficient investment before relying on other sources.

6. The costs and benefits of different renewable energy storage

Several different technologies can be used to store renewable energy, each with its own costs and benefits.

Battery storage systems can store excess energy to be released back into the grid when needed. The main benefit of battery storage is to solve the issue of intermittence of renewable energy and avoid a shortage even when the sun isn't shining or the wind isn't blowing. However, batteries can be expensive to install and maintain, and their capacity tends to degrade over time.

Another way to store energy is pumped hydroelectric storage, which involves pumping water from a lower reservoir to an upper reservoir when excess energy is available and then releasing the water back down through a turbine to generate electricity when needed. Pumped hydroelectric storage is cheap and can be used to store large amounts of energy for long periods. However, it requires a large amount of space making it available to be used only in certain geographical areas.

The use of thermal storage systems for excess energy to heat a medium, such as water or molten salt. Thermal storage systems can be used with a variety of renewable energy sources. The advantage of this type of storage is that it allows renewable energy to be used to generate electricity around the clock without any restriction on the location.

Finally, Power to X, which is a way to store energy in a flexible component that is easy and ready to use like hydrogen, can be produced from excess renewable energy and then used as a fuel in a variety of applications, including transportation and electricity generation. The main benefit of hydrogen storage is that it allows renewable energy to be used in a wide range of applications, and hydrogen can be stored for long periods. However, producing hydrogen from

renewable energy can be expensive, and the infrastructure needed to store and use hydrogen is still in the early stages of development.

Some general estimates for the costs of different renewable energy storage technologies:

The costs of storage system vary significantly depending on their size and type of the system installed. According to the U.S. Department of Energy, the costs of installing battery storage systems can range from around $300 per kilowatt-hour (kWh) for small-scale systems to around $200 per kWh for large-scale systems (Ban et al. 2012).

Prices for installing pumped hydro storage systems varies greatly depending on the installation site, and range usually from about $1,000 per kWh to about $8,000 per kWh with bigger systems costing more due to site preparation and costs relating to construction and engineering (IRENA 2012).

The costs of thermal storage systems according to IRENA, range from around $200 per kWh to around $1,500 per kWh.

Finally, hydrogen storage systems can vary widely depending on the size and type of system being installed. The costs range from around $2 per kilogram (kg) for small-scale systems to around $1 per kg for large-scale systems.

7. The current state of renewable energy financing in Morocco

Morocco has made significant progress in recent years that has been supported by a range of financing sources including the Moroccan Agency for Sustainable Energy (MASEN) which has secured $4.3 billion in financing for its Noor Midelt solar power complex through the financing provided by a consortium of international banks and export credit agencies (MASEN 2018).

The African Development Bank (AfDB) has also provided several loans to support the development of renewable energy projects in Morocco, including a $120 million loan approved in December 2020 as well as a $300 million loan approved in October 2018 (African Development Bank... 2018).

The World Bank has also provided support for renewable energy projects in Morocco, with a $500 million loan approved in January 2019 as well as a $50 million grant from the Clean Technology Fund (CTF) approved in January 2020 (World Bank Approves... 2019; CTF Approves... 2020).

The European Investment Bank (EIB) has approved several loans to support renewable energy projects in Morocco, including a $170 million loan approved in July 2019 and a $242 million loan approved in January 2021 (EIB 2021).

The International Finance Corporation (IFC), a member of the World Bank Group, has provided two loans to support the development of renewable energy projects in Morocco, including a $70 million loan for a 200 MW wind farm approved in October 2019, and a $100 million loan for a 300 MW solar power plant approved in January 2021 (IFC 2016).

The International Renewable Energy Agency (IRENA) has also provided technical assistance and funding to support the development of renewable energy projects in Morocco, including the construction of a 100 MW solar power plant (IRENA 2021).

Overall, these financing sources have played a critical role in supporting the development of renewable energy projects in Morocco, helping the country to make significant progress towards its goal of increasing the share of renewable energy in its energy mix.

8. Discussion and recommendations

8.1. Renewable energy for powering irrigation

The potential of renewable energy for powering irrigation in Morocco is significant. This is principally with regard to the abundant energy resources and the importance of the agriculture sector in Morocco, which is accounting for around 15% of the country's GDP and employing approximately 30% of the population's work force (The International Trade Administration... 2022).

According to the Moroccan Ministry of Agriculture, there are around 4 million hectares of irrigated land in Morocco, representing around 20% of the country's total agricultural land (World Bank Morocco... 2017; Moroccan Ministry of Agriculture... 2022). The majority of irrigation in Morocco uses traditional methods, which rely on unreliable weather conditions and the use of fossil fuels which are not as efficient as modern drip irrigation systems.

The use of renewable energy sources such as solar and wind sources to power irrigation systems, specifically due to the locations agricultural land, is well positioned to benefit from the renewable energy resources as shown in Figure 20.

The use of renewable energy for irrigation in Morocco has numerous other benefits. In addition to reducing greenhouse gas emissions and contributing to the fight against climate change, it also provides a more reliable and sustainable source of energy.

Morocco could follow and learn from the examples of the use of renewable energy to power irrigation systems around the world. One well-known example in New Mexico is the Lujan Farm Irrigation Project. This project, which was implemented by the Middle Rio Grande Conservancy District (MRGCD) and the United States Department of Agriculture (USDA), involved the installation of a solar-powered irrigation system at the Lujan Farm in Los Lunas, New Mexico.

The system, which was completed in 2015, consists of a solar panel array that generates electricity to power a series of pumps that deliver water from the Rio Grande to the farm. The solar panel array has a capacity of 500 kilowatts (kW) and the pumps can deliver up to 1.2 cubic feet of water per second (MRGCD 2023).

According to MRGCD, the solar-powered irrigation system has resulted in significant energy cost savings for the Lujan Farm, as well as reduced greenhouse gas emissions. In addition, the

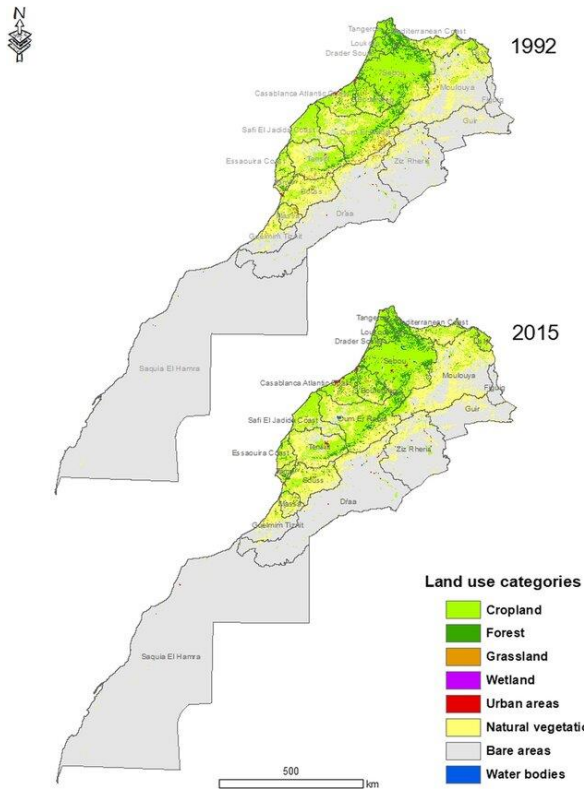


Fig. 20. Morocco's land use (Re-explorer Geospatial analysis... 2023)

Rys. 20. Użytkowanie gruntów w Maroku

project has helped to improve the reliability and efficiency of the farm's irrigation system and has allowed the farm to expand its agricultural operations (USDA 2015).

Another example is the solar-powered irrigation system in the Indian state of Tamil Nadu, which was implemented as a pilot project in the village of Mannargudi. The project used photovoltaic panels to power a submersible pump that supplied water to crops. The project was implemented by the Tamil Nadu Energy Development Agency (TEDA) in collaboration with the United Nations Development Program (UNDP) (Megalingam and Gedela 2017).

The solar-powered irrigation system was successful in increasing crop yields and improving the livelihoods of local farmers. According to a case study published in the Renewable and Sustainable Energy Reviews journal, the project resulted in a 30% increase in crop yields for participating farmers, and a 50% increase in their incomes. The project also had many other benefits, including reducing the reliance on fossil fuels for irrigation, improving the availability of water for irrigation, and reducing the burden of manual labor for farmers (Kumar et al. 2023).

It is worth noting though that the use of renewable energy to power irrigation systems is not without its challenges. As a matter of fact, the initial cost of installing renewable energy systems

can be high, which can be a barrier for farmers and other agriculture stakeholders. In addition, renewable energy systems may require more maintenance and repair compared to traditional systems, which can also increase costs.

Our recommendation is to encourage the government to help and invest in introducing these technologies by sensitizing and supporting the farmers in achieving it, especially since the country suffers from droughts and long summers which heavily impact upon that important sector, which is one of the pillars of its economy.

8.2. Renewable energy for powering desalination

The process of removing salt and other minerals from seawater to make it suitable for drinking and irrigation is known as desalination; it has gained increasing attention as a means of addressing water scarcity in arid and semi-arid regions. As one of the countries that suffer from low pure water resources and irregular rain, Morocco has implemented several desalination projects as part of its efforts to secure a reliable water supply for its growing population.

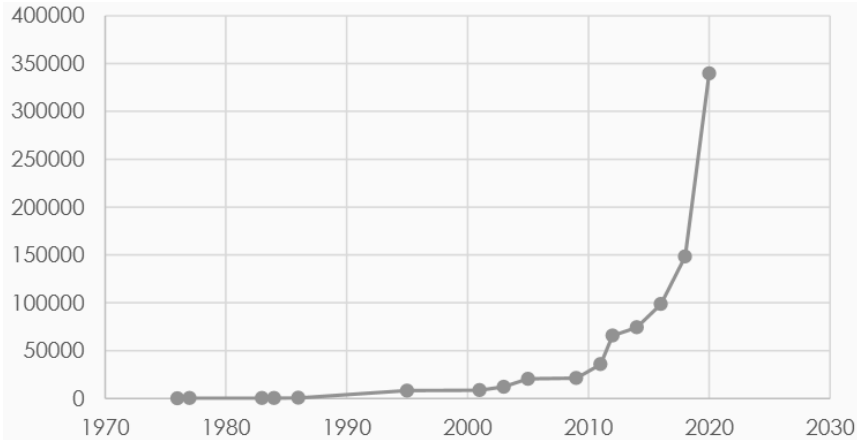


Fig. 21. Morocco's desalination capacity evolution (ONEE 2022)

Rys. 21. Ewolucja zdolności odsalania Maroka

According to its National Water Agency (ONEE), as of 2022, Morocco has had a desalination capacity of around 400,000 cubic meters per day, and another 413,500 programmed by extending the capacity of the existing water production plants and building new plants, mainly that of Casablanca with 300,000 cubic meters per day capacity, considerably enhancing the country's total water production. This capacity is provided by a mix of reverse osmosis (RO) and multi-stage flash (MSF) desalination technologies (ONEE 2022).

Morocco's desalination projects are mainly located on the Mediterranean and Atlantic coasts, where the country's main cities and industries are located. The Mediterranean is Morocco's main source of seawater for desalination (World Bank Morocco 2020).

Many challenges have been faced by Morocco in implementing desalination projects, starting with the high cost of the process. This technology is generally more expensive than other sources of water (surface water or groundwater), due to the energy and other elements required to remove the salt and other impurities. This situation led the kingdom to the adoption of energy -efficient technologies to mitigate the cost of energy needed for its desalination plants.

Despite all of this, Morocco's experience with desalination has demonstrated the potential of the technology as a solution to water scarcity in arid regions. With its growing population and increasing demand for water, the country has no choice but to continue expanding its desalination capacity in the coming years and extend the use of renewable energy to this technology. A combination that was proven to be successful by many desalination plants around the world. One well-known example is The Al Khafji, the world's first large-scale solar-powered desalination plant, located in Saudi Arabia with a capacity of 60,000 m^3 per day, completed in 2018, which uses solely solar energy to serve 100,000 citizens while saving an estimated 1.5 million barrels of oil per day (U.S.-Saudi Business Council... 2021).

Following these successful examples, while having abundant renewable energy, the Atlantic on the west and the Mediterranean Sea on the north, Morocco should focus on desalination using renewable energy instead of the dam strategy to avoid the drought threatening it these few past decades, especially with the growth of its population and the reliability of such a process in Figure 22. As a matter of fact, desalination technologies with renewable energy were proven by many

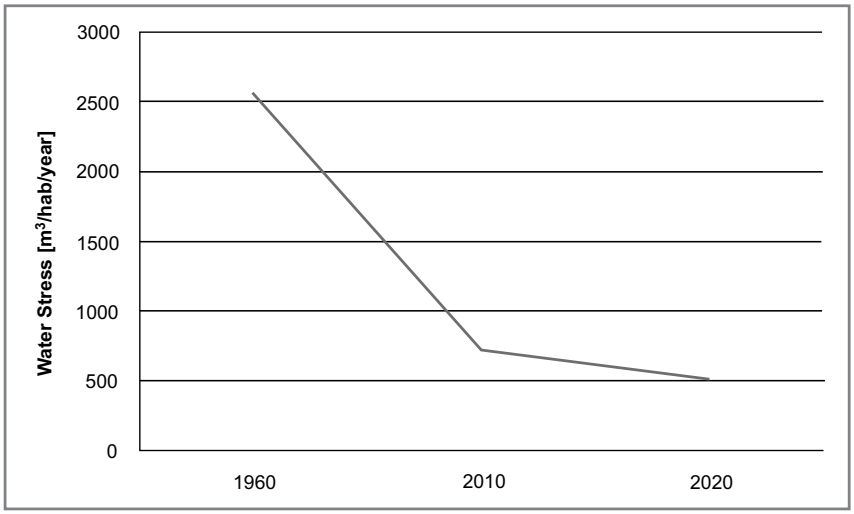


Fig. 22. Morocco's Water Stress Evolution (ONEE 2022)

Rys. 22. Ewolucja niedoboru wody w Maroku

studies as one of the best combinations (Ghaffour et al. 2015), notably because of the possibility to use the excess electricity to produce more water instead of being wasted on the grid, since several renewable energy plants in the country lack the ability to store it, and the location of the desalination stations are suitable for taking advantage of it.

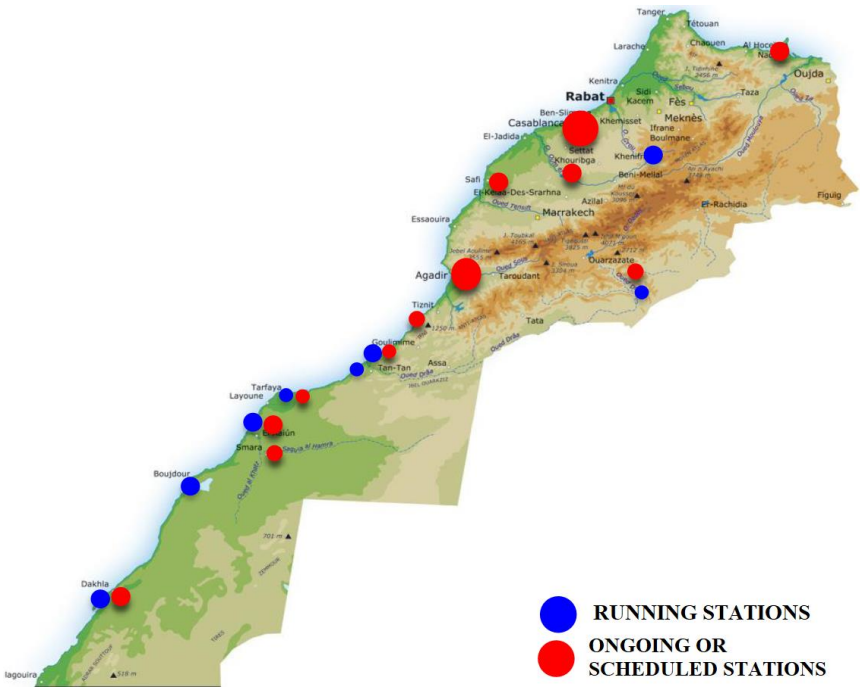


Fig. 23. Morocco's desalination projects (ONEE 2022)

Rys. 23. Projekty odsalania w Maroku

8.3. Renewable energy for powering transportation

One well-known example of the use of renewable energy for powering transportation is the use of electric vehicles (EVs). These battery-powered vehicles emit significantly less pollution compared to traditional gasoline-powered alternatives and are increasing in popularity throughout the world.

Another example is the use of hydrogen fuel cell vehicles which use hydrogen as a fuel source which is then combined with oxygen from the air to generate electricity. Hydrogen fuel cell vehicles emit only water vapor and are becoming increasingly popular in many countries.

Given that transportation in Morocco consumes more than 40% of the country's energy (AMEE 2021), the Kingdom has to accord priority to this sector primarily considering that

there are around five million vehicles in Morocco, using 60,000 km of roads (The Moroccan Ministry 2018).

Even if the country is promoting the use of hybrid and electrical cars through tax exemption, this is not enough, considering the fact that the environmental awareness level of the Moroccan population is often low. It is safe to assume that the use of electric cars will become more popular if the government vehicles themselves use it, in fact, the number of vehicles belonging to public administrations is around 200,000 (Megalingam and Gedela 2017), these administrations can either retrofit the old cars or sell them and buy electric or hybrid cars; this way, the use of this kind of vehicle will gain more popularity and the government can adapt the infrastructure for it, unlike the citizen who may be reluctant to invest on such a young technology that has not yet shown its capability on a large scale. Once this step is achieved, it'll be wise if the government imposes on all companies to buy electric cars, especially those handling public transport.

Another recommendation that could increase the efficiency of transportation is sensitizing the population to the advantages and benefits of car sharing; the public sector could also follow this logic through the use of centralized transport between administrations. In fact, instead of having many vehicles doing the same trip with one passenger each, a centralized transportation system for all administrations could reduce the cost and increase the efficiency of this sector.

8.4. Smart street lighting

Smart street lighting refers to streetlights that use connected technology able to optimize and control the light intensity of streets and public spaces, unlike traditional inefficient systems. This new generation allows the ability to adjust the lighting levels based on the needs and the presence of pedestrians or vehicles, consequently increasing energy efficiency by reducing energy consumption, which results in cost savings for cities and municipalities. In fact, a study conducted in San Diego, California found that the city's smart street lighting system resulted in a 63% reduction in energy usage and a savings of $250,000 per year (Bryant 2017; Brazil 2016).

This kind of street lighting could also improve public safety by using detection sensors, which allow the real-time adjustment of lighting levels, and ensures that streets are adequately lit at all times. Indeed, it has been proven to be capable of reducing the risk of accidents and incidents for both pedestrians and drivers (Rajat et al. 2021).

Many successful applications of smart street lighting have been implemented throughout the world by relying on efficient systems including LED lights and smart control points. These systems have resulted in energy savings of up to 50% (Martirano 2011) as well as improvements in public safety and the gathering of valuable data about the use of public spaces in the city.

Another study also showed that making the right choice from the range of LED lighting lamps available on the market can significantly reduce maintenance and energy costs (Mamalyga 2022).

Unquestionably, considering the fact that street lighting in Morocco is consuming 40% of the urban energy consumption (Moroccan Ministry of...), the kingdoms should place extreme importance on a strategy to modernize its public lighting not only to increase energy efficiency alone but also to improve the quality of life for the citizens, as shown in the previous successful examples.

8.5. Energy-efficient buildings

Energy-efficient buildings are structures that are designed and constructed in such a way that minimizes energy consumption and maximizes energy efficiency.

One of the primary benefits of such buildings in Morocco is their ability to reduce energy costs by using energy-efficient materials and technologies like assuring insulation, with energy -efficient windows, lighting, and more. This can significantly reduce their energy consumption, resulting in lower energy bills for building owners and occupants. In fact, a study conducted in Rabat, the capital of Morocco found that energy-efficient buildings had energy consumption levels that were 37% lower than the traditional levels (Bennis 2019).

Additionally, to reduce energy costs, these buildings can also improve indoor air quality. By using materials and technologies that minimize the release of pollutants and toxins into the air, thus creating a healthier indoor environment for building occupants and positively impacting upon their well-being.

In addition, this new generation of buildings can lower environmental impact by reducing the number of greenhouse gases emitted into the atmosphere and thus contributing to the overall sustainability of the built environment.

There are numerous examples of energy-efficient buildings in Morocco having successfully employed energy-efficient materials and technologies. One notable example is the Moroccan Pavilion at the Marrakech Climate Summit (COP22), which was designed to be a zero-energy building. The pavilion was constructed using energy-efficient materials and technologies, including solar panels, a green roof, and insulation, and was able to produce more energy than it consumed (The United Nations Framework Convention... 2016).

In front of all these benefits, the government can achieve the generalization of energy-efficient buildings without cost but instead harvest the benefit from it.

It is a necessity to encourage the Moroccan urban agency to impose an energy efficiency criterion on all new buildings and administrations since by itself, the population is unlikely to care or bother itself about these criteria.

Such a procedure is crucial and urgent in a country that is still growing and expanding, in fact, Morocco has inaugurated more than four new cities in the last decade. If the urban agency -imposed energy efficiency criteria by then on building companies, Morocco could have at least four energy-efficient cities by now, and lower electricity bills, benefiting both the kingdom and its citizens.

8.6. Micro-grids

Micro-grids are local energy grids operating independently from the traditional grid; they can provide reliable energy to communities and businesses on top of their ability to be powered by a variety of energy sources including solar panels and wind turbines. One of their main benefits is the faculty to provide a secure source of backup power during blackouts and natural disasters.

During these kinds of events, the traditional grid may leave communities without power, while the micro-grids, on the other hand, can continue to operate independently, providing a reliable source of electricity. This can be especially beneficial in areas that are prone to frequent outages or natural disasters (Younesi et al. 2020) by using a hybrid system which combines renewable energy sources with traditional fossil fuel-based power sources, such as natural gas generators.

There are many examples of successful micro-grid projects, starting with the solar-powered micro-grid on the island of Ta'u in American Samoa. This micro-grid, which was developed by the company Tesla, provides reliable, renewable energy to the island's 600 residents. It is powered by solar panels and battery storage systems and can operate independently from the traditional grid (Ospina 2017; Tiwari 2017).

Morocco could follow these successful examples to avoid complications during natural disasters, specifically now that global warming might increase their occurrence and intensity as observed in the region of Al-Hoceima. which is now suffering from frequent seismic events (nine earthquakes of at least magnitude 4, between August 2022 and January 2023) (Earthquaketrack tool for... 2023).

May it be as a backup precaution for a sad occurrence or not, the use of micro-grid benefits goes beyond that and this solution will also help in creating more jobs for the local community and reduce the energy cost while also following the country's ambitious goal of relying more on renewable energy.

8.7. The use of innovative financing mechanisms

As the demand for renewable energy continues to grow in Morocco, innovative financing mechanisms that have proven their efficacy all over the world have become important tools to consider for supporting the development of renewable energy projects in the country.

Some of these innovative financing mechanisms are green bonds, which are a type of debt instrument that is issued to fund environmental projects, including renewable energy projects. They can be issued by governments, corporations, or financial institutions and are typically sold to investors who are interested in supporting the transition to a low-carbon economy.

There is also crowdfunding, which involves the raising of small amounts of money from a large number of individuals; it has become a popular method for financing renewable energy projects around the world, like the "Solar Saves Lives" campaign launched in 2015 to fund the

installation of solar panels in hospitals in developing countries. The campaign, which was run through the crowdfunding platform Indiegogo, was able to raise over $300,000 from more than 2,000 donors (Solar Saves Lives campaign), proving this way its capable potential.

In 2018, the Minnesota-based company Geronimo Energy followed the same idea and launched a community solar program in the state, allowing individuals and organizations to invest in a 20 MW solar project and receive a share of the energy produced (Geronimo Energy community solar program 2018).

Taking into account the huge potential of such an opportunity to solve the financing issue of the country, a survey was done about Moroccan citizen willingness to invest and participate in crowdfunding renewable energy projects in the country.

The population was selected randomly and the data was analyzed using appropriate statistical methods by taking into account various demographic, socio-economic, and environmental factors.

The data revealed that the majority of the Moroccan citizens of legal age regardless of gender, revenue, or employment status, were willing to contribute to such a project, even the unemployed with some funds, as long as their contributions were guaranteed to be used properly through transparent and public financial management.

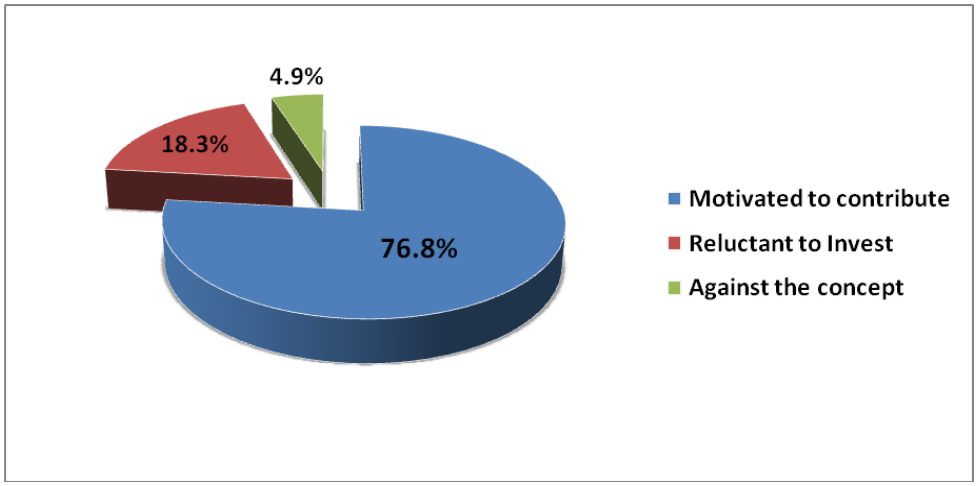


Fig. 24. The Moroccan population willingness to invest in crowdfunding of renewable energy projects

Rys. 24. Skłonność ludności Maroka do inwestowania w finansowanie społecznościowe projektów OZE

The banking of the government had a more slight impact compared to that of a reputable financial institution, yet both were changing factors to take the decision of investing for many citizens.

The amount of investment mostly chosen was below 1,000 Moroccan dirhams regardless of the income, which can be explained by the population's willingness to discover the potential of this investing mechanism with minimal risk.

The idea of harnessing renewable energy that allows sustainable development in Morocco, the reduction of electricity bills in the future, and the preservation of the environment motivated the citizen without being an impacting factor for investing in crowdfunding.

All of these factors indicate that Morocco's goal is within reach and has all it needs to do so, as long as some conditions are fulfilled.

Conclusion

Morocco is a country benefiting from a very advantageous geographical position; in addition to being the door to Europe through Africa and while being an emerging African country with no fossil resources, it was still able to be one of the most successful examples of renewable energy-orientated countries, whether it be wind energy, solar energy, or hydropower, the kingdom has proven that its expectations of renewable energy share were met and is still aiming for more.

However, in addition to social and economic factors, it is important to consider such as the potential impacts on local communities, the need to create jobs and economic opportunities in the renewable energy sector, the high costs of renewable energy technologies, the need for infrastructure investments, and the development of storage solutions to ensure the stability of the grid. The country has many other challenges to address in the hope of increasing and strengthening the country's capacity for renewable energy.

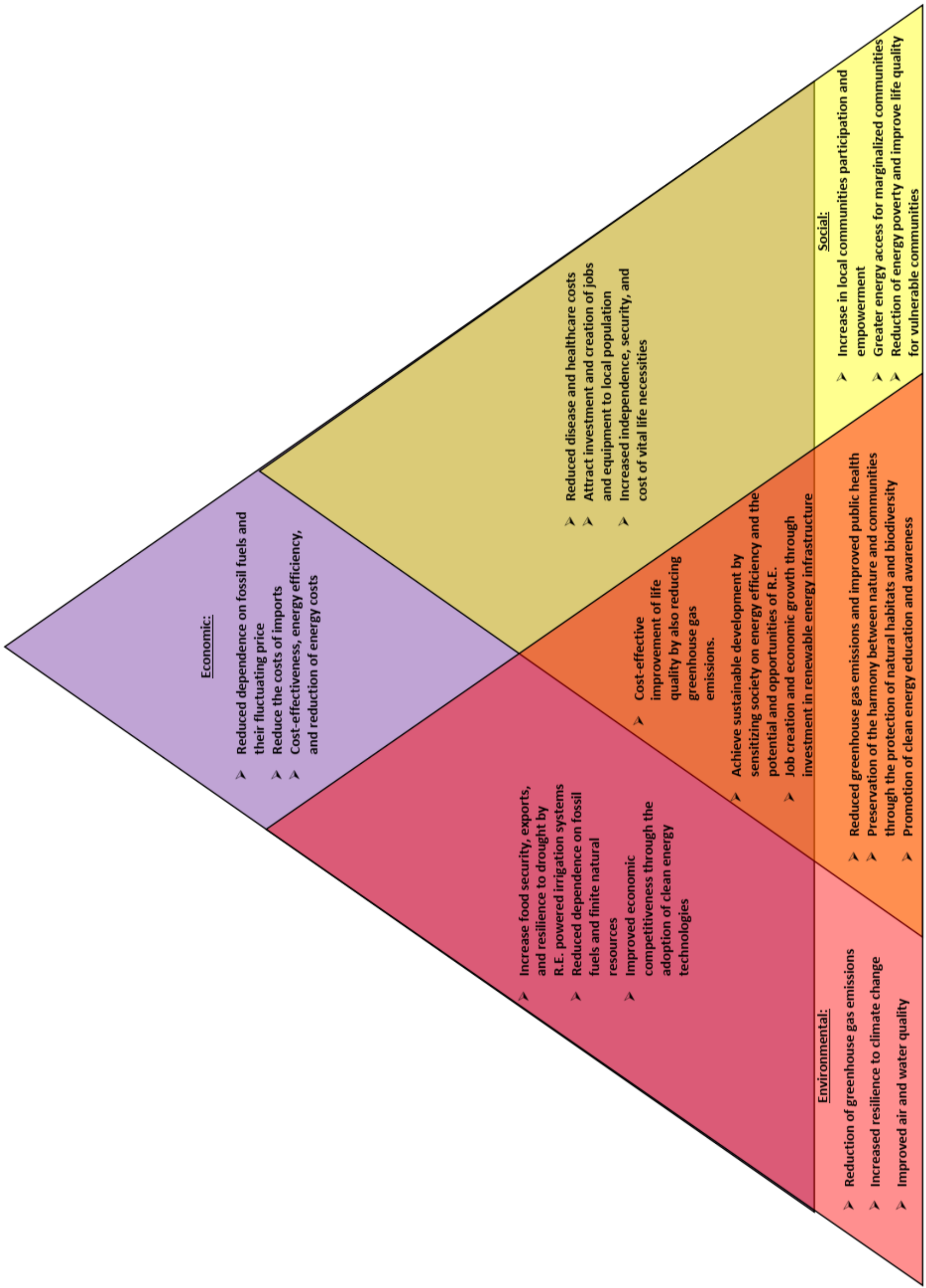
This is why a cost-benefit comparison was performed in this paper between different options to tackle the high price of renewable investment, and in light of that, some decisions could be made, for example, pumped hydroelectric storage was proven to be the most cost-effective energy storage solution available for the country and should be a focus of attention until the hydrogen storage technology reaches maturity.

With the right investments and support, Morocco's renewable energy sector has the potential to make a significant contribution to the country in many fields, notably since the biggest obstacles to achieve that goal are now easier due to guidelines provided and the result of the survey that revealed the will of the population to contribute significantly in the crowdfunding of clean energy projects.

Furthermore, the country has already started to see the benefit and the potential of applying its renewable energy in other fields and shall encourage it to enlarge the scope of its usage.

Some changes in the actual strategy have to be made, such as giving lesser priority to dams constructions and betting instead on the adoption of renewable energy to power desalination; in this way, Morocco can solve two major issues at the same time – water scarcity and the high cost of energy required for desalination. The same applies to transportation – using hydrogen-fuel-cell vehicles or electric vehicles can help the country reduce its greenhouse emissions and improve air quality.

That being said, producing more energy is not the only way to achieve this objective, in fact, through this paper we can see that a considerable amount of energy is wasted, be it by poor ma-


Economic:
Reduced dependence on fossil fuels and their fluctuating price
Reduce the costs of imports
Cost-effectiveness, energy efficiency, and reduction of energy costs
Increase food security, exports, and resilience to drought by R.E. powered irrigation systems
Reduced dependence on fossil fuels and finite natural resources
Improved economic competitiveness through the adoption of clean energy technologies
Reduced disease and healthcare costs
Attract investment and creation of jobs and equipment to local population
Increased independence, security, and cost of vital life necessities
Cost-effective improvement of life quality by also reducing greenhouse gas emissions.
Achieve sustainable development by sensitizing society on energy efficiency and the potential and opportunities of R.E.
Job creation and economic growth through investment in renewable energy infrastructure
Environmental:
Reduction of greenhouse gas emissions
Increased resilience to climate change
Improved air and water quality
Reduced greenhouse gas emissions and improved public health
Preservation of the harmony between nature and communities through the protection of natural habitats and biodiversity
Promotion of clean energy education and awareness
Social:
Increase in local communities participation and empowerment
Greater energy access for marginalized communities
Reduction of energy poverty and improve life quality for vulnerable communities

nagement like in the transportation case, or a lack of knowledge and technique like the biomass case, this country can save more energy and reduce its costs for more power plants by making decisive decisions as shown in the recommendation section.

It goes without saying that there is a need for policy and regulatory support as well as continued research and development in renewable energy in order to give countries like Morocco the opportunity to tap into their abundant renewable energy resources and meet their growing energy needs both sustainably and affordably.

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Przegląd strategii na rzecz zrównoważonej energii w Maroku

Streszczenie

Niniejszy artykuł ujawnia, w jaki sposób populacja Maroka i ekspansja gospodarcza stanowią wyzwanie dla jego zdolności do zaspokojenia zapotrzebowania na energię, zwłaszcza biorąc pod uwagę, jak niedobór paliw kopalnych i ich wysoka cena rynkowa obecnie i w przyszłości rozwijają się i podążają za strategiami osiągania celów zrównoważony rozwój. Efektywność tej inwestycji i ogromna liczba niewykorzystanych zasobów sprawiły, że Maroko postawiło sobie nowy cel, jakim jest uzyskanie 52% swojego zapotrzebowania na energię ze źródeł odnawialnych, co czyni go jednym ze światowych liderów w zakresie energii odnawialnej. W niniejszym artykule przeanalizowano szerokie spektrum odnawialnych źródeł energii i ich potencjał w Maroku, w tym źródła energii słonecznej, wodnej, pływowej, falowej i geotermalnej, a następnie zidentyfikowano bariery powstrzymujące jej rozwój, przechodząc od magazynowania i przesyłania do finansowania, a następnie porównawcze podejście kosztów i korzyści.

W artykule oceniono również strategię kraju na rzecz zrównoważonego rozwoju, podkreślając jej finansowanie, a następnie rozszerzono zakres badań, aby zbadać inne potencjalne zastosowania energii odnawialnej w Królestwie, takie jak odsalanie i transport, a następnie podano listę wytycznych i zaleceń dotyczących tego, w jaki sposób kraj może ominąć przeszkody powstrzymujące go przed ujarzmieniem i wykorzystaniem tych cennych zasobów. Wykonalność tych rozwiązań została oceniona na podstawie ankiety przeprowadzonej wśród ludności, która dała bardzo obiecujący wynik.

Słowa kluczowe: energia odnawialna, zrównoważony rozwój, efektywność energetyczna, odnawialne źródła energii, cena rynkowa energii, inwestycje strategiczne, miks energetyczny, bezpieczeństwo energetyczne