THE MOROCCAN TRANSITION TOWARD 100% RENEWABLE ENERGY

AN INTEGRATED RURAL DECENTRALIZED PILOT PROJECT

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Pr. Touria Barradi

مؤسسة الأطلس الكبير
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PMDER

MESSAGE FROM THE HIGH ATLAS FOUNDATION PRESIDENT

RENEWABLE ENERGY AND BOTTOM-UP DECENTRALIZATION IN MOROCCO

By Yossef Ben-Meir
Marrakech

The Kingdom of Morocco is a place of hope and promise, of honest attempts to make strides commensurate with the humanistic journey. In its Constitution, it recognizes laws, policies, and programs for which community participation is the essential ingredient for achieving optimal outcomes. These outcomes include sustainability and ever-deeper satisfaction among the people.

The premise of the nation's family code is rooted not just in centuries but in millennia, calling for justice and equity regarding women and men and our gender-based experiences. Morocco has also determined—based on its own historically informed outlook and from lessons around the world extracted over time—that concentrating the power of decision-making and control over the affairs that matter the most to people ought to rest among the people and in the public administrative tier closest to them. This is also a matter of recognizing human dignity: distant determinations put upon people are rarely as appropriate as those that people make for themselves and their families alongside their neighbors and community members.

The national commitment for renewable energy is also among Morocco's flagship efforts for a society that lives in balance, not just with each other as a diverse people but also regarding the relationship with the natural environment. The nation's globally noteworthy commitment to renewable energy, backed by finance and political will, is indeed inspiring, and it is part and parcel of Morocco's transformational intent in the other vital sectors of society and growth.

It is, however, also the case that despite the magnitude of the opportunities the country has set for itself, the difficulties and, in fact, inadequacies of their implementation can at times be stark and real. Morocco deserves enormous credit for its honesty. One need not look any further than the Special Report for the New Development Model (spearheaded by H.M. the King of Morocco) for the truth on both the promise and its painful lack of fulfillment, and concluding that it is urgent to chart a recalibrated course.

The national commitment to decentralization—or regionalization—captured in Article 1 of the Constitution is essential. It provides the system by which localities can identify and implement related projects in keeping with their own priorities. The more such community movements take place, particularly in partnership with the public and private sectors, the more decentralization, and its channels of cooperation, are formed and able to be effective.

Decentralization will remain stalled or will flourish to the extent that communities comprising the country's municipalities are vibrant and energized in their collaborative course, implementing the development they most seek. The unsatisfactory level of community actions in this regard is the primary reason decentralization is not providing an empowering structure and necessary difference for the country.

Renewable energy, even with Morocco's sincere dedication and its prominent and impressive projects, has not been integrative of community voices, evaluations, and, arguably, benefits—in a manner felt by the local people that these projects impact.

The High Atlas Foundation and its domestic and international multi-stakeholder partners all hold high hopes and expectations for Morocco's commitment to decentralized renewable energy. They are taking the course that we must first provide opportunities for harnessing empowerment among intended beneficiaries, while engaging in participatory planning of initiatives they most want. We will then see areas where integration of renewable energy can take place within the pathway to development the communities determine.

As with all genuine, empowering local movements, it begins with an invitation by the community members, expressing their desire to fully engage and contribute the time and energy needed to achieve successful outcomes. Many invitations in our program's experience are forthcoming. We analyzed Morocco's renewable energy transition, including opportunities and challenges for its decentralization and extensive interdisciplinary field research; the results of this are summarized in this study. We decided to focus on Youssoufia Province, with a village community in the Jnane Bouih municipality. This was because of the circumstances they face, which include severe scarcity of water and clear vulnerability to climate change's impacts.

Women and men prioritized clean drinking water and a nursery of different endemic fruit-bearing trees and medicinal plants as part of the fulfilling future they seek. To date, with the initial phases of empowerment workshops implemented, organization around registering their cooperative, and sweet and nourishing water found nearly 200 meters below ground, we remain steadfast in completing their individual and collective dream.

The local development experiences looked at comparatively and, in the aggregate, reveal the commonality of needs: difficulty accessing resources to create change, gender-based differences in objectives, and desire to remain in rural communities and not migrate to cities for the sake of bread alone. Experiences examined in these, and other informative ways can actually be helpful in reforming policy. Decentralization's power is not only in its concentration of capacity among the people who drive their own futures and possibilities, but also in its ability to bring forward new approaches and policy frameworks more in line with what people truly want and pursue.

Our experiences in Youssoufia and elsewhere are, in fact, revelatory in that they spotlight the adjustments and programs that can more effectively release the endless energy that people have for improving their lives. Youssoufia is about the immediate needs of its residents. It is also, however, about understanding the needs that transcend to the countryside and that, when sincerely listened to, can bring about laws backed by resources ushering in the Moroccan promise for all its people.

We hope this study will be a repository of information that helps and inspires decision-makers, practitioners, and communities to all do their part in fostering a people-centered, decentralized, and empowering energy transition toward renewables in Morocco, directly satisfying communities' most urgent development needs.

Dr. Yossef Ben-Meir is president of the High Atlas Foundation in Morocco.

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Plateforme Marocaine de Décentralisation des Energies Renouvelables (PMDER)

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PRESENTATION OF THE MOROCCAN MULTI-STAKEHOLDER PARTNERSHIP PROJECT

Transformative changes are realized neither through a top-down nor bottom-up process alone. Cooperative approaches of different actors such as political decision-makers, the private sector, researchers, and civil society are necessary. Transformative multi-stakeholder partnerships (MSPs) can coordinate these actors' expectations and thereby enable changes unachievable by individual actors. Examples of such transformative changes include improved national and regional framework conditions, guarantees and support mechanisms, empowered local communities identifying and managing projects that meet their energy and human development needs, transformative business models for more innovation, and new technologies and instruments. The German Ministry for Economic Cooperation and Development promotes MSPs for implementing Sustainable Development Goal (SDG) 17 from a methodological standpoint.

The Moroccan MSP project aims to establish an MSP at the regional, national, and international levels to demonstrate the many development benefits of decentralized renewable energies in the food–water–energy nexus. It will be implemented in rural communities in Morocco, aimed at identifying lessons learned on how national Moroccan energy policy could better support decentralized, development-friendly, and sustainable expansion of renewable energies. Actors involved in the MSP from the partner countries will also be connected with relevant German and international actors. The project strives to identify best practices for climate change-related issues. This is meant to inform future partnerships for transformation on a broader scale and in more countries and new thematic aspects.

STUDY OVERVIEW

This study aims to introduce the complementarity between decentralization and centralization of renewable energy for enhancing Moroccan performance in renewables. The National Energy Strategy, initiated in 2008, is proceeding in line with its assigned goals. The initial objectives could be achieved, or even exceeded. Morocco's National Energy Strategy, however, has mainly been deployed through centralized projects. Along with the common environmental dimension and the economic impact linked to reduced fuel import, decentralized renewable energy projects remain closer to the population than do larger centralized plants. Indeed, they often adopt an inclusive and participatory approach, promote local industry and services, and have more modest budgets.

Based on the specific advantages of decentralized renewable energy solutions, a vision for an integrated pilot project was developed and is currently being concretized, thanks to stakeholders' partnerships.

Certain energy issues are reviewed herein to highlight key elements linked to this subject. Chapter II describes the local context, dedicated to the country profile. Chapter III gives an overview of the electricity energy sector. As Morocco's energy independence is an objective of the National Energy Strategy, local renewable resources are promoted. Chapter IV addresses the country's potential for hydro, wind, solar, and biomass. Chapter V then gives an overview of selected renewable projects to illustrate the energy transition, along with dedicated accompanying measures.

The study's main focus is on decentralization of renewables. It describes an integrated pilot project targeting rural communities, clearly showing how to capitalize on the project's specific advantages. Extensive criteria were used to select eligible sites, including their renewable energy potential and socio-economic situations. Ultimately, the selected site for the project's first version benefited from the availability of a large area allocated to it, owing to a substantial contribution from the rural commune.

The project was conceived based on local energy needs and in line with a food–renewable energy–water–health nexus. Gender and educational dimensions were also emphasized, as well as the project's aim of stimulating local employment and helping local people acquire new skills. Renewable energy resources will serve as a support for rural productive activities as well as local services using clean energy. Additionally, improvement of lifestyles in the population is achieved through solutions aimed at well-being and the environment, such as a solar communal bath and solar cooking devices.

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ACRONYMS

AFOLU	Agriculture, Forestry, and Other Land Use
AMEE	Agence Marocaine pour l'Efficacité Énergétique (Moroccan Agency for Energy Efficiency)
ANRE	Autorité Nationale de Régulation de l'Electricité (National Electricity Regulatory Authority)
BAU	Business-as-Usual
CCGT	Combined cycle gas turbine
CCPI	Climate Change Performance Index
CDER	Renewable Energy Development Center
CESE	Conseil Economique Social et Environnemental (Economic Social and Environmental Council)
CMC	Centre Marocain de Conjoncture
COP	Conference of the Parties
CO_2	Carbon dioxide
CSP	Concentrated solar power
DRE	Decentralized (or Distributed) renewable energy
DSPP	Decentralized Solar Pilot Project
EE	Energy efficiency
ESCO	Energy services company
FDI	Foreign direct investment
FEW	Food–energy–water
FREWH	Food–renewable energy–water–hygiene
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule
GW	Gigawatt
HAF	High Atlas Foundation
km	Kilometer
kW	Kilowatt
kWh	Kilowatt hour
HCP	Haut Commissariat au Plan (High Commission for Planning)
HDI	Human Development Index
HV	High voltage
IEA	International Energy Agency
IDSPP	Integrated Decentralized Solar Pilot Project
IFC	International Finance Corporation
IMF	International Monetary Fund
INDH	Initiative National de Développement Humain (National Human Development Initiative)
IRENA	International Renewable Energy Agency
IRESEN	Institut de Recherche en Energie Solaire et Energies Nouvelles (Research Institute for Solar Energies and New Energies)
LCOE	Levelized cost of energy
LV	Low voltage
MASEN	Moroccan Agency for Sustainable Energy
MEME	Ministère de l'Energie des Mines et de l'Environnement (Ministry of Energy, Mines and Environment)

MEMDD	Ministère de l'Energie des Mines et du Développement Durable (Ministry of Energy Mining and Sustainable Development)
MENA	Middle East and North Africa
MORSEFF	Morocco Sustainable Energy Financing Facility
MSP	Multi-stakeholders partners
MTOE	Million tons of oil equivalent
MV	Medium voltage
MW	Megawatt
MWh	Megawatt hour
NDC	Nationally Determined Contribution
NDM	Nouveau Modèle de Développement (New Model of Development)
NEES	National Energy Efficiency Strategy
NES	National Energy Strategy
NGO	Nongovernmental organization
ONE	Office National d'Electricité (National Office for Electricity)
ONEE	Office National d'Electricité et d'Eau potable (National Office for Electricity and Drinking Water)
PERG	Programme d'Electrification Rurale Global (Global Rural Electrification Program)
PMDER	Plateforme Marocaine de Décentralisation des Energies Renouvelables (Moroccan Renewable Energy Decentralization Platform)
PNAP	Plan National des Actions Prioritaires (National Priority Action Plan)
PV	Photovoltaic
R&D	Research and development
RDP	Regional Development Plan
RE	Renewable energy
RES	Renewable energy sources
SDG7	Sustainable Development Goal 7
SDGs	Sustainable Development Goals
SE	Solar energy
STEP	Station de Transfert d'Eau par pompage (energy transfer by pumping or hydro-pumped storage)
TER	Taux d'Electrification Rurale (rural electrification rate)
TES	Total energy supply
TFEC	Total final energy consumption
TOE	Tons of oil equivalent
TPES	Total primary energy supply
TW	Terawatt
TWh	Terawatt hour
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WEF	World Economic Forum
WHO	World Health Organization
WRI	World Resources Institute
Wp	Watt peak
WWF	World Wide Fund for Nature (formerly World Wildlife Fund)

Chapter I ENERGY ISSUES

1. Energy and environmental challenges

Humanity is increasingly feeling the effects of global warming. The correlation between global warming and greenhouse gas (GHG) emissions is widely proven, and the energy sector is known as one of the main carbon dioxide (CO_2) emitters. Indeed, around 80% of energy production comes from fossil sources, underscoring the sector's critical impact on the environment. Its contribution to the fight against global warming therefore inevitably involves replacing fossil fuels with clean energy sources. The International Energy Agency (IEA) World Energy Outlook 2020 concluded that to limit climate change in this century to a 2°C increase, energy use must be twice as productive.[1]

The nongovernmental organization Global Footprint Network (GFN) warned that as of July 29, 2019, ecological resources for that year were consumed an estimated 1.75 times faster than ecosystems' regenerative capacity, thus reducing future regenerative capacity, the earliest ever annual date recorded at the time2[2]

GHGs alone account for 60% of the global ecological footprint. The World Wide Fund for Nature (WWF) therefore argues that reducing GHGs is the main mechanism for ensuring that humanity's annual resource consumption does not exceed Earth's capacity to regenerate those resources in that same year. Such an observation fosters awareness of the consequences of climate change and stimulates the emergence of new trends in terms of supply, demand, and technologies.

In 40 years, the world population has grown from four to 7.9 billion and is expected to exceed eight billion in 2030. As an effect of socio-economic development (urbanization, industrialization, lifestyle change, etc.), electricity generation has grown 250% to cope with exponential demand growth. Figure 1 illustrates electricity demand over the last 2 years.

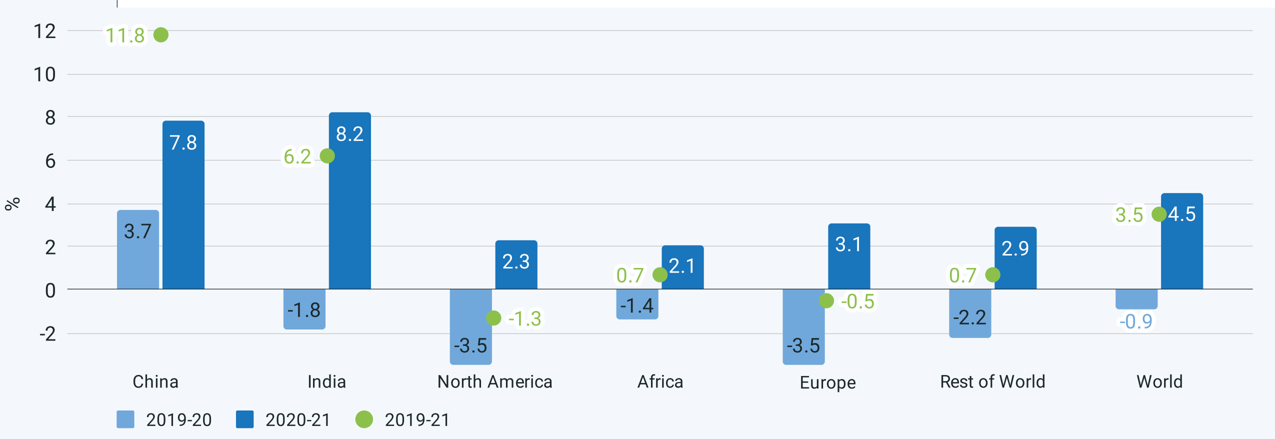


FIGURE 1 Change in electricity demand in 2020 and 2021 by region (Source IEA 2019, as modified by High Atlas Foundation)

1 IEA 2020
2 Global Footprint Network

Globally, an estimated 759 million people still lack access to electricity.[3] While in 2017, those lacking such access fell below one billion, about two billion did not benefit from modern energy services provided by electric appliances and end-use devices. According to the recent annual Fostering Effective Energy Transition report of the World Economic Forum (WEF), a substantial gap remains between electrification rates in countries from emerging and developing Asia and those from Sub-Saharan Africa (Figure 2). On the African continent, several hundred million people, mainly in rural areas, lack electricity. Access to clean and affordable electricity has thus become a central component of economic development and emissions reduction strategies.

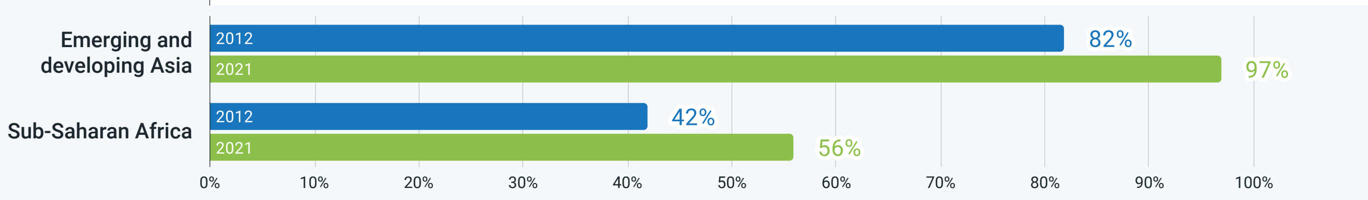


FIGURE 2 Electrification rates in emerging and developing Asia and Sub-Saharan Africa (based on: World Economic Forum 2021)

The energy generation landscape is notable in several regions of the world, including Africa, for the predominance of fossil fuels. Indeed, in 2018, those sources supplied 81% of the world's energy.[4] According to the April 2020 International Renewable Energy Agency (IRENA) annual report, however, solar (especially photovoltaic [PV]) and wind power accounted for 90% of the world's newly added renewable energy (RE) capacity.

2. RE and energy efficiency as pertinent solutions

Solar energy reaching the Earth in 1 hour is estimated to be higher than the combined worldwide human consumption of energy in 1 year. Fortunately, many of the world's regions benefit from high solar potential (Figure 3).

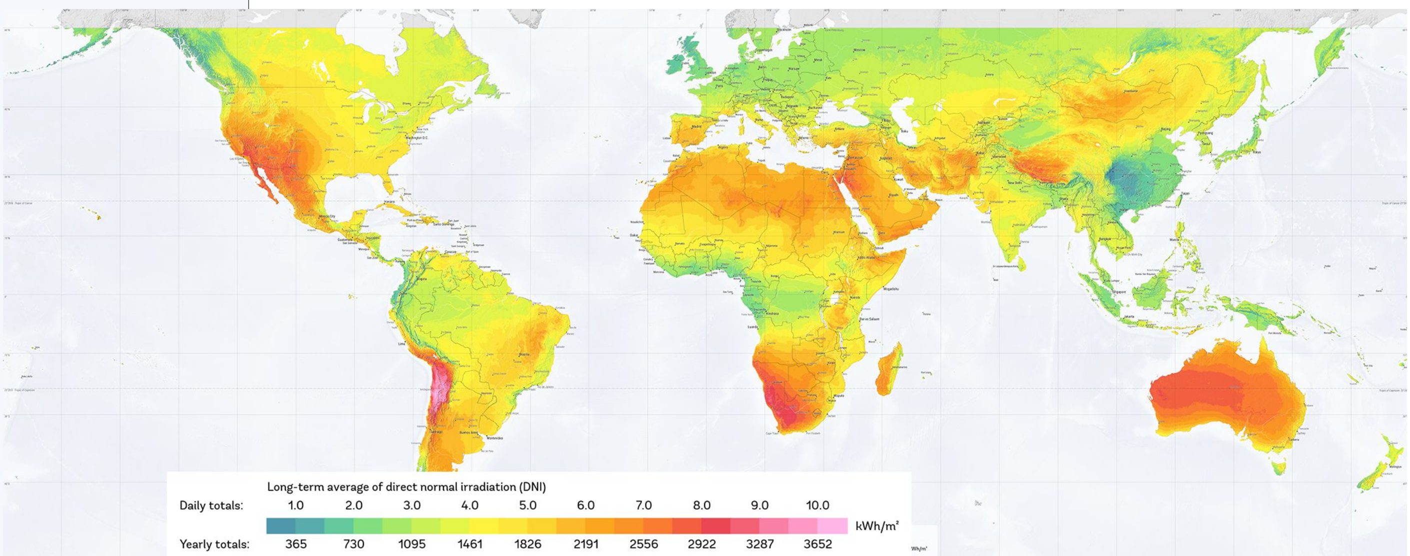


FIGURE 3 World map of direct normal irradiation

3 WHO 202
4 IEA 2020

As the last decade witnessed a global dynamic around renewables, leading to higher RE infusion into the energy mix of different regions, the International Energy Agency (IEA) and IRENA announced that future investments may continue to form in the clean energy sector. During 2019 was the first time in decades that fossil fuel-based generation declined while overall electricity generation increased.[5] Energy efficiency is also receiving increasing attention, as it contributes simultaneously to limiting investments dedicated both to electricity production and transmission infrastructure. It also makes a simultaneous contribution to mitigating GHG emissions volume via the economy of energy realized. RE and energy efficiency are the main levers for reducing CO_2 emissions. Their relative impacts, however, could quantitatively differ. The IEA suggests energy efficiency will make the more substantive contribution in the future (Figure 4).

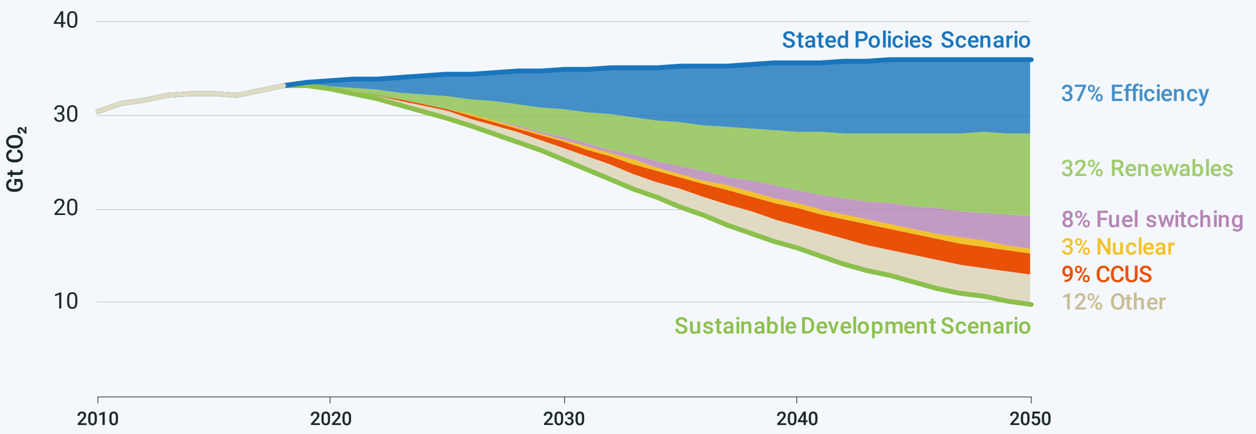


FIGURE 4 Relative contribution of mechanisms to reduction of carbon dioxide (CO2) emissions (Source IEA 2019, as modified by High Atlas Foundation)

In contrast, based on RE power generation's increase moving faster than overall power demand, IRENA estimated that the RE effect on reducing CO_2 emissions would be greater (Figure 5). Indeed, the 2018 IRENA Renewable Energy Roadmap reported that, by 2050, around 65% of the total final energy use would come from renewables, with nearly three-quarters from solar and wind resources. In keeping with the IEA vision, IRENA considered renewables and energy efficiency as the keys to global energy transformation (Figure 5). Together, they offer over 90% of required carbon reductions.[6]

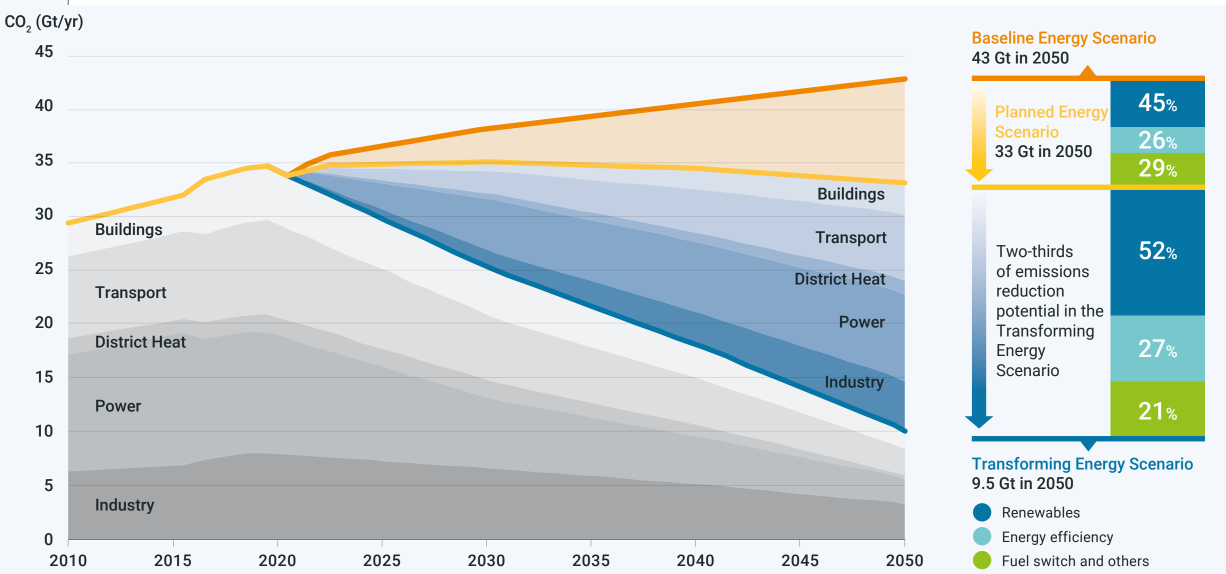


FIGURE 5 Expected effects of renewable energy efficiency on reducing energy-related carbon dioxide (CO_2) emissions, 2010–2050 (Source: International Renewable Energy Agency 2020)

5 Kåberger 2019
6 IRENA 2020

3. Renewable technology competitiveness and trends

Solar PV and wind are the lowest-cost sources of electricity in many markets. The kilowatt-hour (kWh) price of renewable electricity has decreased substantially, reaching record low levels (Figure 6).

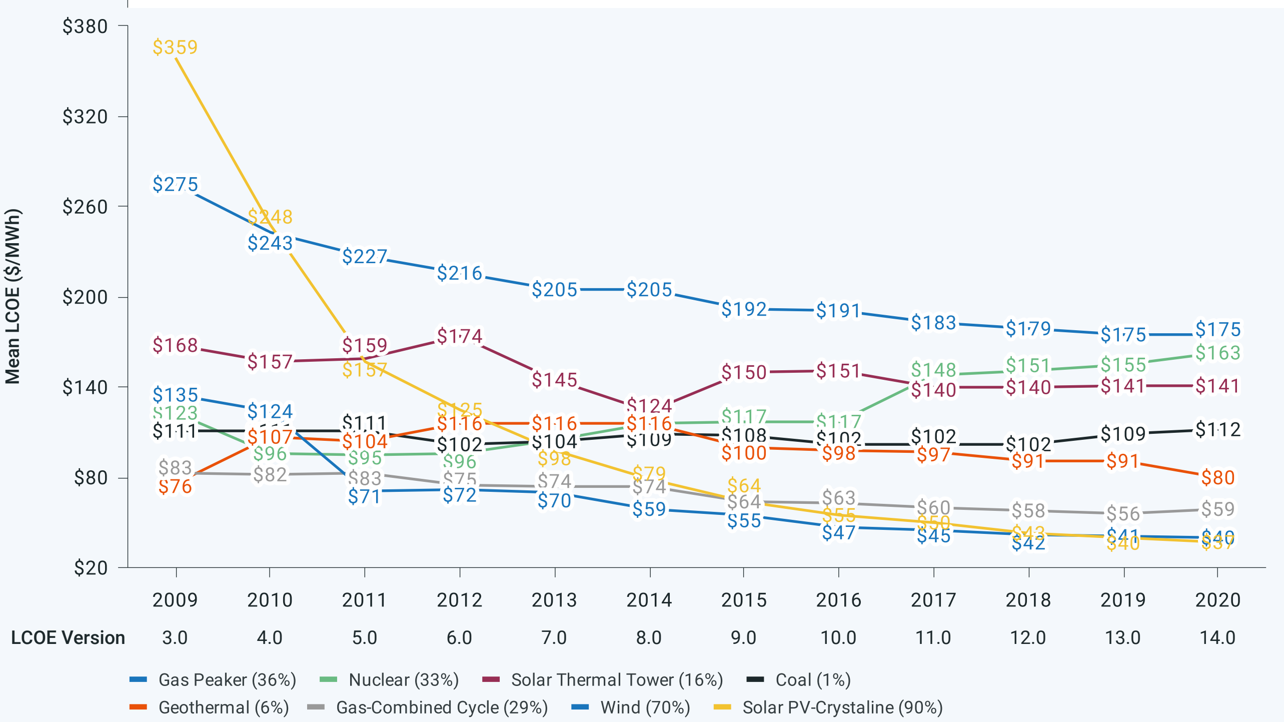


FIGURE 6 Levelized cost of energy, by renewable energy technologies, during the last decade (based on: Lazard 2020)

The cost reduction of electricity generated by renewable sources further encourages governments to install more renewable capacity (Figure 7).

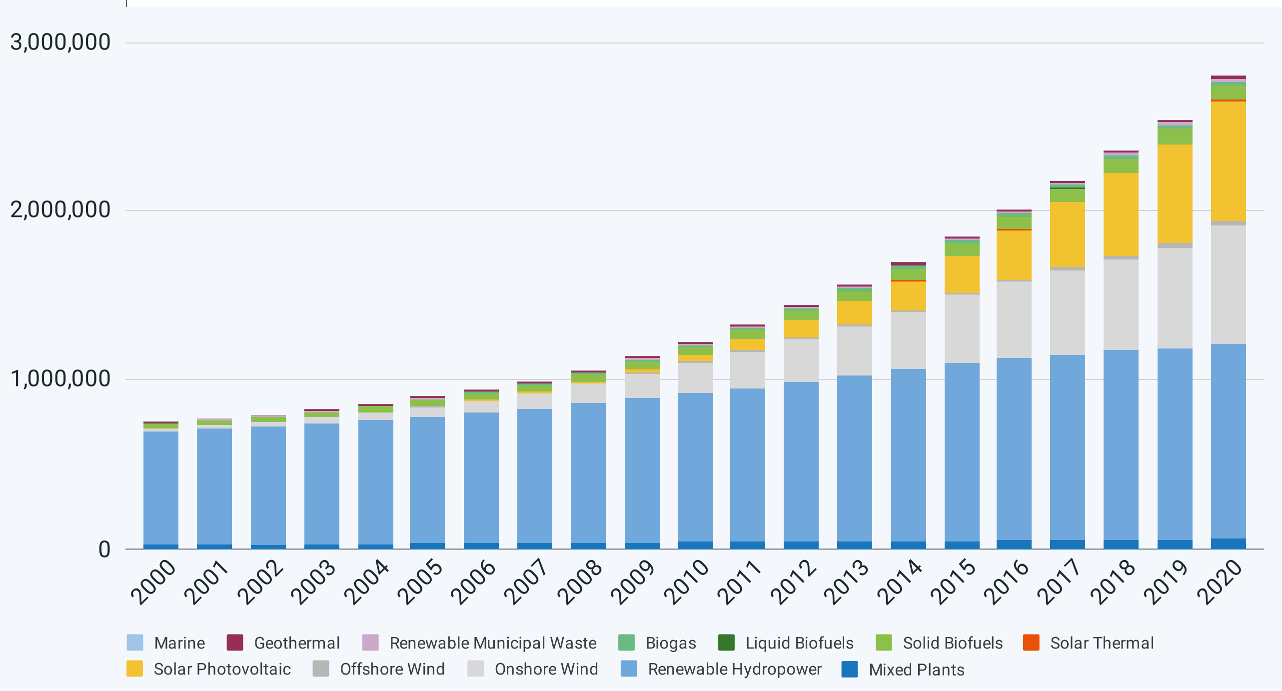


FIGURE 7 Global trends in renewable energy and technologies (based on: International Renewable Energy Agency)

Regional trends in RE reveal that Asia still predominates (with more than half of 2019's RE installations worldwide) and Africa remains challenged (Figure 8).

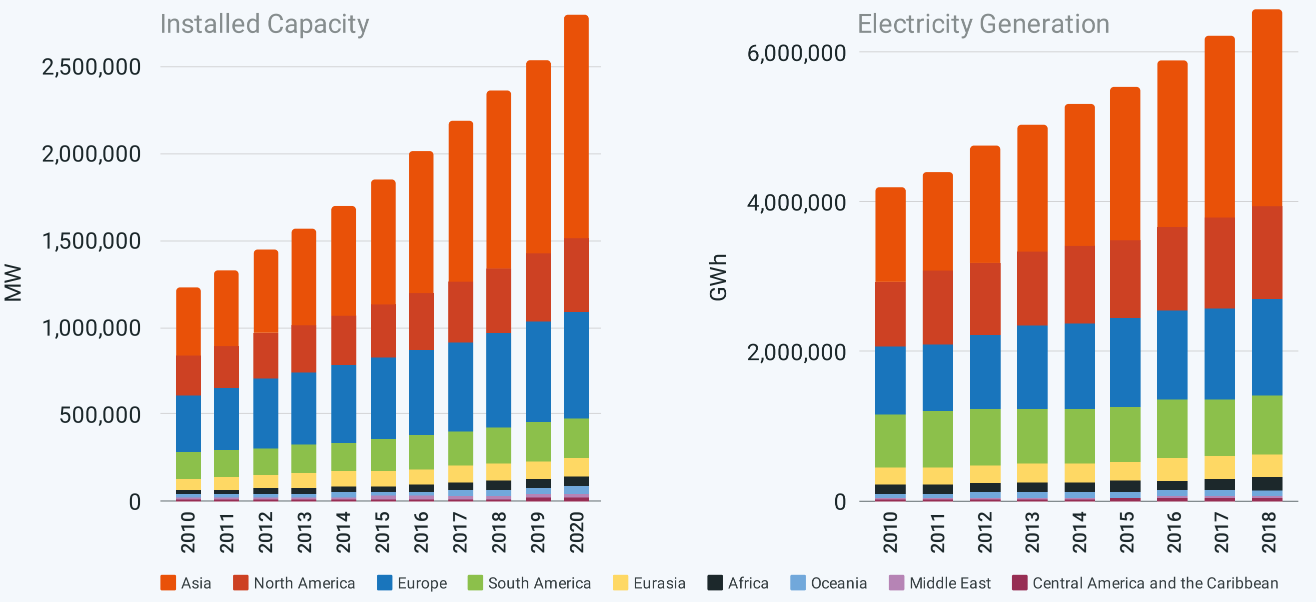


FIGURE 8 Global overview of renewable energy installed capacity and electricity generated across regions (based on: International Renewable Energy Agency)

In Africa, the 2019 RE installed capacity (51,639 MW) represented <2% of the global total. Morocco, however, is among the top five countries on the continent.[7] In 2019, the country's renewable installed capacity was distributed as renewable hydropower (40%), onshore wind energy (37.4%), and solar thermal energy (16.2%).

The new IEA World Energy Outlook 2021, for the first time in the report, placed compliance with the 1.5°C limit from the Paris Agreement at the center of its analysis. The IEA thereby confirms renewables as among the most important tools for climate protection. The report shows that globally, the rate of RE expansion must double, and it underscores that coal, oil, and gas must be phased out much faster than previously planned. Likewise, energy efficiency at the global scale needs to double the pace it had over the past decade.[8] The efforts must be amplified to face the remaining constraints and limits adversely affecting renewables, typically solar and wind. These include intermittency, inadequate generation-consumption, and storage capacities. Decentralized solutions offer a promising option needing further exploration.

Decarbonization of the energy sector requires urgent action at a global scale. Accordingly, IRENA estimated the investments needed between 2016 and 2050, highlighting renewables, energy efficiency, and electrification as priority areas (Figure 9).[9]

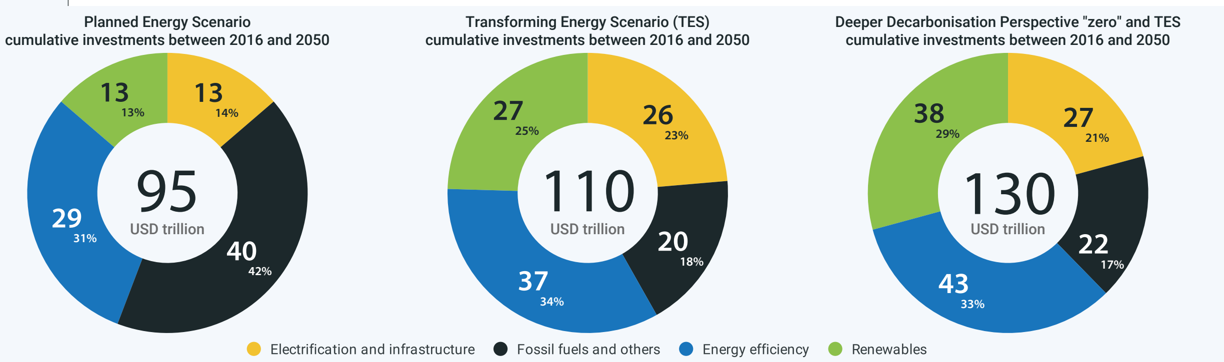


FIGURE 9 New investment priorities: Renewables, efficiency, and electrification (based on: International Renewable Energy Agency, 2020)

7 IRENA
8 IEA 2021
9 IRENA 2020

4. Impact of the public health crisis

The crisis induced by COVID-19 seems unprecedented and unique from the crises of 1929, 1973, or 2008, which triggered the strongest economic recessions. Marked by a simultaneous crisis of supply and demand,[10] the global energy system has experienced "its greatest shock, in more than seven decades," as mentioned in a special report released April 30, 2020, by the IEA.[11]

Reduced coal and oil use resulted in global energy-related CO_2 emissions in 2020 reaching their lowest level since 2010. Despite this annual record owing to the temporary slowdown in human activity, the existential path needed to decarbonize societies and achieve sustainability goals did not change. Forecasts that predicted a post-COVID-19 rebound-linked recovery of fossil fuel use have restoration over the long term.

According to the IEA Global Energy Review 2020:

- The energy demand drop was an estimated 6% in 2020. Advanced economies were expected to see substantial declines, with demand set to fall 9% in the United States and 11% in the European Union.
- Changes in electricity consumption during closures resulted in a substantive drop in overall demand for electricity, estimated at 5% in 2020, the largest since the Great Depression that spanned 1929–1939.
- The drop dramatically affected all the main fuel sources (coal, oil, and gas). Only RE was spared from this unprecedented decline in electricity consumption.
- Renewables were the only energy source that would grow in 2020, with their share of global electricity generation projected to jump thanks to their priority access to grids and low operating costs. Solar PV and wind were on track to help lift renewable electricity generation by 5% in 2020, aided by higher output from hydropower. Despite the resilience of renewables in electricity generation in 2020, their growth was lower than in previous years. The price volatility of fossil fuels, however, undermined their viability and made the business case for renewables even stronger.

5. Conclusion

The benefit of investing in green energy is one of the lessons learned from the COVID-19 experience. This may persuade governments to integrate energy transition into their recovery strategies to build new healthy, inclusive, and sustainable socio-economic models. Some specialized sources projected that accelerating RE investment could underpin the global economy's COVID-19 recovery and help curb the rise in global temperatures.

Power system transformation and the achievement of deep decarbonization would require a massive introduction of renewables (both in centralized and decentralized configurations), promotion of energy efficiency, and development of energy storage, smart grids, and electro-mobility.

10 BP 2021
11 IEA 2020

[1] IEA (2020), *World Energy Outlook 2020*, International Energy Agency, Paris.
Available at: https://www.iea.org/reports/world-energy-outlook-2020

[2] Global Footprint Network (2021),
Available at: https://www.footprintnetwork.org/2019/06/26/press-release-june-2019-earth-overshoot-day/

[3] WHO (2021), Global Launch: Tracking SDG7: The Energy Progress Report. Available at:
https://www.who.int/news/item/07-06-2021-global-launch-tracking-sdg7-the-energy-progress-report

[4] IEA (2020), World total energy supply by source 1971-2018, World Energy Balances 2020.
Available at: https://www.iea.org/data-and-statistics/charts/world-total-energy-supply-by-source-1971-2018

[5] Kåberger, T. (2019), Global Power Sector Developments: RE Finally Dominated Growth.
Available at: https://www.renewable-ei.org/en/activities/column/REupdate/20200302.php

[6] IRENA (2020), Reaching Zero with Renewables: Eliminating CO_2 emissions from industry and transport in line with the 1.5°C climate goal. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/IRENA_Reaching_zero_2020.pdf

[7] IRENA (n.d.), Regional Trends: Trends in Renewable Energy by Region. Available at:
https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Regional-Trends

[8] IEA (2021), World Energy Outlook 2021, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2021

[9] IRENA (2020), Global Renewables Outlook: Energy transformation 2050.
Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf

[10] BP (2021), Statistical Review of World Energy 2021, 70th edition.
Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

[11] IEA (2020), Global Energy Review 2020: The impacts of the Covid-19 crisis on global energy demand and CO_2 emissions. Available at: https://iea.blob.core.windows.net/assets/7e802f6a-0b30-4714-abb1-46f21a7a9530/Global_Energy_Review_2020.pdf

Chapter II COUNTRY PROFILE

1. General overview

Located on the southern shore of the Mediterranean, near Europe and in northern Africa, Morocco is often described as the gateway to Africa. With an area of 710,850 km², the country is the 18th largest on the continent. Its political capital is Rabat, but the business and economic capital is Casablanca, 85 km southwest. The population was near 37.5 million as of October 2021.[12] This population is roughly 51% to 49% female to male, and quite young (the average age is 25 years), with life expectancy exceeding 76 years. About 63.8% of the population is urban. In 2021, the activity rate reached 46.1% (42.6% in urban areas and 52.9% in rural: 70.6% among men and 22.5% among women), at 61.7% for people aged 35–44 years and 24.2% for 15–24 years.[13]

Traditionally, the country's economic performance has strongly depended on rain-fed agriculture. Faced with irregular and insufficient precipitation, Morocco's economy has become increasingly resilient, owing to reform and diversification. Sustained growth is supported by solid investment flows and rising exports in several sectors, such as phosphates, automotive, textiles, and subcomponents. Industry, construction, agriculture, and tourism are among key sectors supported by energy. Infrastructure investments are underway to continually improve the country's competitiveness, particularly in Tangier, with its new port and free trade zone, and Casablanca, which aims to become a regional financial hub. There is also a high-speed railway between these cities.

2. Socio-economic indicators

The Human Development Index positioned Morocco at 123 of 189 countries. Employment of younger people and increasing social equity remain among the country's major challenges. Adult literacy has reached approximately 70%, but still is quite low in rural areas. The unemployment rate was 12.5% in 2020 (as high as 12.7% for the third quarter, according to Haut Commissariat Au Plan [High Commission for Planning: HCP]). It rose to 12.8% in the second quarter of 2021 from 12.3% in the same period a year ago – the highest jobless rate since the last quarter of 2001, due to the effects of the COVID-19 pandemic.[14]

Among the policy changes underway are a substantial budget increase from 2019 to the educational sector, sweeping reforms to overhaul the professional and vocational training system, and recently, financial incentives to encourage entrepreneurship and innovative projects.

In 2018, the country's gross domestic product (GDP) was US$118.5 billion, while in 2019, GDP per capita was $3,460. In constant prices and purchasing power parity terms, the indicator has risen more than two-thirds over the past two decades. The World Bank indicates the GDP grew by 3.2% in 2018, almost double the 1.7% projection for the Middle East and North Africa (MENA) region. Table 1 reports key economic indicators of the country.

12 Worldometer, 2021.
13 Haut Commissariat au Plan (HCP) 2020
14 Trading Economics

	2017	2018	2019	2020 Proj.	2021 Proj.	2022 Proj.	2023 Proj.	2024 Proj.	2025 Proj.
Output									
Real GDP growth (%)	4.2	3.1	2.5	-7.2	4.5	3.9	3.6	3.7	3.7
Real nonagricultural GDP growth (%)	3.1	3.1	3.7	-7.5	4.2	3.9	3.6	3.6	3.7
Employment									
Unemployment (%)	10.2	9.8	9.2	12.5	10.5	9.7	9.1	8.7	8.5
Prices									
Inflation (end of period)	1.7	0.1	1	0.2	0.8	1.2	1.6	1.8	2
Inflation (period average)	0.7	1.6	0.2	0.2	0.8	1.2	1.6	1.8	2
Central government finances									
Revenue (% GDP) 1/	26.6	26.1	25.6	26.9	26.2	26.4	26.6	26.8	27.2
Expenditure (% GDP)	30.1	29.9	29.7	34.6	32.6	32.7	32.2	31.7	31.3
Fiscal balance (% GDP) 1/	-3.5	-3.7	-4.1	-7.7	-6.3	-6.2	-5.6	-4.8	-4
Primary balance	-2	-1.7	-1.8	-5.5	-3.9	-3.7	-2.8	-2.1	-1.2
Public debt (% GDP)	65.1	65.2	65.2	76.5	76.9	77.3	77.7	77.3	76.6
Money and credit									
Base money	5.5	4.1	3.7	5.1	…	…	…	…	…
Broad money (% change)	5.5	4.1	3.7	5.1	3.6	3.8	4.1	4.2	4.3
Credit to the economy (% change) 2/	3.3	3.4	5.4	3.4	3.9	3.9	4	4	4
Velocity of broad money	0.8	0.8	0.8	0.7	…	…	…	…	…
Balance of payments									
Current account excluding official transfers (% GDP)	-4.5	-5.6	-4.3	-6.7	-5.8	-5.1	-4.6	-4.5	-3.8
Current account including official transfers (% GDP)	-3.4	-5.3	-4.1	-6	-5.4	-4.8	-4.3	-4.4	-3.7
Exports of goods (in U.S. dollars, percentage change)	12.8	14.5	0.2	-18.4	15.1	10.2	7.7	6.6	6.8
Imports of goods (in U.S. dollars, percentage change)	7.8	13.5	-0.5	-18	14.4	7.4	6	6.2	6.3
Merchandise trade balance	-16.5	-17.2	-16.7	-14.6	-15.1	-14.8	-14.6	-14.6	-14.6
FDI (% GDP)	1.5	2.4	0.5	1.2	1.1	1.3	1.4	1.4	1.5
Gross reserves (months imports) 3/	5.7	5.3	6.8	7.3	6.9	6.7	6.5	6.3	6.9
External Debt (% GDP)	35	32	32.8	39.7	39.3	39.3	39.9	39	39.1
Exchange rate									
REER (annual average, % change)	-0.4	0.9	0.5	…	…	…	…	…	…
Memorandum Items									
Nominal GDP (in billions of U.S. dollars)	109.7	118.1	119.7	113	124.2	131.1	138.2	145.7	153.8
Net imports of energy products (in billions of U.S. dollars)	-7.2	-8.8	-7.9	-3.9	-5	-5.1	-5.2	-5.6	-5.9
Local currency per U.S. dollar (period average)	9.7	9.4	9.6	9.5	9.1	9	9	9	9

TABLE 1 Selected economic indicators, 2017–2025 (Source: International Monetary Fund, 2021)

3. Elements of energy country profile

Morocco has fewer hydrocarbon reserves than its neighbors. That forces it to rely heavily on fossil fuel imports to develop the economy, though the current policy trend aims to progressively reduce the country's reliance on imports. The efforts deployed to increase the share of renewable resources and natural gas in the country's energy mix are set to lower the energy import bill and reduce fossil fuel emissions.

According to the Office National d'Electricité et d'Eau potable (ONEE: National Office for Electricity and Drinking Water), the electrification rate was 100% in urban areas and 99.85% in rural zones as of 2020. This owes to a combination of centralized and decentralized (solar PV individual installations) solutions.

3.1. Main country results from Climate Change Performance Index 2021

The Climate Change Performance Index (CCPI) publishes national performance based on four indicators: GHG emissions, RE, energy use, and climate policy.[15] Four indicators defined each of the first three criteria: current level, past trend, well-below-2°C compatibility of the current level, and well-below-2°C compatibility of countries' 2030 targets. That investigation, in which some members of Plateforme Marocaine de Décentralisation des Energies Renouvelables (Moroccan Renewable Energy Decentralization Platform: PMDER) participated, including this study's authors, evaluated and compared the climate performance of 57 countries and of the EU, which are together responsible for more than 90% of GHG emissions. Table 2 shows Morocco's status per these indicators.

Indicators	Rating	Rank
GHG Emissions	High	8
GHG per Capita - current level (incl. LULUCF)	High	8
GHG per Capita - current level (excl. LULUCF)	Very low	54
GHG per Capita - compared to a well-bellow-2°C pathway	High	8
GHG 2030 Target - compared to a well-bellow-2°C pathway	Very high	5
Renewable Energy	Medium	28
Share of Renewable Energy in Energy Use - current level (incl. hydro)	Very low	55
Renewable Energy - current trend (excl. hydro)	Very high	4
Share of Renewable Energy in Energy Use (excl. hydro) - compared to a well-bellow-2°C pathway	Very low	46
Renewable Energy 2030 Target (incl. hydro) - compared to a well-bellow-2°C pathway	Low	44
Energy Use	High	6
Energy Use (TPES) per Capita - current level	Very high	4
Energy Use (TPES) per Capita - current trend	Low	39
Energy Use (TPES) per Capita - compared to a well-bellow-2°C pathway	Very high	4
Energy Use (TPES) 2030 Target - compared to a well-bellow-2°C pathway	Very high	4
Climate Policy	High	6
National Climate Policy	High	4
International Climate Policy	High	15

TABLE 2 Country scores well-below-2°C compatibility of current levels and 2030 targets

Based on climate performance adopted for CCPI 2021, the country's ranking places it among the leading group.

15 Burck et al. 2021

3.2. Water local resources' situation

The impacts of climate change, population growth, and economic growth expose many countries to water stress. The MENA region is particularly affected. Morocco continues to be vulnerable because of its strong dependence on spatially and temporally irregular precipitation. The country has one of the lowest volumes of water per capita. Water availability is less than 700 m³/capita/year and could fall to 500 m³ by 2030. The World Resources Institute (WRI) adopted a scale from 0 (low stress (<10%)) to 5 (extremely high stress (>80%)) to showcase the level of water scarcity. According to its 2015 report, Morocco was 4.68 and could lose more than 80% of its current resources by 2040.[16]

Unfortunately, in Morocco, the most exposed sectors are also key sectors. These include agriculture and industrial, as well as some important services. They all contribute substantially to social and economic stability (Table 3).

Indicator	Agriculture	Industry	Services
Sectorial employment (% of total jobs)	34.1	21.8	44.0
Added value (in % of GDP)	11.4	26.0	50.0

TABLE 3 Socio-economic indicators of main sectors (Source: lebrief.ma)

Recently, Morocco decided to resort to seawater desalination, using RE. This accomplishment is an example of the local deployment of the food–energy–water (FEW) nexus that should become a transverse component of the major sectorial strategies.

4. Main competitive advantages

In the mining sector, Morocco holds the world's largest phosphate rock reserves: 72% of the global total. Morocco is the world's leading exporter and second largest producer of phosphates. This performance is highly relevant because the mineral is essential for production of agricultural fertilizers.

5. Focus on renewables and energy efficiency

A voluntary and ambitious National Energy Strategy (NES) was launched in 2008 and adopted in 2009, with the dual objective of reducing the energy bill linked to imports of hydrocarbons and fossil fuel emissions, through RE development and energy efficiency promotion. The strategy was supported by institutional, regulatory, financial, and support measures, such as training, research, communication, and awareness-raising. The framework dedicated to renewables was particularly underscored by the 13-09 and 58-15 laws.[17] Thus, the country developed the NOOR Ouarzazate Solar Power Station, the world's largest multi-technology solar complex, supplying electricity to two million people.

Additionally, the developers of one of the most important wind power plants have announced production of energy at the lowest, most competitive kWh cost in the world. Morocco is also working on the world's largest seawater desalination complex, powered by solar energy (SE). Moreover, a recently announced interconnection project will export green energy to the United Kingdom. The cable to ensure this transit would be the world's longest. Other mega-projects, such as a gas pipeline between Nigeria and Morocco, are also being initiated.

Substantial public and private investments are also being made to increase production capacity, develop the power network, and increase the share of renewables and natural gas in the country's energy mix. Renewables-oriented investments will be as much as $30 billion by 2030.

16 Maddocks et al. 2015
17 The 13-09 law provides a right of access to the national electricity grids for electricity produced by independent operators from RE sources. The 58-15 law modifies and complements it to introduce a new metering scheme for solar and wind power plants.

5.1. Renewable energies

Solar

Morocco enjoys an estimated 3,000 hours of sunlight per year, holding an average annual solar potential of 5 KWh/m². This potential has been valued in high-, medium-, and low-scale energy solar plants, including Programme d'Electrification Rurale Global (PERG: Global Rural Electrification Program), which deployed partial-PV technology to supply energy to remote areas ineligible for grid connection.

Wind

Thanks to its 3,500-km-long coast, Morocco has annual technical wind-energy potential estimated at just under 5,000 TWh, with potential to install 25,000 MW of capacity. Wind speeds vary depending on the geographic area, ranging 7.5–11 m/s. Integrated and wind energy programs are deployed as implementations of the NES to take advantage of this potential.

Hydropower

Initiated in the 1960s and known as the "Large dam policy," this traditional component has continued to be a part of the power mix, but its contribution will be decreased as it faces water scarcity. The electricity generation system's flexibility needs improving, aimed at massive integration of renewables. A specific program dedicated to developing storage solutions, such as hydro-pumped ones, is ongoing.

5.2. Other resources

Gas Infrastructure

Morocco has several gas facilities such as the combined-cycle 385-MW Tahaddart Power Station, generating 3,100 GWh annually and the 470-MW Ain Beni Mathar Integrated Thermo Solar Combined Cycle Power Plant, with annual production of 3,538 GWh. The 1,620-km-long Maghreb Europe Gas (MEG) pipeline, connecting Algeria to Spain via Morocco, with annual capacity of 12 billion m3; was recently stopped.

Green hydrogen and bioenergy

Specific national roadmaps are ready and the industrial and research and development (R&D) dynamic around these fields have been initiated.[18]

5.3. Energy efficiency

Energy efficiency is a pillar of the NES and has been considered a national priority. Its deployment as part of a dedicated national strategy is supported by specific institutional, regulatory, financial, and support measures, such as training, research, communication, and awareness-raising. The updated energy-saving objectives (in 2013) were 5% by 2020 and 20% by 2030. Industry, building, transport, agriculture, and public lighting were identified as the five priority sectors that should contribute to achieving these targets (Figure 10). Public administration was also called on to serve as a model.

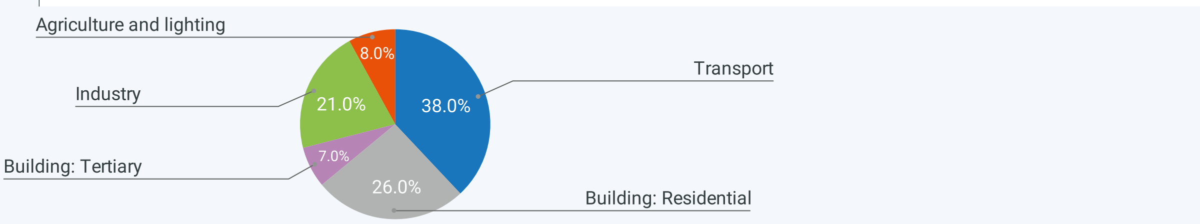


FIGURE 10 Relative energy consumption of key sectors (based on: Moroccan Agency for Energy Efficiency, 2013)

The National Energy Efficiency Strategy (NEES), spanning 2015–2030, uses specific measures covering creation of institutions, elaboration of legislation, regulation, financial, fiscality, and accompanying instruments, such as communication, training, research, and sensitization. A specific law (47-09) was adopted with the aims of increasing efficiency in use of energy sources, and avoiding waste and reducing costs, as well as enhancing sustainable development in the nation.

6. Interconnections

The possibility of exchanging electricity with neighboring countries provides additional flexibility in the management of relevant countries' resources, along with mutual technical, economic, and environmental benefits.

Morocco's strategic location at the intersection of Europe, the Maghreb, and Sub-Saharan Africa, and the synchronization of its electrical network with the standards of the related networks, are important assets for facilitating electricity exchange between two shores of the Mediterranean, via the Moroccan hub (Figure 11).

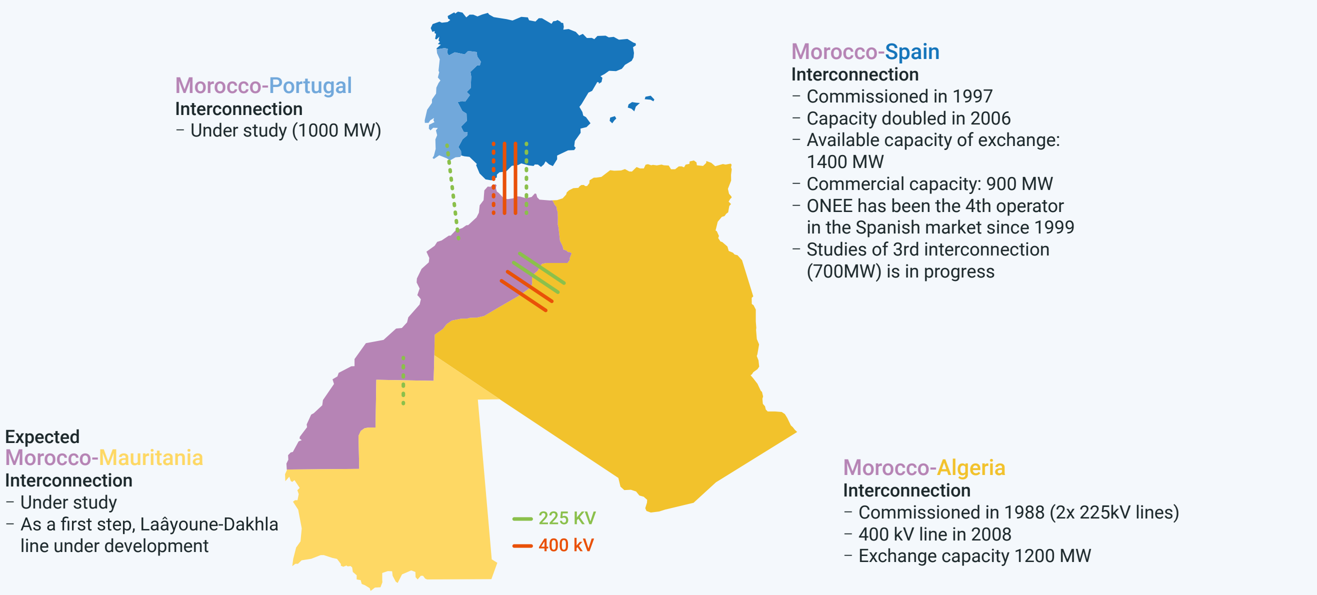


FIGURE 11 Crossroads of electricity transit (based on: Habachi et al. 2019)

Morocco realized considerable interconnection capacity with Spain (1,400 MW) and a unique submarine electric connection between Europe and Africa. A third line, for 700 MW of added capacity, will reinforce this interconnection. Interconnections with Sub-Sahara are also planned, starting with a line to link Morocco and Mauritania.[19]

7. Other national strategies and main sectoral plans, linked to sustainability

The country has developed national programs, plans, and sectoral strategies, including those related to sustainable development. These include:

- National Strategy for Sustainable Development, adopted in June 2017 and focused on creating an inclusive and environmentally friendly economy by 2030
- Framework Law 99-12 on the National Charter for the Environment and Sustainable Development
- Green Morocco Plan
- National Biomass Strategy (project under development)
- PERG, launched in 1996. This program positioned Morocco as the top performer in the MENA region and second in Africa.

Since the 1990s, PERG has shown outstanding results in providing electricity access for rural communities incapable of connecting with the country's main grids. PERG has operated on the basis of choosing local solutions based on local contexts.

From 1995 to 2020, PERG's achievements[20] resulted in:

- Electrification, by connection to networks, of 41,146 villages, providing electricity to 2,142,042 households.
- Equipment with individual PV kits of 51,559 households in 3,663 villages in 1998–2009; 19,438 households in 900 villages as part of the Initiative National de Développement Humain (INDH: National Human Development Initiative) solar project in 2016–2018.

During the last 25 years, the rural electrification rate increased from 18% to 99.78%. The country now enjoys one of the highest electrification rates in Africa. At the socio-economic level, the program helped generate 261,000 income-generating activities and electrification of 1,070 clinics and 12,789 rural schools. PERG has also enabled a leap in terms of economic and social development through improved living, hygiene, and public health conditions, and safety in the villages, thanks to public lighting. Longer schoolwork hours at school and at home, improved income through diversification of activities, development of income-generating activities, and reduction of the rural exodus have been other substantial benefits of the program. Technically, the high performance of the national electrical system is also in the service continuity, grid quality, system stability, and the efficient management of the demand-generation balance.

8. Continental synergy around energy

Morocco's foreign policy objectives focus on spearheading intra-African cooperation and positioning the country at the center of Europe–Africa relations. In recent years, Morocco has accomplished multiple initiatives oriented toward sub-Saharan states to strengthen ties with African countries. Banks, telecommunication operators, industrial companies, and professionals have developed distinct partnerships with their African associates and shared their experiences.

In renewables and electrification, the country capitalizes on its expertise toward promoting the South–South partnership. The country also contributes to its partners' skills development. Many conventions have been concluded, involving the Moroccan Agency for Sustainable Energy (MASEN), ONEE, industries, and consulting firms.

The strategy of supporting countries in Sub-Saharan Africa is confirmed in Morocco's national guidelines. In terms of capacity development, several support actions from Morocco are contracted with Sub-Saharan partners. Some efforts are also deployed to develop interconnections with neighboring African countries.

20 ONEE 2020

9. National Determined Contribution

Despite its low responsibility for the climate change problem, Morocco has drawn up its Nationally Determined Contribution (NDC) with conviction that global ambitions for tackling the problem call for a substantial commitment to the approach of mitigation, adaptation of means of implementation, cooperation, and transparency.

Morocco's NDC is an improved version of the Intended Nationally Determined Contribution it presented to the United Nations Framework Convention on Climate Change (UNFCCC) on June 5, 2015.

For mitigation, Morocco set a national GHG emissions reduction target of 42% below Business-as-Usual (BAU) emissions by 2030, if benefiting from support from the international community. It commits, however, to an unconditional reduction target of 17% below BAU levels by 2030 (with 4% coming from Agriculture, Forestry, and Other Land Use [AFOLU] actions). Without AFOLU actions, the reduction target is 13%.

This covers the sectors of electricity production, housing (residential and tertiary), agriculture, industry, transportation, waste, and forestry. Figure 12 shows their expected mitigation contributions.

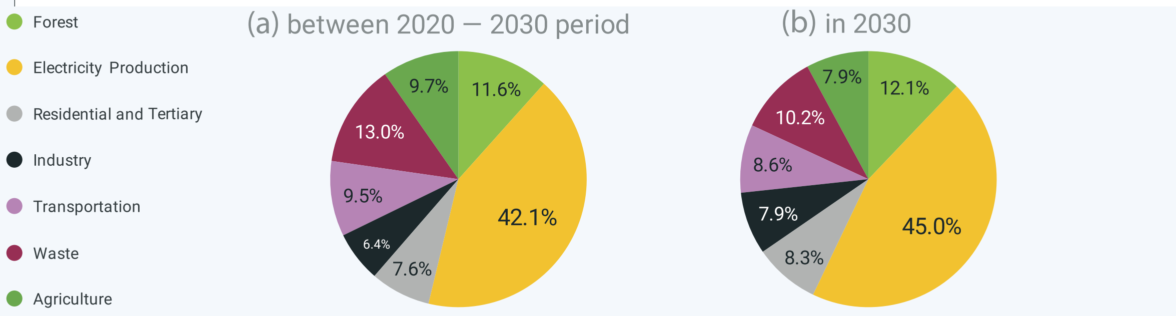


FIGURE 12 (a) and (b): Distribution of expected mitigation effort by sector to achieve the overall target (with Agriculture, Forestry, and Other Land Use) (based on: United Nations Framework Convention on Climate Change, 2016)

The GHG mitigation goals rely heavily on an important transformation of the energy sector (Figure 13).

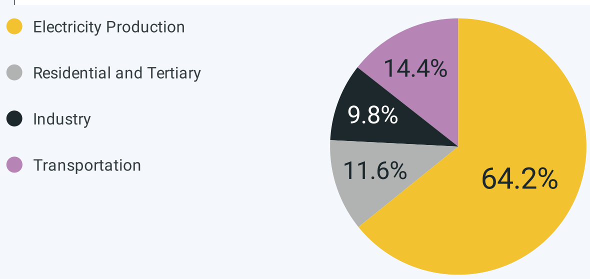


FIGURE 13 Distribution of expected mitigation effort in energy generation and consumption for a variety of purposes to achieve the overall target (based on: United Nations Framework Convention on Climate Change, 2016)

As the agriculture, forestry, and water sectors are most vulnerable to climate change, the adaptation needs to reach the objective are estimated at $2.5 billion.[21] In 2016, Morocco benefited from the World Bank's technical support to implement the NDC. The first phase of the support project targeted energy efficiency in the buildings sector.

An updated version of the NDC was submitted on June 22, 2021, to the Executive Secretariat of the UNFCCC, with enhanced targets.[22] The GHG reduction is now increased to 45.5% by 2030, of which 18.3% is unconditional and will be achieved without international cooperation support.

The revised NDC is structured around 61 mitigation projects, including 27 conditional on international support. The estimated total cost is $38.8 billion, including $21.5 billion allocated to the conditional projects. The NDC also includes strategic adaptation objectives.

21 UNFCCC 2016
22 Bahra 2021

10. Effects of the pandemic

The spread of the COVID-19 pandemic and the accompanying movement restrictions of populations in many countries decreased visibility of how the health, economic, and social situations may turn out. The conventional forecasting theories and models have faced challenges in yielding reliable conclusions.

As with the global economy, there was such a profound economic shock in Morocco that not only the initially optimistic forecasts were seriously thwarted, but also the trend completely reversed, leading to a deep economic recession. This economic underperformance results from the multiple effects triggered by COVID-19, such as the marked decrease in tourism, measures to contain the virus' spread, a recession in Europe, and a drop in commodity prices. The health crisis also coincided with an aggravating situation – a shortage of precipitation. That has intensified the decrease in national GDP due to the contraction of agriculture.

Plausible assumptions, such as falling foreign trade and reduced domestic demand (due to drops in energy, durable goods, transport, and other expenditures), led to negative GDP growth in 2020, with the largest deficit in 25 years (Figure 14).

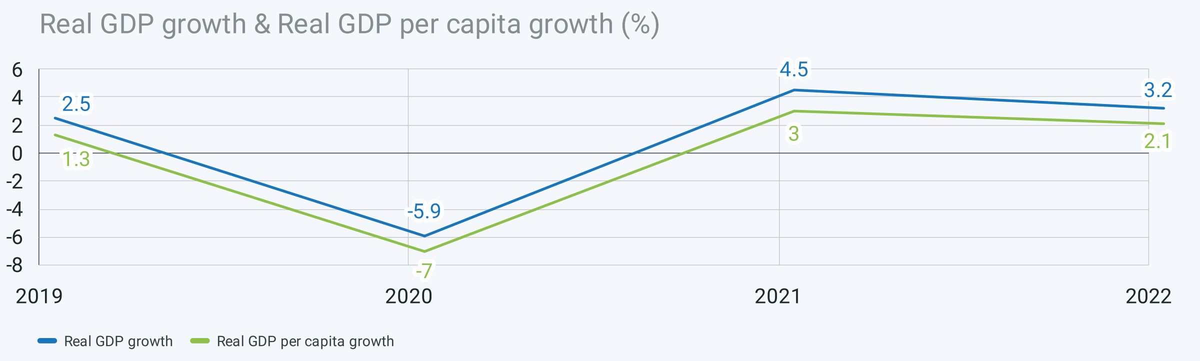


FIGURE 14 Morocco's gross domestic product (GDP) growth rate during the COVID-19 pandemic (based on: African Development Bank Group 2020)

Given the crisis' multi-sectoral impacts, the International Monetary Fund (IMF) changed the 2020 GDP forecast for Morocco,[23] as shown in Figure 15.

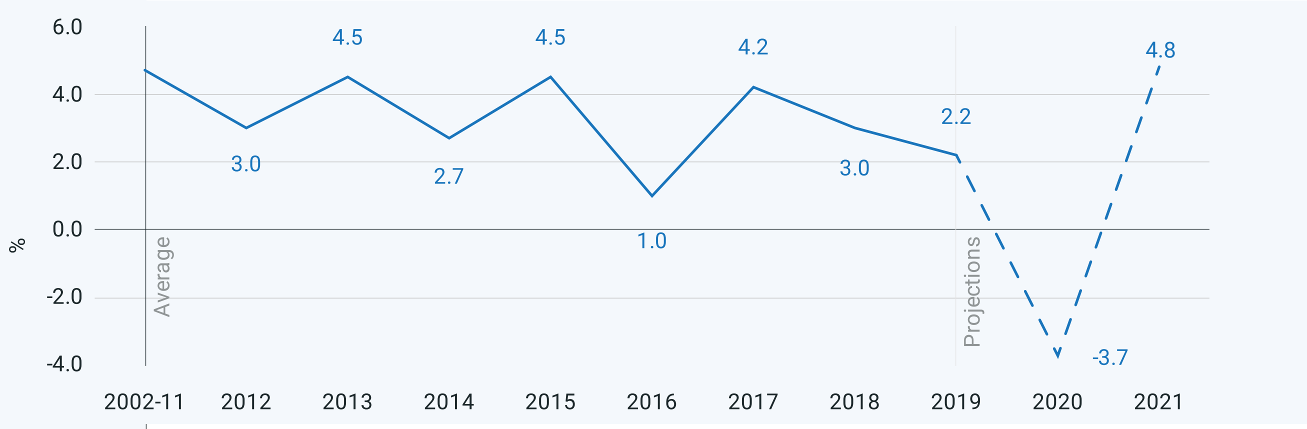


FIGURE 15 Morocco's annual gross domestic product (GDP) percent growth projection (based on: International Monetary Fund, 2020)

The Moroccan High Commission for Planning (HCP) on April 8, 2020, published an economic note that was revised on April 28, in which it stated that in Q1 2020, the economy would grow by 0.7% (vs. +1.1% estimated in the first publication) and would decrease by 8.9% in Q2 2020 (vs. −3.8% forecast on April 8).[24] The Centre Marocain de Conjoncture (CMC) also revised its initially optimistic forecast,[25] and announced a −3.2% GDP growth rate for 2020.

Obviously, the above projections remain subject to revision in light of the changes in public health, global economic conditions, and the impact of recovery programs. Falling oil prices, curtailing import-intensive investment, and increasing foreign subsidies will provide some relief. Its international credibility and rank as one of only two African countries with Investment Grade, are also positive factors in favor of a recovery, given favorable conditions.

Projections of HCP, CMC, and other institutions agree Morocco's economy should rebound and expect GDP growth in 2021, owing to resumption of infrastructure projects and the continuous expansion of manufacturing supply. Forecasts, reassured by successful management of the health crisis, predict an inversion of the negative values announced for 2020, or even higher.

23 IMF 2020
24 Haut Commissariat au Plan 2020
25 Centre marocain de conjoncture 2020

[12] Worldometer (2021), Morocco Population. https://www.worldometers.info/world-population/morocco-population/

[13] Haut Commissariat au Plan (2021), *Les principales caractéristiques de la population active occupée en 2019* (in French). Available at: https://www.hcp.ma/Taux-d-activite_r88.html

[14] Trading Economics (2021), Morocco Unemployment Rate. Available at: https://tradingeconomics.com/morocco/unemployment-rate

[15] Burck, J., Hagen, U., Bals, C., Höhne, N., Nascimento, L. (2021), Climate Change Performance Index 2021. Available at: https://ccpi.org/download/the-climate-change-performance-index-2021/

[16] Maddocks, A., Young, R.S., Reig, P. (2015), Ranking the World's Most Water-Stressed Countries in 2040. Available at: https://www.wri.org/insights/ranking-worlds-most-water-stressed-countries-2040

[17] Bentaibi, W. and Pape, B. "Electricity regulation in Morocco: overview." Gide Layrette Nouel. 1 January 2021. https://www.gide.com/en/news/electricity-regulation-in-morocco-overview. "Morocco amends renewable energy law." Renewables Now. 4 January 2021. https://renewablesnow.com/news/morocco-amends-renewable-energy-law-507698/

[18] MEME (2021), *Hydrogène vert vecteur de transition énergétique et de croissance durable* (in French). Available at: https://www.mem.gov.ma/Pages/actualite.aspx?act=278

[19] ONEE, *ONEE au Maroc et en Afrique* (in French). Available at: http://www.one.org.ma/FR/pdf/Brochure_ONEE_Africa_VF_COP22_V2.pdf

[20] ONEE (2020), *Electrification Rurale* (in French). Available at: http://www.one.org.ma/FR/pages/interne.asp?esp=2&id1=6&t1=1

[21] UNFCCC (2016), Morocco Nationally Determined Contributions under the UNFCCC. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Morocco%20First%20NDC-English.pdf

[22] Bahra, K. (2021), *Révision à la hausse des objectifs d'atténuation des émissions de gaz à effet de serre* (in French), Lebrief.ma. Available at: https://www.lebrief.ma/11918-le-maroc-revu-la-hausse-lambition-de-sa-contribution-relative-lattenuation-des-emissions-de

[23] IMF (2020), World Economic Outlook, April 2020: The Great Lockdown, p. 132. Available at: https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

[24] Haut Commissariat au Plan (2020), *Prévisions révisées de la croissance économique nationale pour le premier et le deuxième trimestre 2020* (in French). Available at: https://www.hcp.ma/Previsions-revisees-de-la-croissance-economique-nationale-pour-le-premier-et-le-deuxieme-trimestre-2020_a2500.html

[25] Centre Marocain de Conjoncture (2020), *Note de conjoncture*, Maroc-conjoncture-n324 (in French). Available at: https://www.cmconjoncture.com/cmc/publications/detail/maroc-conjoncture-n-324

Chapter III STATUS OF THE ELECTRIC POWER SECTOR

1. General context

Given electricity is a vector of development and growth, the national guidelines promote accessibility of electricity for all. This priority in public services has prompted restructuring of the sector's governance. At the societal level, the impact is seen in lower instability, improvement of citizens' living conditions, and decreased unemployment, which particularly affects young people.

The electric power sector, situated at the heart of the development process since the country's independence, has been the object of key stages marking its history. Figure 16 illustrates the timeline of development of Morocco's policy framework for the energy and electricity sector over recent decades.

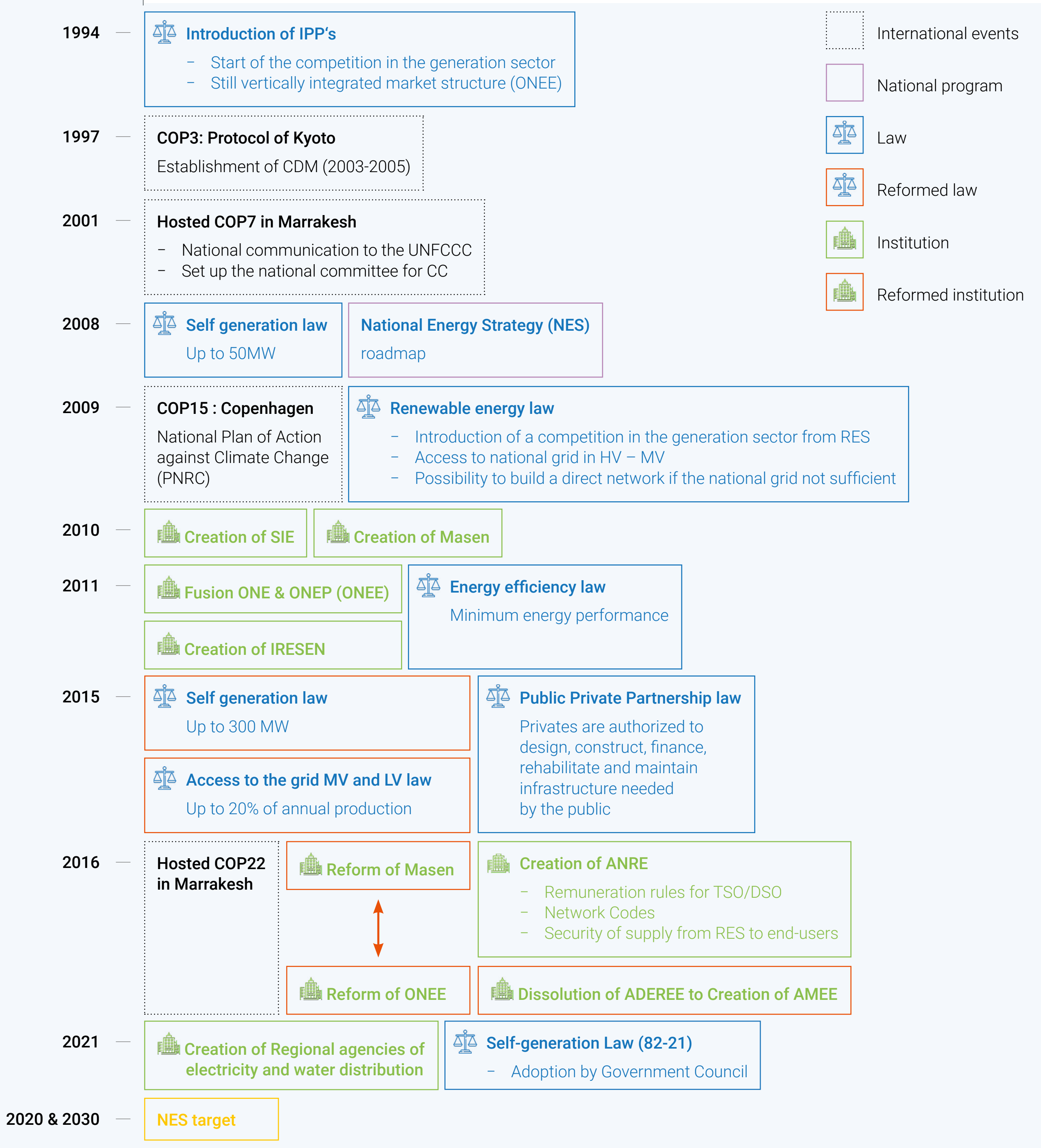


FIGURE 16 Timeline of Morocco's policy framework (based on: RES4MED 2018)

Related to this study's main subjects (RE decentralization, inclusive and participative approaches, and energy access for rural people), PERG is an example of an inspiring project, capitalizing on a collective synergy in favor of electricity access for all. This mega-project that mobilized $3 billion leads to about 12 million citizens gaining access, owing to the combined efforts of ONEE and the INDH. The program has substantially reduced the energy (electricity) gap between urban and rural citizens. The associated budget was 24.65 billion Moroccan dirhams (approximately $2.7 billion US).

2. Main actors

Additional to the supervisory bodies overseeing general policy and in charge of control, the sector is mainly driven by:

- ONEE – electricity branch and a player in producing and distributing electrical energy. It exclusively provides the transport service, plans development of the sector, and manages the supply-demand balance at the national scale.
- MASEN (formerly the Moroccan Agency for Solar Energy) – in charge of renewables
- National and foreign independent producers
- Self-producers
- Producers under law 13-09 (RE)
- Interconnections
- *Régies autonomes* (municipally owned utility providers)
- Delegated managers
- Agence Marocaine pour l'Efficacité Énergétique (AMEE: Moroccan Agency for Energy Efficiency)
- Autorité Nationale de Régulation de l'Electricité (ANRE: National Electricity Regulatory Authority)
- Industries, as well as other stakeholders of the ecosystem, such as R&D institutes including Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN: Research Institute for Solar Energies and New Energies), financial players, universities, training institutions and centers, engineering structures, and incubators.

3. Present status

The bulk of electricity is derived from imported fossil fuels because of the nation's limited hydrocarbon resources. Currently, around 94% of primary energy needs, mainly fossil fuel-based, are imported. The energy bill highlights the gap between imports and exports (Table 4).[26]

	Janvier - Octobre		**Évolution (%)**
En Millions MAD	**2019**	**2020***	
Importations	63550,3	41147,2	-35,3
Exportations	3537,9	1086,5	-69,3
Facture énergétique nette	60012,4	40060,6	-33,2

*Chiffres provisoires

TABLE 4 Data on Moroccan net energy bill in 2019 and 2020 (Source: MEME 2020)

Additional to the strong dependency on foreign resources and the volatility of energy prices, demand growth is another major challenge to be faced, as well as the energy sector's environmental impact.

26 MEME 2020

Load curves are representative of the national profile of electricity consumption. They are useful for different actors, such as planners, investors, operators, consumers, and financial parties, informing on the nature of electricity consumption (industrial, domestic, etc.) and revealing gaps between lows and peaks.

Notably, as of July 12, 2021, the country experienced records in electricity demand[27], both in the morning and evening. The night peak of 6,710 MW was recorded at 21:45, corresponding to a 270-MW increase from the same period one year ago. The daytime peak reached 6,634 MW at 12:00, a 279-MW year-on-year increase.

The national electricity demand was 38,372 GWh at the end of 2020, down 1.2% compared with the achieved record in 2019. This was due to the pandemic and its economic and social impacts on the country.

To meet the growing demand for electricity, preserve the environment, and reduce energy dependence on foreign countries, Morocco has turned to the development of its own resources, including renewables. This will also provide it with a diversified energy mix. The NES emphasized renewables and promoted energy efficiency. Specific institutional reforms and a regulatory framework are needed to support the ambitious national energy transition. These constituted the pillars of the NES, launched in 2009 (Figure 17).

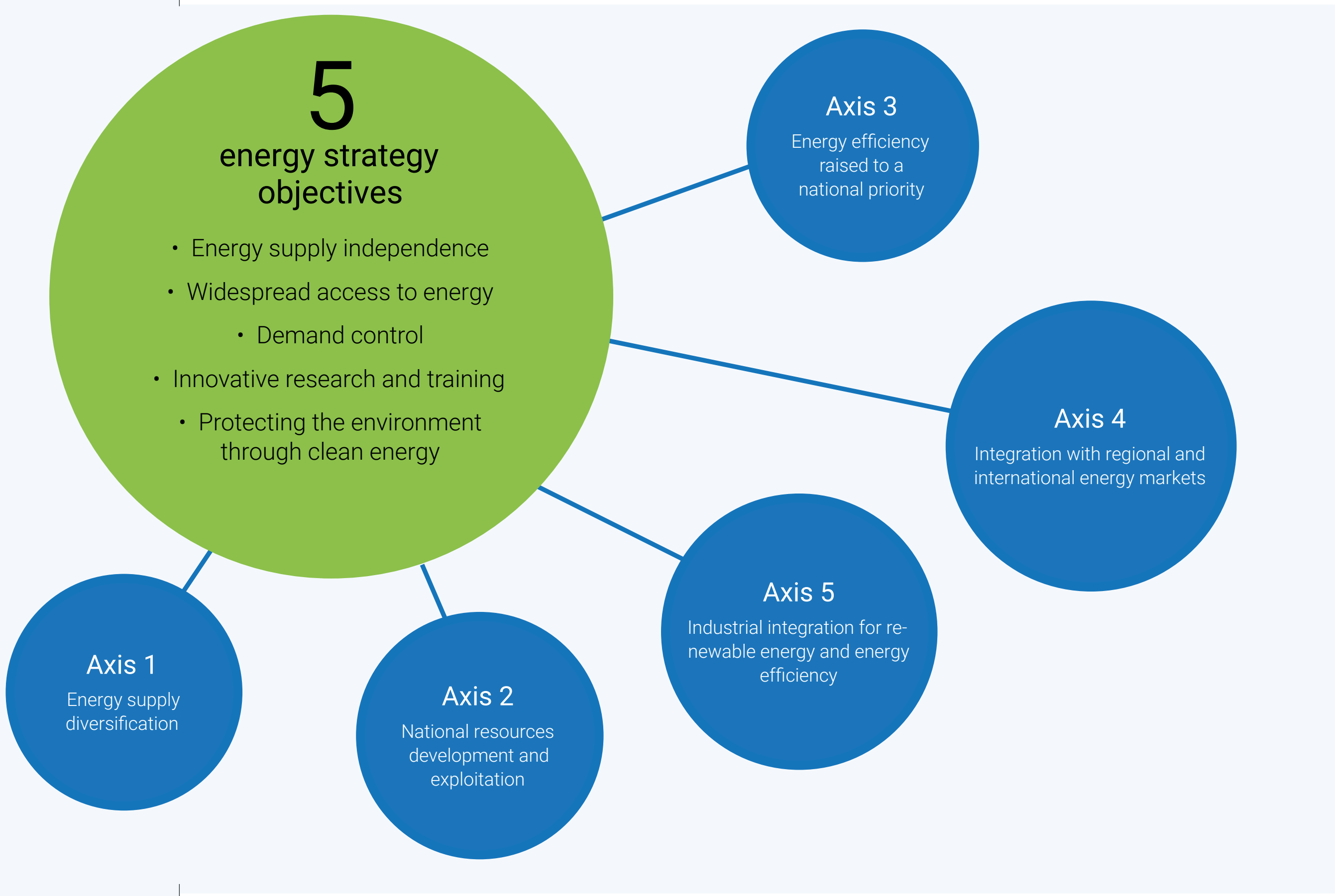


FIGURE 17 Structure of the National Energy Strategy (based on: International Energy Agency, 2019)

27 Le Matin 2021

Morocco's NES, one of the most ambitious in the MENA region, set out RE development and energy efficiency as priorities for the country's energy sector. This aims at meeting the country's fundamental energy objectives: (i) increase Morocco's energy independence, (ii) guarantee energy access through secure and affordable energy supply, and (iii) protect the environment.

The strategy's key pillars were to promote development of RE to achieve 42% of installed generation capacity from renewable sources by 2020, raise energy efficiency as a national priority, and reduce GHG emissions, targeting 32% by 2030.

As at the global level, the bulk of electricity is currently still derived from non-renewable resources. In Morocco, however, this situation will be transformed by 2030 (or earlier), when the predominance in the energy mix turns to renewables rather than fossil fuels. Since the NES launch, this aim has continued to develop in line with the strategy's objectives.

Figures 18 and 19 show the evolution, from 2019 to 2020, of the produced and injected electricity and the relative shares of different sources.

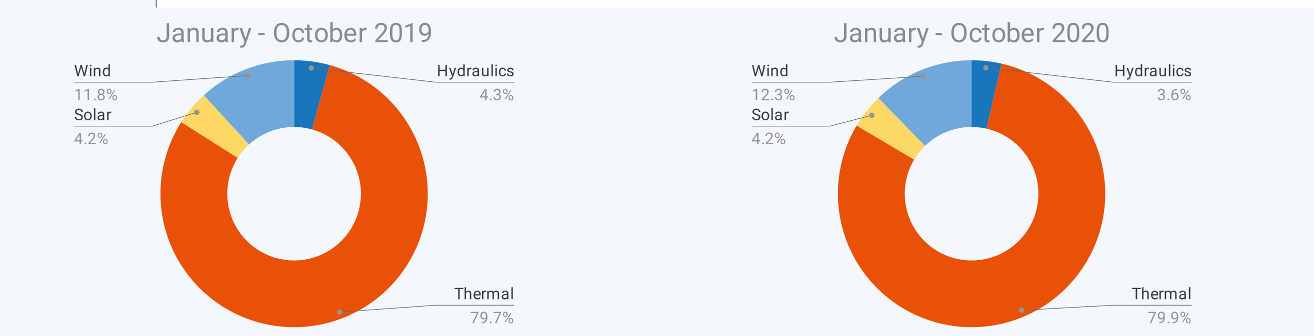


FIGURE 18 Distribution of energy produced, by source (based on: Ministry of Energy, Mines and Environment, 2020)

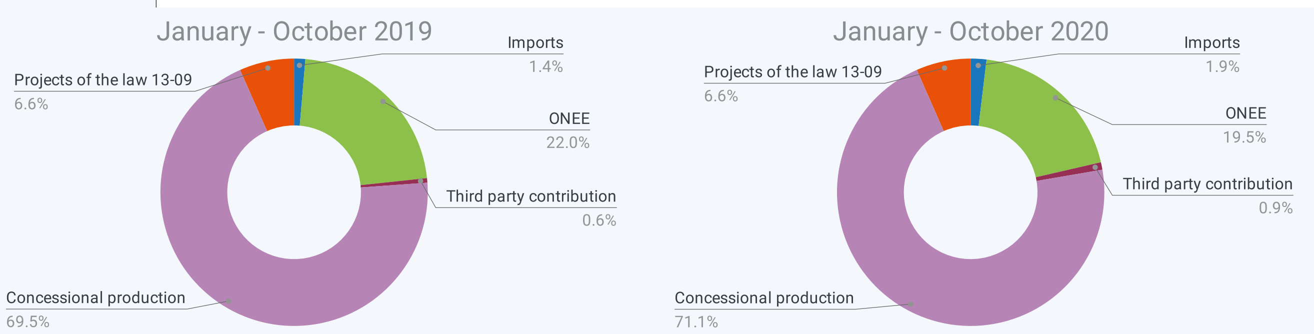


FIGURE 19 Energy injected, by source (based on: Ministry of Energy, Mines and Environment, 2020)

About 4,000 MW of the power from renewables is already operational (750 MW solar, 1,430 MW wind, and 1,770 MW hydro).[28]

Interconnections contribute to the electricity flux. They offer technical and economic added value to the electricity services in the interconnected countries, providing reinforcement amid the prospect of unforeseeable events, ensuring better service quality for consumers, and pooling resources for better optimization of investments.

Additionally, as mentioned, Morocco intends to reinforce its electricity exchange with certain Sub-Saharan and European countries.

4. Transformation of the electricity mix – Present and perspectives

Although thermal energy production based on fossil fuels still dominates the electricity generation mix, the coming years will see an increased share of renewables and increased emergence of gas (Figure 20). By switching to RE, 62 million tons of CO_2 emissions will be avoided by 2030.[29] The country has exceeded the target of a 42% RE share initially planned for 2020. In total, around 12,000 MW of electricity production capacity is to be installed.

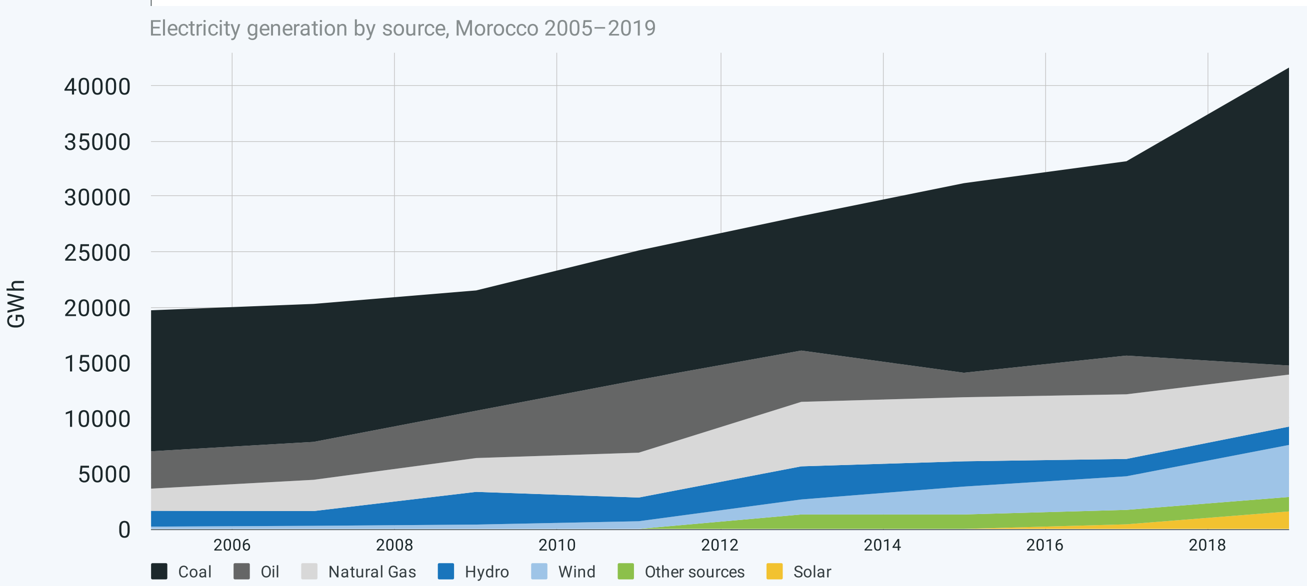


FIGURE 20 Electricity generation in Morocco, by source (Source IEA 2019, as modified by High Atlas Foundation)

Renewables have been expanding in use since 2010, at 20% on average annually for wind and 27% for solar, while total power capacities grew by 4% annually. Table 5 provides interesting indicators, such as the total decline in oil, continuous increase in wind capacity, substantial emergence of PV, and possibility that the rate of renewables will exceed the 42% and 52% targeted, respectively, for 2020 and 2030.

29 MEME - Stratégie énergétique nationale

Power Plants	End 2017	End 2020	End 2030	End 2040
Yearly Peak	**6180**	**6770**	**9853**	**13622**
Thermal power plants	**5850**	**6373**	**7679**	**10082**
Oil	600	0	0	0
Coal	2895	4116	4466	4166
CCGT	836	836	2036	2636
TG20 + TG33 + TG100	1230	1110	912	615
OCGT-400MW	0	0	0	2400
Gas Oil	289	311	265	265
Renewables (excluding pumped storage)	**2501**	**5012**	**10227**	**18977**
Classical hydro	1306	1356	1724	1724
Wind	1015	1819	5180	10063
PV	0	1307	2493	6360
CSP	180	530	830	830
Pumped storage	**464**	**464**	**814**	**814**
Total System Capacity	**8815**	**11849**	**18720**	**29873**
Share renewables (excl. pumped st.)	28.4%	42.3%	54.6%	63.5%
Share renewables (incl. pumped st.)	33.6%	46.2%	59.0%	66.3%

TABLE 5 Summary mix, in MW, for Morocco (Sources: National Office for Electricity and Drinking Water; Ministry of Energy, Mines and Environment)

By 2030, wind and solar will provide 38% of the total generation capacities. Certain sources (institutions' declarations) indicate the 52% target will even be increased by 59%, if not >60%, by 2030. Overall installed capacities will be close to 20,000 MW by 2030.

Regarding natural gas, a national plan was established for liquefied natural gas development. Total investment is estimated at $3.9 billion (combined cycle gas turbine [CCGT] plants: $1.8 billion; gas infrastructure: $2.1 billion). The generation is estimated at about 12,000 GWh annually with installed capacity to 2,400 MW, representing 14% of all installed capacity by 2025. The program may avert 10 million tons of CO_2 emissions by that time.

5. Forward-looking transformation in management of the water and electricity sectors

The Ministry of Interior recently decided to aim at generalizing standardization of the management of the water and electricity sectors.[30] Local authorities for water and electricity management would set specific provisions. The Ministry is also reportedly preparing a major regionalization project, and the country intends to deploy regional development companies specializing in management of the water and electricity sectors by 2027. The local authorities of each territorial region, ONEE, and the State, through certain ministries, will also be key players in the new sectoral landscape. Similarly, management of water and electricity will be entrusted to Morocco's 12 regions through transfer of competencies in this area to local development companies created at the level of regional councils, as planned by the project led by the Directorate-General for Local Communities.

30 Benbaba 2021

[26] MEME (2020), *Secteur de l'énergie chiffres clés Decembre 2020* (in French), p. 8. Available at: https://www.observatoirenergie.ma/wp-content/uploads/2021/01/Chiffres-cl%C3%A9s-D%C3%A9cembre-2020.pdf

[27] Le Matin. (2021) *Le Maroc enregistre des records de la puissance électrique appelée* (in French). Available at: https://lematin.ma/express/2021/maroc-enregistre-records-puissance-electrique/361448.html

[28] LeVert (2021), *Aziz Rabbah: Noor Ouarzazate permet d'alimenter près de deux millions de Marocains en électricité* (in French). Available at: https://www.levert.ma/aziz-rabbah-noor-ouarzazate-permet-dalimenter-pres-de-deux-millions-de-marocains-en-electricite/

[29] MEME, *Stratégie Energétique Nationale Horizon 2030* (in French). Available at: https://www.solarthermalworld.org/sites/default/files/news/file/2019-10-08/strategie_energetique_nationale_maroc_2030.pdf

[30] Benbaba, I. (2021), *Gestion de l'eau et de l'électricité: du nouveau dans le secteur* (in French), Le 360. Available at: https://m.le360.ma/economie/gestion-de-leau-et-de-lelectricite-du-nouveau-dans-le-secteur-243935

Chapter IV RENEWABLE ENERGY POTENTIAL

1. Global potential

Renewable capacities depend on geographic and climate characteristics of regions, countries, and cities, as shown in the following maps.[31]

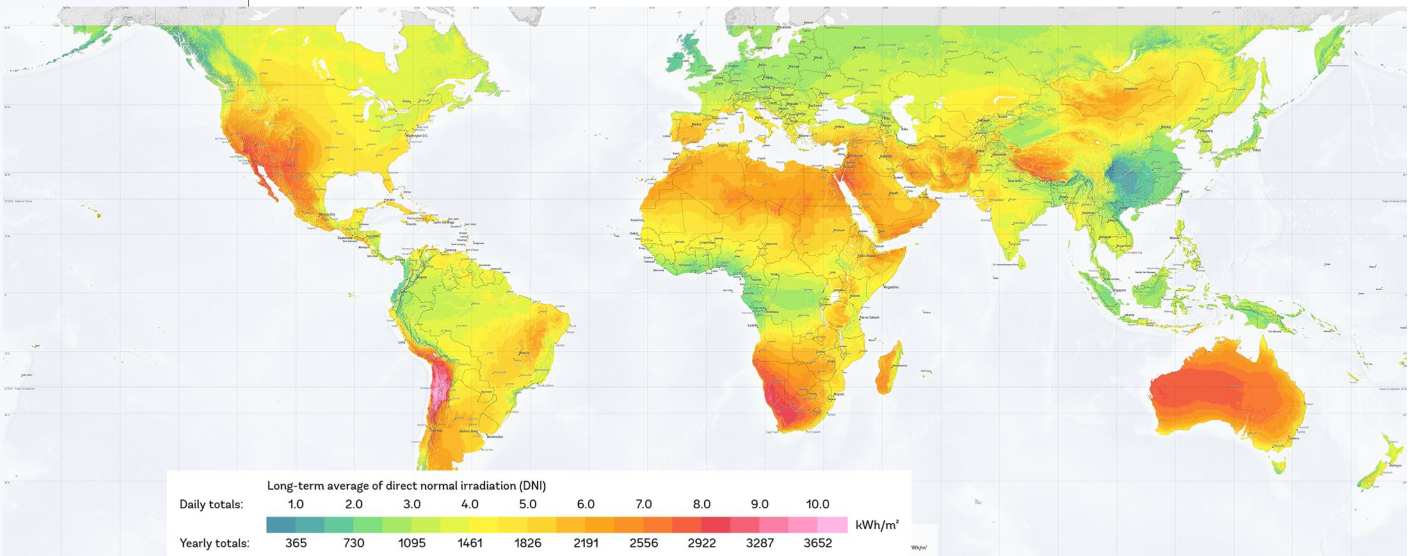


FIGURE 21 World map of direct normal irradiation (Source: Solargis)

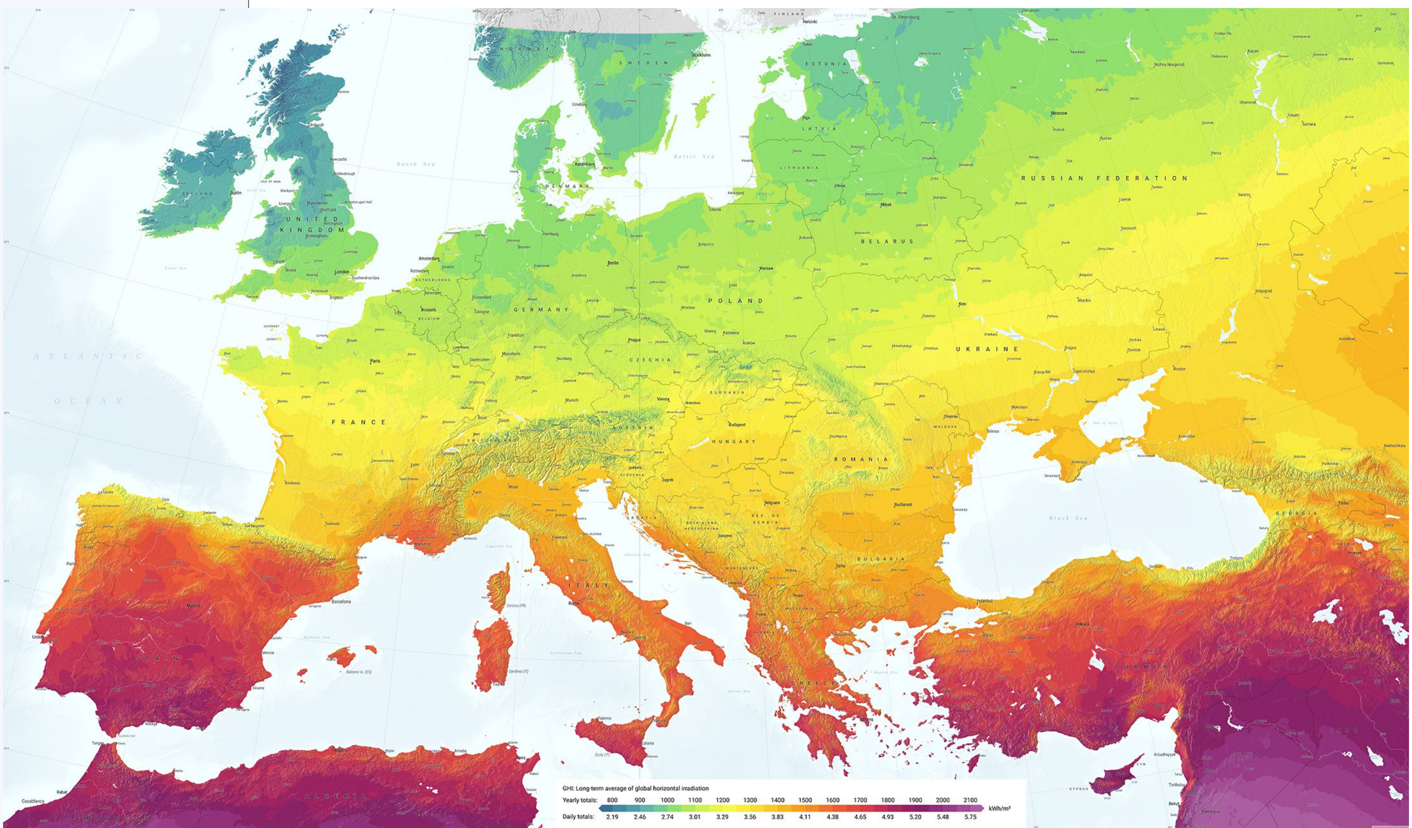


FIGURE 22 Horizontal global irradiation in Europe (Source: Solargis)

A focus on the African continent reveals its huge renewable potential – in solar (11,000 GW), wind (109 GW), hydroelectric (350 GW), and biomass (15 GW).

2. Potential of renewables in Morocco

Morocco benefits from high potential in solar and wind, though hydro resources remain less advantageous.[32] Solar and wind offer steady supply both temporally and spatially. The country capitalized on this high-performing national environment to develop an ambitious policy based on large-scale deployment of RE. The objectives of reaching 42% of renewable electric capacity by 2020 and 52% by 2030 were adjusted upward to reach renewable electricity production of 59% or even >60% by 2030. The strategic geographic proximity to Europe predisposes Morocco to also become a potential supplier of green molecules (hydrogen) with high added value.

Hydroelectricity

An ambitious public policy to produce clean power through dam construction was launched in the 1960s. Hydroelectricity generation, however, remains heavily reliant on rainfall. In the short term, only small- or micro-scale hydropower plants (100–1,500 kW) are expected to be built. The target is to increase hydro-generation capacity to 3 GW by 2030 and develop hydro storage with energy transfer from pumping systems.

Wind

The country enjoys 3,500 km of coastline, offering superior wind speeds exceeding 6 m/s. There is enormous wind potential of 5,290 TWh/year (2,645 GW), technical potential estimated at 5,000 TWh/year, and possible effective installed capacity of 25,000 MW onshore. These exceptional performance levels also led to the world's lowest cost per kWh ($0.03) for an 850-MW wind project (won by a consortium including Nareva, Enel, and Siemens).

Solar

With irradiation of about 6.5 kWh/m²/day and 3,000 hours/year, particularly in the country's south and east, the exploitable technical potential is estimated at 13,000 TWh/year and PV potential at 37,450 TWh/year.

Biomass

A study commissioned by the Ministry of Energy, Mines and Environment (MEME) found the national technical potential estimated at 11.5 million MWh per year. This was spread over four key sectors: agriculture (6.6 million MWh/year), forestry (1.7 million MWh/year), green waste (3 million MWh/year), and wastewater (0.2 MWh/year). A national roadmap for energy recovery from biomass, and forward implementation planning, have been established.[33]

Unlike solar and wind power, biomass does not suffer from intermittency. As a storable energy, the source could be adapted for basic charge, peak power, and regulation/reserve services. It also offers more regional added value through ways such as deforestation limitation, clean environment preservation, and job creation.

3. Perspectives

Morocco intends to develop its natural resources and capitalize on their multiple dimensions. It has elaborated roadmaps for green hydrogen (using SE) and bioenergy (biomass, biofuels, etc.). Efforts also continue to be deployed in the gas sector and mega-projects for desalination are being implemented or under study.

32 Benslimane 2015
33 MEME 2021

[31] The World Bank (2020), *Global Solar Atlas 2.0, Solar resource data: Solargis* (in French).
Available at: https://solargis.com/maps-and-gis-data/download/world

[32] Benslimane,I. (2015), *Les défis énergétiques au Maroc* (in French), EnergyStream.
Available at: https://www.energystream-wavestone.com/2015/08/maroc-vers-une-nouvelle-marche-verte/

[33] MEME (2021), *Feuille de Route Nationale pour la Valorisation Energétique de la Biomasse* (in French).
Available at: https://www.mem.gov.ma/Lists/Lst_rapports/Attachments/29/ValorisationEnerg%C3%A9tiqueBiomasseMaroc.pdf

Chapter V ENERGY TRANSITION

1. General overview

The energy transition corresponds to a pathway toward global energy sector transformation from fossil-based to zero-carbon by the second half of this century. Despite declining use of fossil fuels, they continue dominate globally (Figure 23). Oil and coal alone represent 58.4% of all primary energy consumption.[34] At the regional level, the energy mix varies (Figure 24).

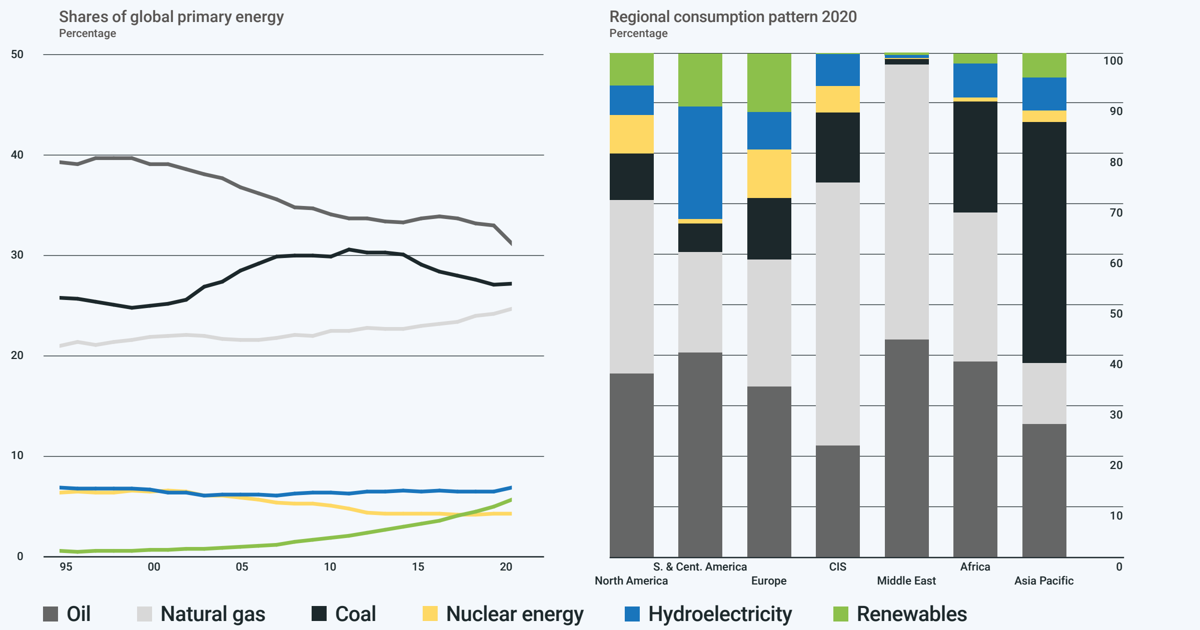


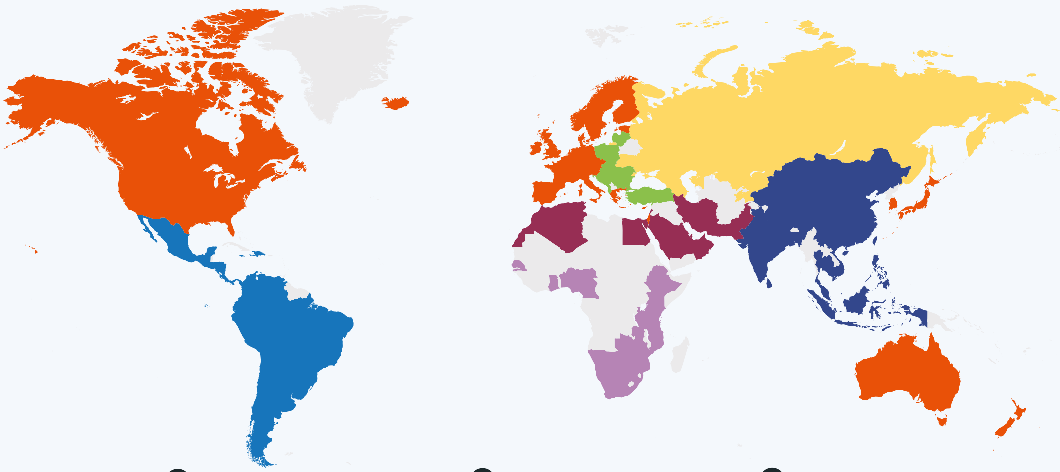
FIGURE 23 Shares of global primary energy (based on: BP 2021)

FIGURE 24 Regional consumption pattern 2020 (based on: BP 2021)

The IEA and IRENA predict fossil fuels will continue to dominate the global energy mix even by 2050, which signals a gradual energy transition. Awareness of the need for an energy transition is constantly increasing, considering fossil fuels' environmental impact. A rapid, low-cost energy transition requires ambitious policies accelerating energy solutions development with cleaner, smarter, and more efficient technologies. Development of more sustainable energy systems and flexible networks, by way of decentralization, energy efficiency solutions, electric vehicle charging systems, and interconnected hydroelectricity are some levers for accelerating the transition.

The Energy Transition Index (ETI) is an indicator reflecting the interdependencies of energy system transformation with macro-economic, political, regulatory, and social factors. The ETI allows comparison of countries based on their energy systems' performance, as well as their readiness for transition to a secure, sustainable, affordable, and reliable energy future. The WEF has evaluated the ETI regionally and globally for the last decades (Figures 25 and 26).[35]

34 BP 2021
35 WEF 2021



68.2 ↑2% 30% | 13% | 10.1t

Advanced economies

Advanced economies have improved the group average score by 2 points over the past decade, though the improvements have plateaued. Progress has been made in reducing CO, per capita and the CO2 intensity of the fuel mix, however emissions remain structurally higher than the rest of the world. Economic development and growth considerations, reliability of energy systems from increased intermittency and decarbonization of hard-to-abate sectors will be focus areas for energy transition in this group.

56.8 ↑5% 6% | 3% | 8.5t

Commonwealth of Independent States

The Commonwealth of Independent States improved their aggregate ETI scores by 5% over the last decade. Average scores on the economic development and growth dimension have declined as fuel export revenues fell due to commodity market volatilities. However, progress is encouraging in environmental sustainability, energy access and quality of electricity supply. Looking forward, efforts towards economic diversification and a stable regulatory environment to support energy transition will be critical.

54.9 ↑6% 40% | 47% | 3.74t

Emerging and developing Asia

Emerging and developing Asia has improved at the fastest rate compared to other regions 6% since a decade ago. Gains have been especially pronounced in energy access and security. However, challenges over the next decade abound. Energy demand per capita has grown 18% in the last decade and is projected to double by 2050. Recent trends indicate that coal continues to play a significant role in the energy mix. Creating a robust enabling environment to support investments and accelerate deployment of new technologies, while pursuing "just transition" pathways, can help the region to meet future demand in a climate-friendly way.

58.6 ↑2% 5% | 8% 2.4t

Latin America and the Caribbean

Latin America and the Caribbean region's average ETI score remained consistent over the last decade. The region leads in environmental sustainability, due to a heavy hydroelectric-installed base. Further improvements can be unlocked through improving energy affordability electricity prices on a purchasing power parity basis remain high in the region.
Although the region has achieved near-universal access to electricity, the quality of supply remains challenging in many countries. Increased diversification of the import counterparts and diversifying the energy mix can further improve energy security.

52.8 ↑2% 7% | 7% | 3.9t

Middle East and North Africa

Scores in the Middle East and North Africa fell last year but the overall trajectory remains moderately positive. Heavy reliance on oil revenue continues to present challenges to sustainable growth. Diversification of the economy and the energy system can improve prospects. Challenges remain in access and security, with heavy concentration in primary energy sources.
Several countries in the region have set out ambitious renewables targets for 2030. For this region, the coming decade presents opportunities to invest in an energy transition that can unlock significant cross-system benefits.

61.0 ↑5% 3% | 2% | 5.2t

Emerging and developing Europe

Emerging and developing Europe's average ETI score increased by 5t% between 2012 and 2021. The region saw a balanced improvement across all three dimensions of the energy triangle. Improved diversity of energy mix, higher quality of electricity supply and strong energy intensity reductions were primary improvement levers. However, this region has a higher share of coal than the European average and flexibility remains low, which may prove challenging as the share of renewable energy grows in power generation. According to IRENA, renewable sources could cover more than one third of energy demand in this region, with benefits in savings from energy costs, health and reduced dependence on imports for primary energy.

50.7 ↑2% 2% | 8% | 1.1t

Sub-Saharan Africa

Sub-Saharan Africa's trajectory on the energy transition journey has been a positive one, although the region remains the most challenged globally in access and security. Access to electricity and basic energy services remains lowest in this region at 56%. The region has great potential to leapfrog by avoiding expensive, inefficient and more polluting energy infrastructure. Countries should consider all avenues to improve access, including off-grid electrification given the falling costs of solar panels. Improving the enabling environment for the energy transition, including policies for energy efficiency and electrification of transport, can acceler ate progress in the region.

FIGURE 25 Regional scores – ETI 2021 and change from ETI 2012 (based on: World Economic Forum 2021).

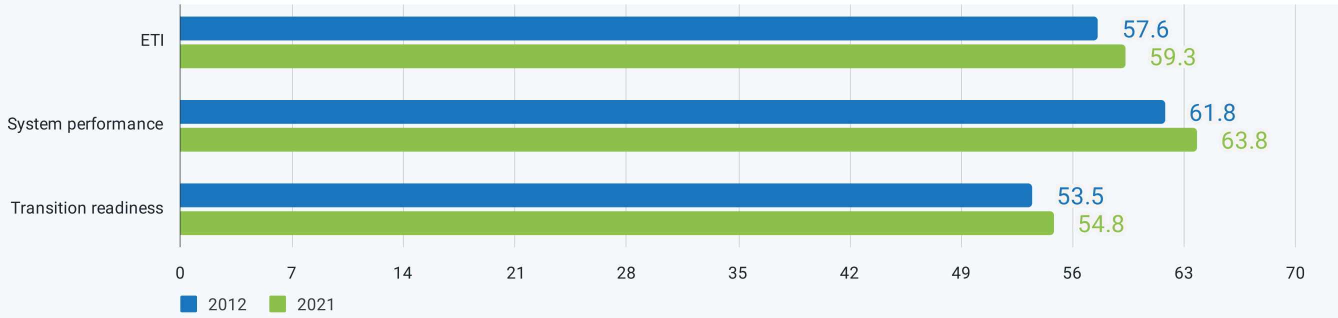


FIGURE 26 ETI 2021 Global average scores (based on: World Economic Forum 2021)

Some studies have addressed benefits vs. costs to prove the profitability of investments in the energy transition, quantifying in the short, medium, and long terms. An IRENA publication summarized, in the graph below (Figure 27), the cumulative system costs and savings from reduced externalities for the Transforming Energy Scenario to 2050 and Deeper Decarbonization Perspective to 2060.[36]

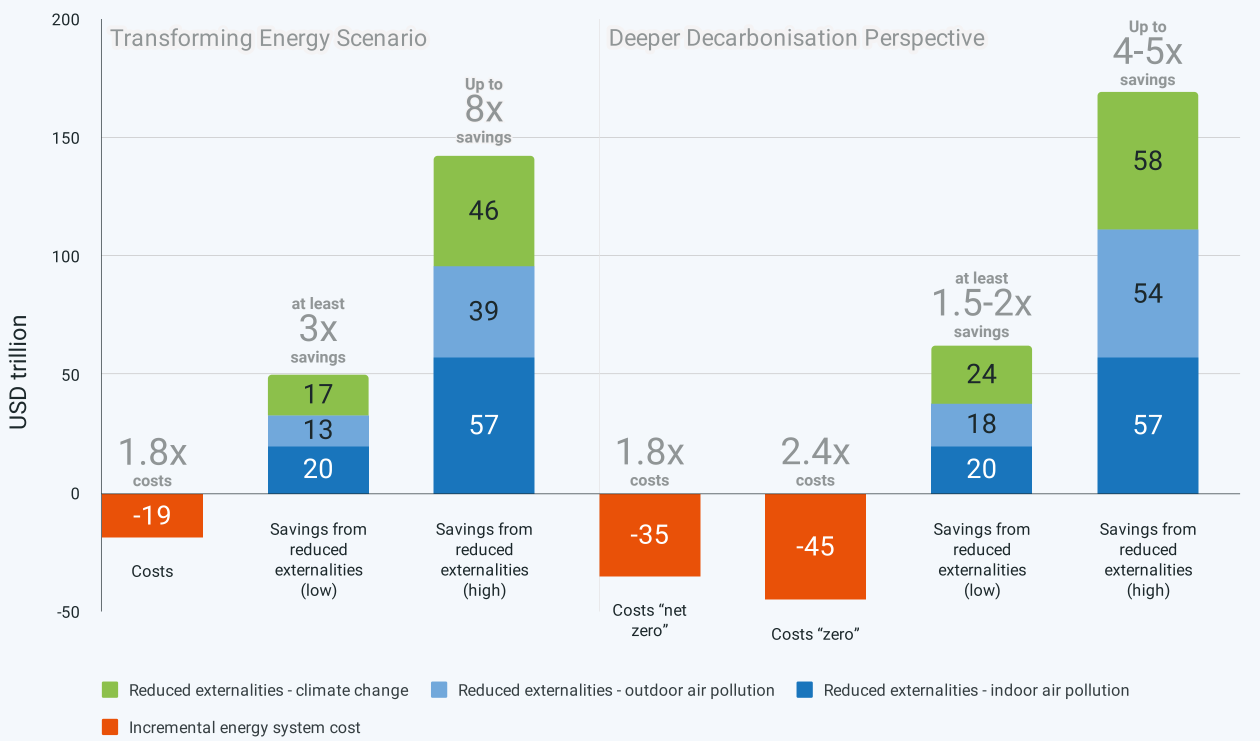


FIGURE 27 Benefits compared with costs in the energy transition (based on: IRENA 2020).

In 2020, for the first time, global investments in the energy transition (RE, electrification of transport, hydrogen, etc.) exceeded those in upstream oil and gas. Although spending on the latter is rising again in 2021, the oil and gas industry remains under strong pressure from the pandemic and from energy transitions.[37] For the MENA region, the Arab Petroleum Investments Cooperation expects the investments in the energy sector will exceed $800 billion by 2026, and about 40% from the $250 billion devoted to the electricity sector will be reserved for RE.[38]

36 IRENA 2020
37 IEA 2021
38 APICORP 2021

2. Specifics of the local situation

In Morocco, the energy transition was mainly crystallized by the NES, based on RE and energy efficiency solutions. The strategy targeted 52% renewables in the energy mix and a 42% reduction of GHG by 2030. Acceleration of the energy transition was confirmed on May 12, 2021, by the Moroccan Minister of Energy, announcing that the 52% target of RE installed capacity would be achieved before 2030, estimating it may be before 2026. The MME also revealed that national roadmaps for green hydrogen and bioenergy have been expanded. The 4 GW of RE (solar, wind, and hydro) now account for about 37% of the total power generation mix.

2.1. National context

Morocco, exposed to fluctuations in the price of imported fossil fuels, has opted for sustainable development. Energy transition constitutes one of its main pillars. Based on substantial penetration of renewables in the energy mix and on deployment of energy efficiency measures, the transition has been accelerated with the country's recent international commitment.[39]

Long before 2009 (when the NES was implemented) investments were made in the hydro and wind power sectors. The "Large dam policy" has been deployed since the late 1960s. Other steps followed, including creation of the Renewable Energy Development Center (CDER) in 1980, formation of the Moroccan Association of Solar Industries in 1987, installation of two PV panel encapsulation units in the early 1990s, launch of PERG in the late 1990s, and realization in 2000 of the Koudia El Baida wind farm, at 50 MW the largest wind farm in Africa at the time.

2.2. National Energy Strategy

The decision to focus on renewables came in March 2008, when demand for electricity was rising by 5–6% per year, oil prices skyrocketed, and natural gas was virtually unavailable. The government adopted a voluntarist NES to address the energy sector. Implemented since 2009, the NES has resulted in effective, progressive penetration of renewables in electricity generation. A few years later, the initial objectives for 2030 were revised upward:

- 52% of installed electrical power of renewable origin – of which 20% is SE, 20% wind, and 12% hydro
- 20% energy savings compared with current trends; the breakdown of expected energy savings by sector is 48% for industry, 23% for transport, 19% for residential, and 10% for services
- Additional installed capacity of 3,900 MW of combined cycle technology running on imported natural gas
- Supplying major industries with imported and re-gasified natural gas via pipelines

Installed electrical capacity reached 10,627 MW, with a substantial portion of that from RE. The most recent examples are the 40-MW Erfoud Photovoltaic Plant (Tafilalet Solar Project) and the 210-MW Midelt Wind Farm.

39 UNFCCC 2016

2.3. Accompanying measures

The main concrete measures to achieve the above objectives were:

- Solar Plan, published in 2009, targeting 2,000 MW in 2020
- Integrated Wind Energy Plan, published in 2010, targeting 2,000 MW in 2020
- Specific regulations
- Institutional measures
  - Creation of:
    - MASEN
    - Société des Investissements en Energie (SIE: Company of Energy Investments) in 2010, becoming a super energy services company (ESCO) in 2018
    - Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN: Research Institute for Solar Energies and New Energies) in 2011
    - IFMEREE – Institut de Formation aux Metiers des Energies Renouvelables et de l'Efficacite Energetique (Training Institute for Renewable Energy and Energy Efficiency Professions) network
    - ANRE as a regulatory authority
- Transformation from CDER to Agence de Développement des Énergies Renouvelables et de l'Efficacité Énergétique (Renewable Energy and Energy Efficiency Development Agency) in 2010, and to AMEE later
- Mobilization of specific funds
- Development of programs to deal with intermittency
  - STEP (energy transfer by pumping): Morocco already has an installed capacity of 1,770 MW. The Afourer STEP had capacity of 460 MW. The one in Abdelmoumen will have a capacity of 350 MW and be operational in the first half of 2022, allowing Morocco to exceed 2,000 MW of hydroelectric power capacity. Another program oriented toward marine STEPs is also under development.
  - CCGT: This was positioned as a suitable solution for RE intermittency. The national gas strategy includes construction of a terminal with substantial additional CCGT capacity, estimated at an investment of $4.6 billion. The option to develop the gas sector has a double objective: contribute to reducing electricity production's impact on the environment and better adaptation of existing infrastructure to RE's specificities to ensure flexibility necessary for managing a large RE production capacity.
  - Interconnections: Morocco, already interconnected with southern Europe and the Maghreb, will develop new interconnections, such as building a 220-km line connecting Morocco and Portugal, with 1,000-MW capacity, at an estimated investment of $580 million, a plan to strengthen interconnection with Spain via a third line with 700-MW capacity, and a line with Mauritania is currently under consideration.

In late 2014, Morocco eliminated subsidies for gasoline, diesel, and fuel oil, dramatically reducing outlays that weighed on the country's budget and current account.

3. Projects' overview

3.1. General objectives

RE's penetration in the energy mix has been set at 42% in 2020, 47% in 2025, and 52% in 2030. As a result, 2030 would mark a historic turning point in which the share of renewable electricity would exceed that from fossil origins (Figure 29). As mentioned in the previous chapter, the previous rates are now being exceeded.

To achieve these targets, the country is planning 10,100 MW of additional RE capacity (4,560 MW from solar power, 4,200 MW from wind, and 1,330 MW from hydro). This plan, which spans 2016–2030, will requires investment of approximately $40 billion. The 800-MW Noor Midelt hybrid power plant and the 850 MW Boujdour wind farm – both commissioned in 2019 – have strengthened the sector's ambitious achievements. More ambitious than the Noor Ouarzazate Solar Complex, some new RE projects, such as the Noor Midelt Solar Power Project, another solar mega-project has just been launched, for a planned capacity of 800 MW for phase I. Morocco also aims to reduce consumption by 20% by 2030 (energy efficiency target) and GHS emissions by 42%, conditional on international support.

Since the NES launch, the strategy's implementation has yielded a gradual transformation of the energy mix and the initial goals are even being exceeded (Figure 28).

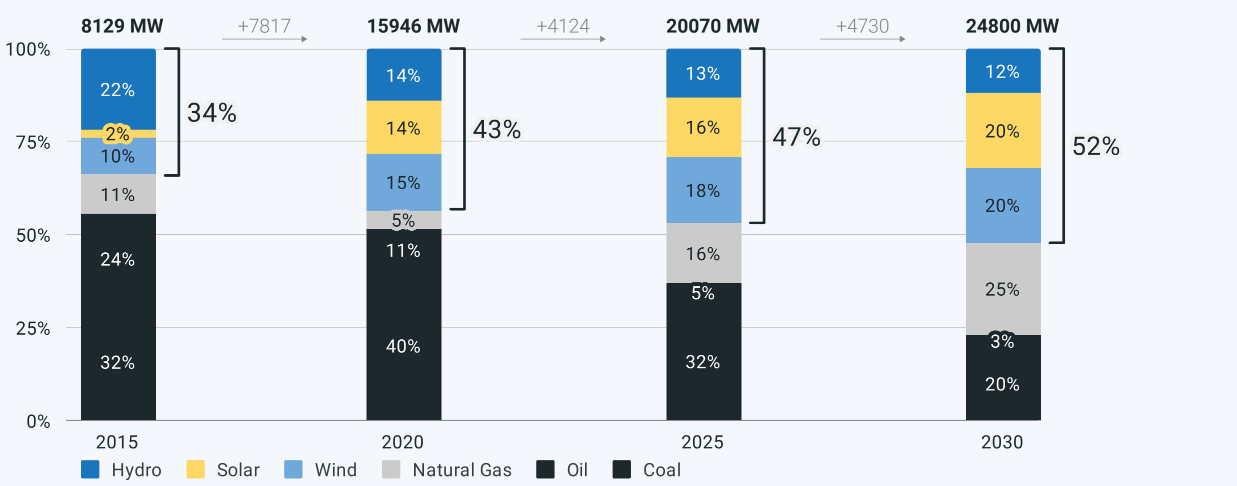


FIGURE 28 Evolution and perspectives of the energy mix (based on: École Nationale de la Statistique et de l'Administration Économique Alumni, IP Paris [2019])[40]

3.2. Wind projects

As indicated above, the installed capacity targeting 2,000 MW by 2020 was reached ahead of plan. The Integrated Wind Energy Plan is expected to save 1.5 million tons of oil equivalent (TOE) of fuel per year and avoid 5.6 million tons of CO_2 emissions annually. The plan's overall cost is around $3.8 billion.

3.3. Solar projects

Different technologies are being tested at several sites, per a national roadmap. The rising performance of PV technology, however, is encouraging development of PV power plants.

40 ENSAE Alumni, IP Paris 2019

4. Incidence of energy dependency

The important efforts made to implement the NES have produced results comparable with those expected in decreasing dependency on hydrocarbon imports. Some assumptions lead the Conseil Economique Social et Environnemental (CESE: Economic Social and Environmental Council) to expect an accelerated reduction in energy dependency (Figure 29).

According to the Foreign Exchange Office, Morocco's energy bill fell by 34.6% (26.4 billion dirhams, or approximately $29 billion USD) year on year in 2020. This drop is explained by the decrease in both imported quantities and prices and the new dynamics of electrical power that allowed Morocco to meet its internal needs and become an electricity exporter.[41]

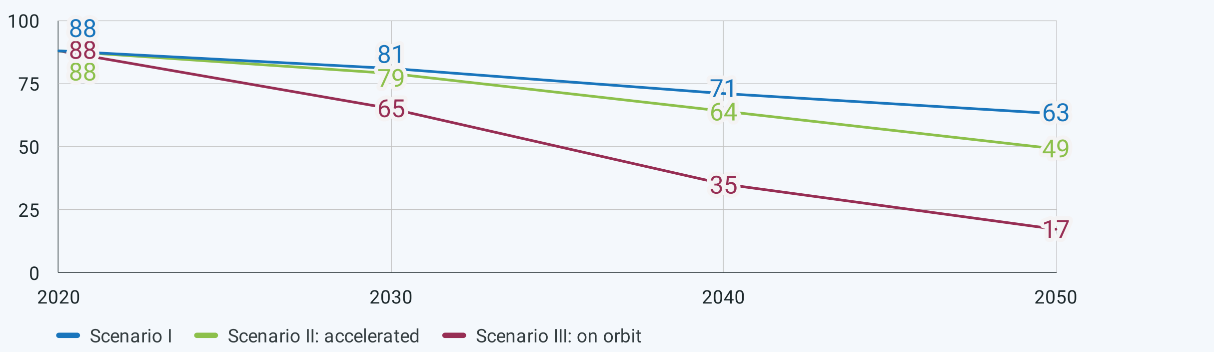


FIGURE 29 Rate of energy dependence (based on: Economic Social and Environmental Council, 2020)[42]

5. Conclusion

Implementation of the Moroccan energy transition, as the NES's main component, focuses primarily on large-scale, centralized projects. Complementing these utility-scale projects with decentralized, small-scale SE initiatives that directly benefit local communities has thus far not been a priority. The few initiatives that were implemented have only been undertaken as a part of energy efficiency solutions. The "Green Mosques (or Green Building)" initiative is a well-known example of this. The inauguration of Africa's fully solar-powered village close to Essaouira and even PERG – for its part supported by the INDH – were conclusive experiences, but not replicated. Solar water pumping, one of the decentralized solar applications in rural areas, awaits concrete incentives.

PV, compared with other renewable technologies less suitable for individual use, lends itself well to the decentralized applications, as has been demonstrated in multiple countries' experiences. Morocco's PV potential and the technology's competitiveness have recently encouraged policymakers to promote some small- and medium-sized projects, aiming to stimulate the industrial sector and promote decentralized solutions for domestic, industrial, and tertiary sectors. Indeed, along with the thermal use of the solar resource for heating water in homes, solar will also be exploited for self-production of electricity for all categories of consumers.

Morocco has made progress in liberalizing electricity and toward the use and support of RE within its legal framework. Law 13-09, for example, allows any producer of RE-based electricity (private or public) to be connected to the medium-, high-, and very high-voltage national electricity grid. Law 58-15 amends and supplements this law and allows RE producers to sell surplus electricity to the grid. This is, however, limited to 20% of their annual production and only for the high-/very high-voltage grid, which inhibits small-scale, decentralized project development. To capitalize on the multiple opportunities RE offers, and further extend their applications to different sectors, however, it will be necessary to speed up the regulatory process relating to opening the low-voltage network.

41 Fédération de l'Energie 2021
42 CESE 2020

[34] BP (2021), Statistical Review of World Energy 2021, 70th Edition, Shares of global primary energy. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

[35] WEF (2021), Fostering Effective Energy Transition 2021 edition. Available at: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf

[36] IRENA (2020), Global Renewables Outlook: Energy Transformation 2050. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_Summary_2020.pdf5

[37] IEA (2021), World Energy Investment 2021. Available at: https://iea.blob.core.windows.net/assets/5e6b3821-bb8f-4df4-a88b-e891cd8251e3/WorldEnergyInvestment2021.pdf

[38] APICORP (2021), MENA Energy Investment Outlook 2021-2025: Overcoming the Pandemic. Available at: https://www.apicorp.org/wp-content/uploads/2021/05/APICORP_MENAEnergyOutlook2021-2025_EN_FINAL.pdf

[39] UNFCCC (2016), Morocco Nationally Determined Contributions under the UNFCCC. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Morocco%20First%20NDC-English.pdf

[40] ENSAE Alumni & IP Paris (2019), *Stratégies énergétiques: cas du Royaume du Maroc* (in French). Available at: https://www.ensae.org/fr/news/strategies-energetiques-cas-du-royaume-du-maroc-761

[41] Fédération de l'Energie (2021), *La facture énergétique chute de 34,6% en 2020* (in French). Available at: https://www.fedenerg.ma/2021/07/29/la-facture-energetique-chute-de-346-en-2020/

[42] CESE (2020), *Avis du Conseil Economique, Social et Environnemental Auto-saisine n°45/2020 Accélérer la transition énergétique pour installer le Maroc dans la croissance verte* (in French). Available at: http://www.cese.ma/media/2020/11/Av-transitionEnergetique-f-1.pdf

Chapter VI RENEWABLE ENERGY DECENTRALIZATION AS A SUPPORT FOR RURAL ENERGY NEEDS AND PRODUCTIVE ACTIVITIES

1. Introduction

In electrification, Morocco is one of Africa's leading countries (Figure 30). It is also a pioneer in the RE field. Fossil sources, however, still dominate electricity generation and, in the same way, the RE landscape is marked by centralization. As a result, the majority of consumers do not receive supply of clean energy sources and dependence on the national grid still dominates.

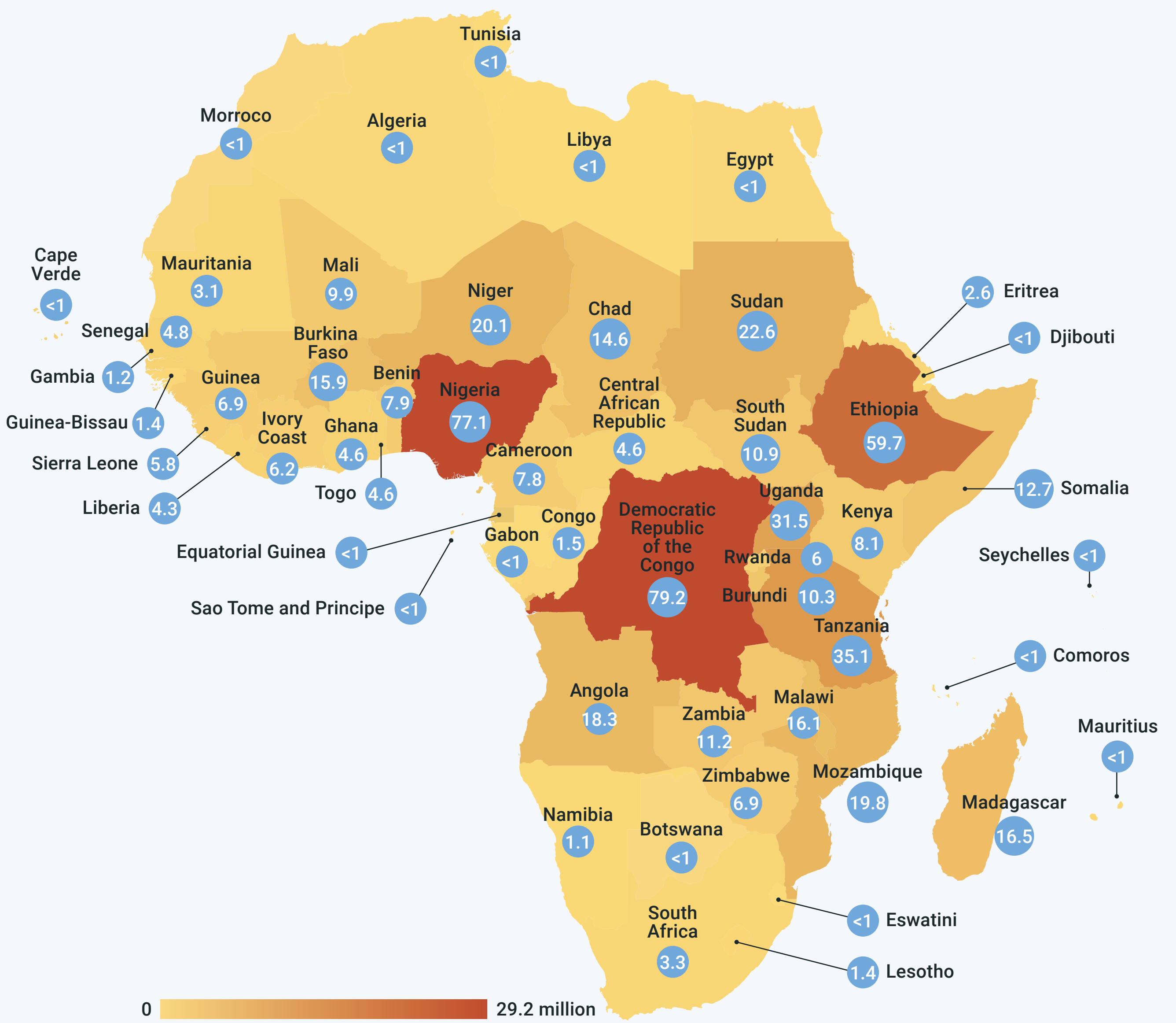


FIGURE 30 Population without access to electricity in Africa, by country (Source IEA 2020, as modified by High Atlas Foundation)

As mentioned, the 2021 CCPI ranked Morocco in the top 10 regarding its GHG emissions, energy consumption, and climate policy. The country's performance, however, was medium regarding the RE criterion.

The combination of RE centralized supply – currently almost dominant – with decentralized production should be explored to improve this underperformance and reduce the gap between the target and trajectory to much lower than 2°C.

While RE development has ambitious objectives, which the current trajectory seemingly confirms, the RE component of the NES's deployment shows certain needs.

- The energy transition has been driven by a government policy aimed at reducing the country's energy dependence and limiting emissions from fossil fuels. As a top-down approach, the participation of populations concerned, or their representatives, is not put forward, in particular to make citizens aware of energy's economic and environmental challenges.
- The developed, developing, or planned projects remain large-scale, capitalistic, and have a high landuse rate. Furthermore, for some solar plants, a considerable amount of water could be required for the
- panels' maintenance.
- The RE plants planned as part of the NES must be connected to the national grid. This calls for upgrading the network infrastructure to integrate intermittent energies, with a constantly growing penetration rate.

2. Centralized vs. decentralized electrical systems

2.1. Constraints and limits of the centralized energy model

The centralized model of electricity production and supply currently has certain constraints and limitations. As with the global energy mix, fossil fuels still dominate the national energy mix; these have a particularly negative environmental impact. Additionally, any necessary extension of the electrical network is accompanied by added losses on the electrical lines. With the materials currently used, these losses cannot be eradicated, despite efforts made to reduce them.

As an example, the grid extension under PERG has tripled the network length. Technical and non-technical losses in lines and transformers have resulted, with a corresponding annual deficit of around $1.1 million. A part of the produced energy is also not distributed. This is more important in an antenna configuration than in a looped network. Additionally, the network's capacity and configuration limit its RE absorption capacity. Integration of renewables in a centralized power system, with a high penetration rate, thus constrains the grid, while the share of RE in the energy mix is set to increase in future years.

Decentralized networks integrating RE substantially reduce or overcome the above constraints. Mini-grids and standalone systems are a more competitive alternative for more than half of the people without access to electricity. Micro- or mini-grids can be deployed in collective or individual farms, in agricultural or artisanal cooperatives, as well as in processing or packaging factories of agricultural or fishing products, located in rural or isolated areas.

IMAGE 1 Solar-powered drip irrigation is a zero-emission technology that provides water efficiently for agricultural use.

2.2. Overview of the decentralized energy situation and perspectives

Until the early 1900s, humanity conventionally adopted a decentralized energy model along the entire value chain. Indeed, each family group had to source, store, and manage its own energy resources. This model disappeared with the emergence of power plants and power grids. The current orientation toward a decentralized model is, in a sense, a return to the past. The emergence of clean technologies, their increasing affordability, and the high potential for reducing pollution accelerate achievement of climate objectives. In electricity generation and distribution, the off-grid solar sector, started in 2008, was deployed with the first mini-grids and equipment in 2014, and since 2017, it has not stopped to expand the range of specific devices.

As IRENA forecasted in 2016,[43] the share of decentralized energy in the RE mix's composition (Figure 31) reveals that only the Southern Africa region intends to substantially develop distributed PV solar.

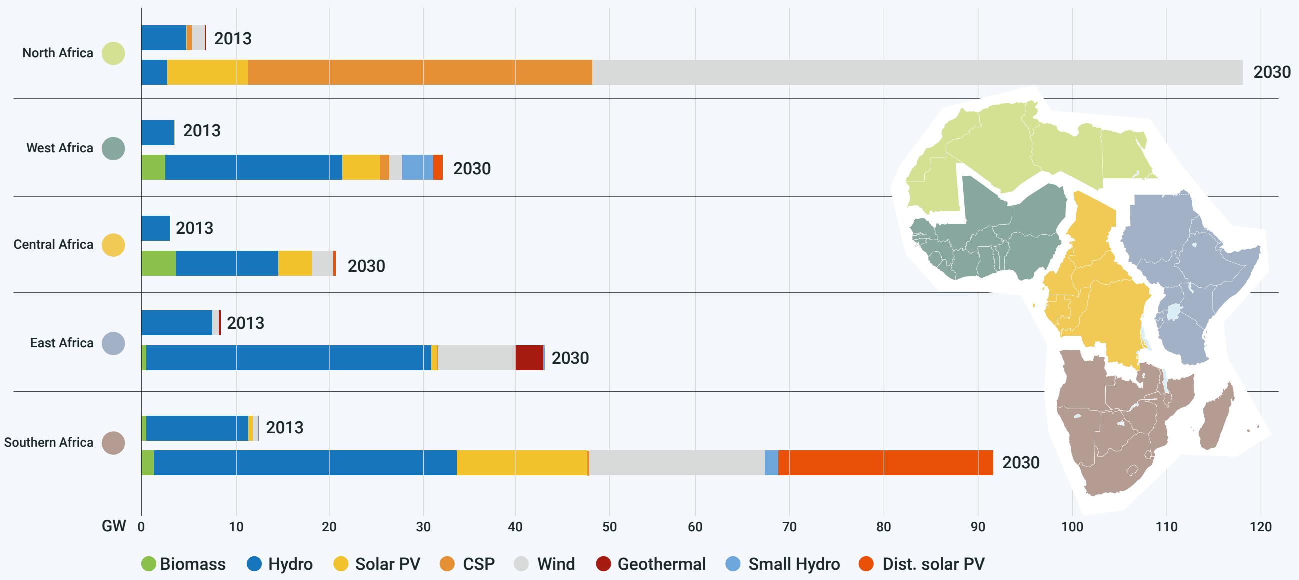


FIGURE 31 Capacity development of renewable energy map options in 2030 (based on: IRENA 2015)

Decentralized solutions have already provided access to essential energy services for around 15 million people in Africa.[44] Meanwhile, while around 18 million solar home systems are currently in use, serving tens of millions of people.[45] Solar PV systems' distribution in Morocco was jointly done through PERG by ONEE and INDH. The PV equipment led to electrification of 51,559 households in 3,663 villages in 1998–2009 and 19,438 households in 900 villages as part of the INDH solar project in 2016–2018.

Table 6 quantitatively summarized the situations of decentralized RE in Africa and Morocco.

	Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total RE	Africa	294 351	336 876	391 964	435 195	515 772	665 929	916 835	1 177 138	1 304 297	1 353 668
	Morocco	13 500	19 000	20 000	20 000	23 800	23 800	25 870	29 456	29 457	29 465
Solar PV	Africa	87 976	109 229	154 515	189 861	237 687	358 168	605 966	844 404	961 073	997 639
	Morocco	13 500	14 000	15 000	15 000	18 800	18 800	20 870	24 456	24 457e	24 465e
Other RE	Africa	66779	86799	91 571	97 691	123 711	133 592	135 953	138 822	139 312	139 417
	Morocco		5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000e

e = estimated by IRENA

TABLE 6 Off-grid renewable capacity (MW) in Africa and Morocco (Source: International Renewable Energy Agency 2020)

43 IRENA 2015
44 ESMAP, 2019
45 ESMAP 2020

3. Fundamentals of the pilot project

The project discussed in this paper aims for accessibility, reliability, and sustainability in line with the overall concept comprising the country's NDC, and specific national strategies and programs (NES and NEES, Green Morocco Plan, etc.). These key values are deployed throughout the process, from the choice of energy source (clean and decentralized) to the project objectives, while adopting a participatory and inclusive approach.

Thus, for the project's main components, regarding accessibility, solar represents an affordable electricity source. Recent years' decreased prices have increased competition and the development of solar PV energy. The technology has been confirmed as reliable, making it possible to multiply its applications and extend them to several sectors. Regarding sustainability, solar technology emits little CO_2. The same goes for electronic (inverters) and monitoring information technology associated with the foreseen solar solutions, here the above values are also continuously improving.

Additionally, the project aims to transform decentralized solar installations in rural areas from means of consumption to levers supporting productive activities, upgrading their role. It will also adopt the FEW nexus approach and enrich it through the hygiene dimension, now one of the key health measures that should be mainstreamed.

Finally, the decentralized energy system can help build an inclusive energy system aimed at accelerating the transition to sustainable, low-carbon economies and resilient societies. Certain social, economic, and environmental goals could be achieved, such as:

- Comfort and energy autonomy, thanks to the proximity of energy sources
- Energy saving, by absence of losses associated with transport and distribution of energy
- Non-need for high investment budgets for constructing large power plants, network extensions, and their maintenance
- Reduced CO_2 emissions
- Bypassing still predominant fossil sources
- Diversifying and promoting rural activities
- Emergence of new professional competencies; stimulating local employment opportunities to benefit younger people, promoting the management spirit of community work

3.1. Focus on rural activities

Agriculture implies food security worldwide and is the dominant employment sector in Africa, accounting for more than 50% of the active population in sub-Saharan Africa. It contributes to 23% of the continent's GDP.[46] Africa's expected population growth by 2030 will increase food demand by 60% vs. 2015.[47] Sustainable energy sources offset the threat of climate change by increasing agricultural production to meet food needs and enhance food security.

In Morocco, with its rural population of around 43%, agriculture also plays a socio-economic role, substantially contributing to GDP (9–14%) and employment (around 40% of the active population), remaining the most dominant economic activity. The agro-industry is insufficiently developed and not uniformly distributed across the territory, with the majority of services concentrated in urban centers. Thus, opportunities for rural inhabitants are mainly in agriculture and animal husbandry.

46 Pais et al. 2020
47 RES4Africa 2019

3.2. Water at the heart of concerns

Agricultural performance depends on rainfall and weather. Admittedly, 2008's Green Morocco Plan, a strategy aiming to improve productivity and added value of the sector, has in 10 years led to a 60% production increase and quadrupled exports; however, the sector experiences water scarcity from the double constraint of over-exploitation of water resources and scarce precipitation. Water availability per capita fell below the recommended threshold. Forecasts surrounding certain water basins indicate residents' water availability will decrease to the point of shortage by 2050. In 2019, the Moroccan Economic, Social and Environmental Council again warned of water-source overexploitation. Demographic growth, economic development, and modern life place increasing pressure on this natural resource's reserves.

Morocco is also exposed to global warming, like many countries. Current trends and forecasts show its great vulnerability to the impacts of climate change. Precipitation observations and projections converge in a state of water scarcity that, accordingly, impacts agriculture and food.

3.3. Renewables as a privileged source of energy and a lever for productive activities

Morocco's leadership and high RE production potential, on the one hand, and its environmental commitments on the other, combined with continued progress in solar PV technology, constitute tangible arguments for the project's energy source choice. Generalization of decentralized SE systems accelerates energy transition to achieve objectives sooner, or even exceed them.

The most conventional use of PV SE in distributed systems is the supply of electricity to rural households for essential needs (e.g., lighting, refrigeration, mobile phone charging). Pumping water for irrigation is also the most common application using PV for productive activity. Additionally, the project suggests extending use of SE to other agricultural and non-agricultural productive activities, as well as community and professional services, likely to be supported by decentralized SE systems.

3.4. Toward an extended food–energy–water nexus, and recent challenges

Access to essential resources of clean water, modern and non-polluting energy services, nutrients, and sufficient food is vital for humanity, especially since the COVID-19 crisis pushed back a "zero hunger" goal set by international organizations (including the Food and Agricultural Organization of the United Nations) from 2030 to an undefined date.

The innovative approach to sustainable development called the FEW nexus considers existing interactions between these components at the heart of the fight against global poverty and effectively implementing sustainable development objectives. Integrated management of these components helps in facing Morocco's challenges of global warming and water stress. The joint impact of drought and COVID-19 on Morocco's economy (e.g., productivity reduction, import reduction) heightens the relevance of building the new model by transitioning from the FEW nexus approach toward a more sustainable and resilient future.

Through an integrated vision, the project adopts the FEW nexus concept, but by favoring clean energy sources and introducing a complementary dimension linked to health, that of hygiene, which has now become a decisive factor with the widespread health crisis. This complementary dimension is all the more relevant as the project is aimed at the rural community. The FEW nexus will now be labelled food–RE–water–hygiene (FREWH).

3.5. Inclusive and participative approach

Appropriate solutions adapted to local contexts will ensure the initiative's success. Community ownership and partnership with stakeholders through a participatory process will yield the best conditions for decisive results. The participatory approach entails the overall development process being driven by local people who are engaged in every step—from identifying challenges to finding innovative solutions, managing projects, monitoring, and evaluating results—with integration into all project phases. Under this framework, resulting initiatives directly satisfy communities' needs and are well-suited to local social and environmental conditions. Meaningful engagement first requires an enabling environment of inclusive participation: running capacity workshops, empowering women, providing skills-training, promoting literacy, engaging in group dialogue, etc.

The project therefore involved citizens and local representatives in deliberation, identification of priority needs, and proposal of adapted solutions. The High Atlas Foundation also facilitated the rights-based "Imagine" self-discovery workshops for women prior to their participation in collective development planning. Initiated by New York's Empowerment Institute and adapted to African and Middle Eastern countries, the Imagine methodology focuses on overcoming limiting beliefs surrounding seven core life areas: emotions, relationships, work, money, body, sexuality, and spirituality. Community development design activities based on self-defined visions for one's future enable pursuit of a clearer sense of purpose and confidence and result in greater gender parity, freedoms, and independence. Additional skill training and capacity workshops will be identified based on local needs and conducted later on in the process. Further, all stakeholders were made aware of and informed about the need for their continuous engagement throughout all project's phases.

IMAGE 2 Women empowerment training for women and girls in Youssoufia in Morocco, facilitated by the High Atlas Foundation. The empowerment training aims to enable participants to create the life they most want and to strengthen women as rights holders by providing tools to advocate and act on their needs and goals.

4. Decentralized RE initiatives and experiences

Various decentralized experiments have been conducted around the world, capitalizing on the advantages of low-carbon or carbon-free energies. On-grid and off-grid systems have been tested, covering sectors such as agriculture, industry, transport, construction, health, welfare, and domestic use. The variety of the applications' size, however, underscores the particular adaptability of PV technology compared with other RE sources.

In Africa, distributed solar PV systems are deployed for rural electrification, telecommunications, street lighting, water pumping, cooling, heating, and cooking. They do, however, comprise a relatively small portion of the total final energy consumption that goes to productive uses.

In Morocco, some conclusive experiences have been accomplished in different sectors. They are as follows.

Rural electrification

The combined experience of ONEE and INDH in PERG achieved better territorial coverage by electrifying rural homes with small solar PV kits (75 Wp and 200 Wp). This provided electricity to rural houses for basic domestic services. The operation benefited villages outside the eligible areas, far from the network. Despite the relative cost, however, the rate of homes equipped with solar PV kits remains low (Table 7).

Period	Phase
1996 – 2002	PERG 1 & PERG 2
2002 – 2004	PERG 3
2004 – 2006	PERG 4 – 1st stage
2006 – 2017	PERG 4 – 2nd stage
2016 – 2018	INDH (solar PV)
2018 – 2020	PERG 4 – 3rd stage

TABLE 7 Deployment of joint PERG (Global Rural Electrification Program) and INDH (National Human Development Initiative) rural electrification program

Solar pumping

Owing to declining PV module prices since 1985, installations have multiplied, and their size has evolved. While butane gas is subsidized in Morocco via the compensation fund (up to 67%) to help households, it has been found to be misused in pumping of water for farm irrigation. An ambitious national program aimed at limiting this scourge has been the subject of a multi-party agreement but is waiting to become operational. Development of solar pumping remains the subject of individual initiatives by farmers.

Off-grid supply for an isolated village

Thanks to local production of SE and an autonomous network, a village in the Essaouira region has now been electrified. In this example of an isolated site, the decentralized solar solution was more competitive than the one connected to the national grid. This made the village the first in Africa to be fully solar powered. The power station, comprising 32 PV panels producing 8.32 kW, is connected to a mini-grid that supplies electricity to about 20 households (about 50 people) for their domestic energy needs: lamps, refrigerators, televisions, water heaters, ovens, and outlets for recharging devices. A battery provides 5 hours of autonomy for service continuity.

Energy supply for a professional community

As part of an energy self-sufficiency initiative, a fishing village in the province of Boujdour, has benefited from a project commissioned by the Office National de Pêche (National Fisheries Office). This is aimed at improving the working conditions of fishermen, enhancing their socio-economic conditions and modernizing the fishing industry, while upholding the requirements of sustainable development. The decentralized solar solution consists of a PV hybrid system with a capacity of 126 kWp and comprising 500 PV panels, storage batteries, and diesel generators.

With 233,000 kWh of annual production, the system covers the village's energy needs, estimated at 600 kWh per day and intended for refrigeration, cold storage, and domestic infrastructure. The installation, equipped with an energy management system, was designed for autonomous self-consumption and helps reduce diesel costs (95%) and CO_2 emissions (99%).[48]

NOOR PV II Project

As mentioned, deployment of RE as a pillar of the NES was accomplished in a centralized form. Recently, some actors, such as the CESE and the New Development Model Commission,[49] highlighted the interest in energy sector decentralization, particularly in RE. The MEME has also initiated a new type of approach, with the NOOR PV II project[50]. Launched in January 2021 by the MEME and MASEN as part of the NOOR PV II Program, the call for projects for the first time opened up the medium voltage segment to players in the RE sector. Some qualified and pre-equipped sites were located near Sidi Bennour, Kelaa Sraghna, Taroudant, Bejaad, El Hajeb, and Ain Beni Mathar.[51]

Using only PV technology, the solar plants of NOOR PV II could achieve 400-MW peak of cumulative power. This multi-site project aims to be accessible to local private operators. Indeed, its modular design allows companies to bid alone or as a part of a group. To differentiate it from the centralized model, however, the NOOR PV II project limits the number of lots per group of bidding companies.

This initiative will be a substantial experience toward decentralizing green energy generation, also benefiting private actors from the qualified and pre-equipped sites. It also provides operators with interconnection infrastructure, access to the national network (with a defined capacity), measured solar data relating to sites, and qualification studies (e.g., topographical, geotechnical, seismic, hydraulics, erosion, and sediment).

Sites were chosen based on their suitability for solar technology, accessibility, topography, and local environmental and social impact of the implemented project, as well as their non-competition with other economic activities. Table 8 shows the chosen sites.

Name of the sites	Estimated DC Capacity (MWdc)
Sidi Bennour	48
Kelaa sraghna	48
Taroudant	36
Bejaad	36
El Hajeb	36
Ain Beni Mathar (several lots ranging from 12 – 44 MWdc each)	184

TABLE 8 Selected sites for NOOR PV II project

The project works to strengthen industrial integration and intends to contribute to local, inclusive, and sustainable development of territories. For each site, private operators' bids must be accompanied both by local development and industrial integration plans defining the measures set out to achieve the industrial integration rate indicated in the commercial offer.

Several months after the initial deadline in the call for projects, however, the 32 bidding companies are still awaiting amendment of the law on RE.[52]

48 Laabid 2018
49 La Commission Spéciale sur le Modèle de Développement 2021
50 MEME & MASEN 2021
51 MASEN 2021
52 Gharbaoui 2021

5. Basic elements of an integrated decentralized solar pilot project

The pilot projected is intended to be a local part of the dynamic of RE decentralization initiated in the country. It is aimed at certain RE-favorable sites. Admittedly, in adopting similar site selection criteria as the NOOR PV II project and favoring sustainable solutions, a scale factor should be emphasized. Indeed, the level of power introduced in the pilot project's solar installation is lower than in NOOR PV II projects, for a more restricted target and to have a direct impact on the community.

The project's salient features are its integrated design, type of target beneficiaries (rural community, including women and young people), inclusive and participatory approach, emphasis on productive activities in using renewable resources, and adoption of an FEW nexus integrating relevant issues (clean energy and hygiene). The project also suggests cogeneration technology to meet the rural community's electrical and thermal needs.

The pilot project's basic configuration remains similar to that of typical decentralized SE systems. Figure 32 shows the main structure, with certain options (storage, grid connection, and backup supply).

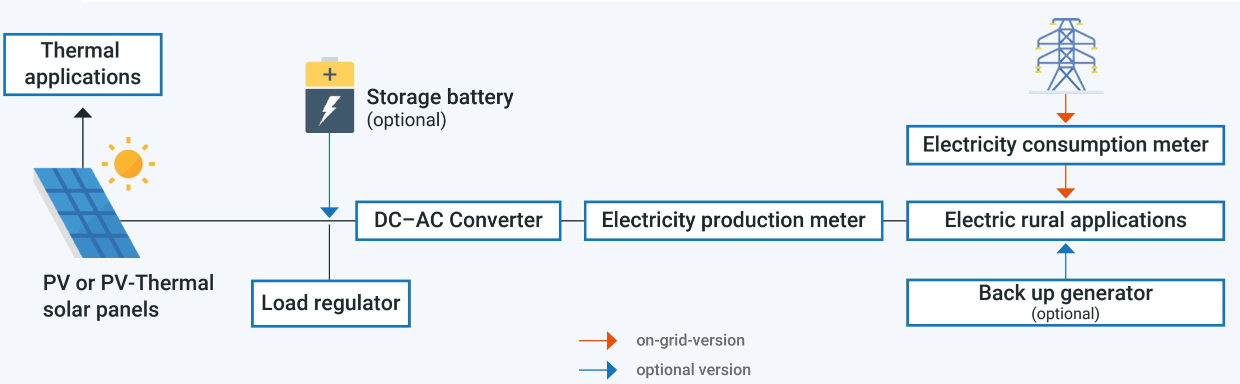


FIGURE 32 Bloc diagram of the installation

In this diagram, electrical applications include water pumping – to supply homes, school, livestock, an agricultural nursery, and the community bath – and productive activities. Thermal applications concern heating/cooling of the water/air required for conditioning agricultural products, growth of greenhouse plants, and needs of the community bath. Houses not yet electrified on the site may be the subject of individual solar installations, like the solution adopted in PERG.

5.1. Choice of appropriate renewable technology

As the site has no forestry heritage, its biomass reserve is limited to domestic and animal waste. Despite the main advantage of biomass over solar and wind resources – namely, the possibility of storage – thus avoiding the vagaries of intermittency, the local potential is insufficient for generating the amount of energy required by the local community. This is in the same way wind technology was not chosen because of factors such as noise pollution, installation cost, and lack of local know-how.

5.2. About solar technology

RE now provides the cheapest sources of energy (Figure 33). These are also easier, faster, and more sustainable for rural areas.

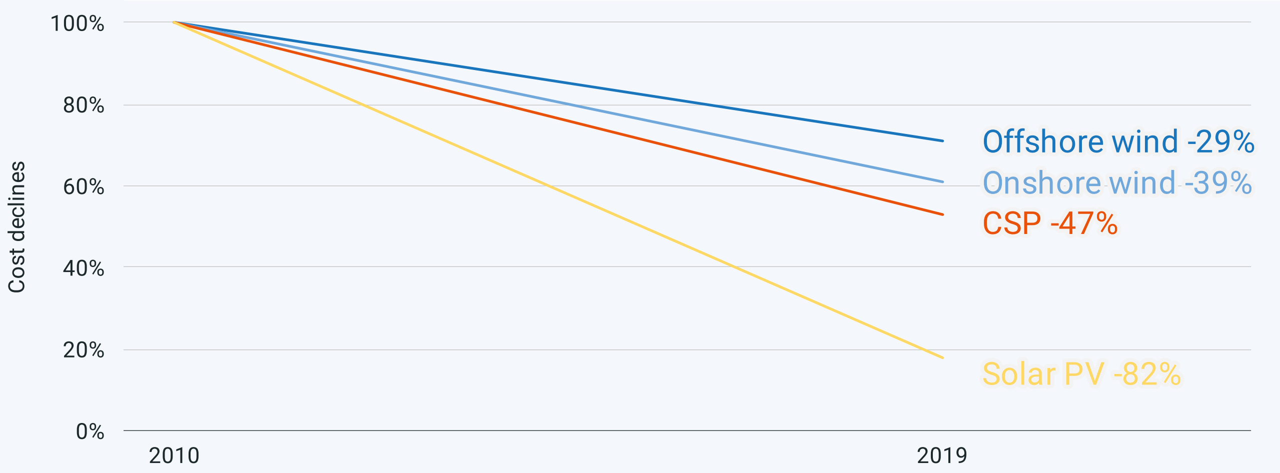


FIGURE 33 Cost decreases of renewable power technologies (based on: IRENA 2020)

The continued decrease in the cost of solar technology (Figure 34) has motivated investments in different regions of the world.

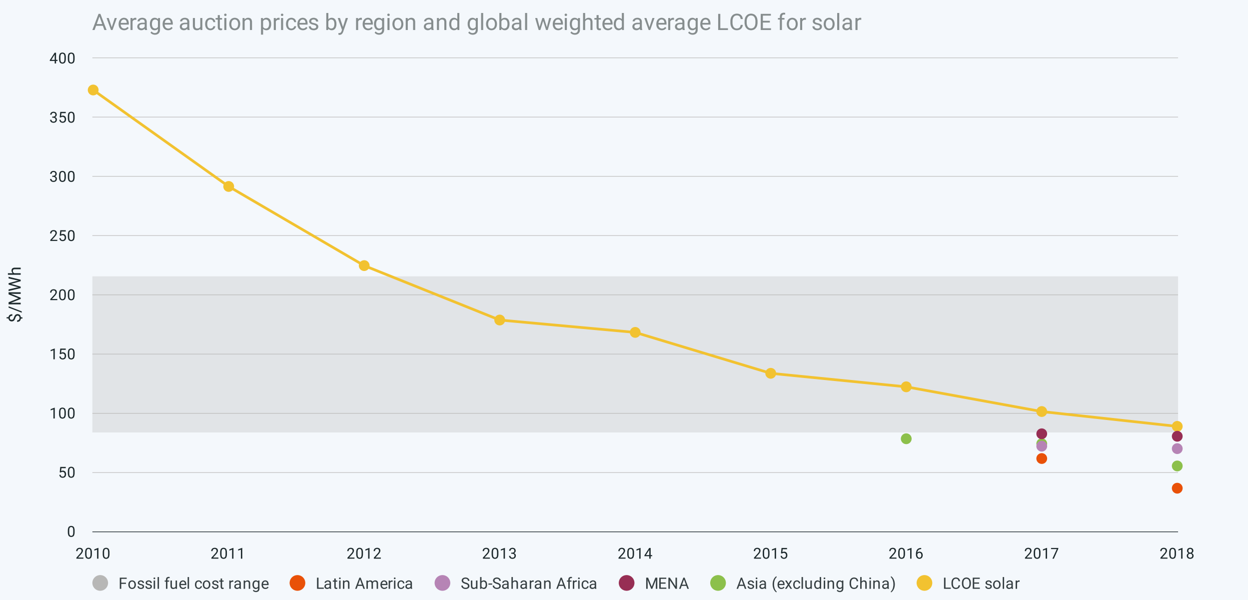


FIGURE 34 Average auction prices by region and global weighted average levelized cost of electricity (LCOE) for solar (based on: RES4Africa Foundation 2020)

Mutually, the competitiveness of electricity produced by solar PV resulted in a growing expansion of the technology. Rapid reduction of PV module costs worldwide, falling 75% from 2009 to 2015, impacted the levelized cost of electricity (LCOE) on the continent. South Africa, in fact, experienced a record LCOE (below $0.075 per kWh) for a utility-scale PV project.

In Morocco, the prices of PV modules (cost, insurance, and freight, in dirham per Wp) wavered by ±25% around a steady per-year decrease of nearly 9.5% (Figure 35).

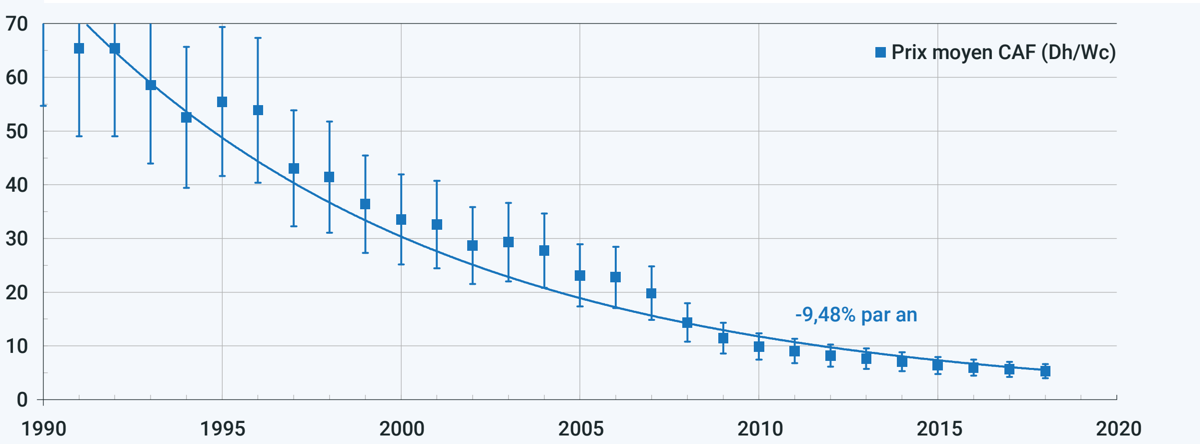


FIGURE 35 Evolution of the (wholesale) unit price (dirham per watt-peak of photovoltaic modules) (based on: Bennouna 2019)

For SE technologies, the production cost in PV plants has fallen by up to 12 times that of concentrated solar power (CSP) plants. As an example, the Al Dhafra power plant near Abu Dhabi has the world's lowest production cost (around 0.13 dirham per kWh, or 12 times less than Noor I, developed with CSP technology). As IRENA report,[53] indicated the global weighted average LCOE of large-scale PV plants has fallen by 82% over the past decade, while that of CSP has fallen by only 47%, onshore wind by 39%, and offshore wind by 29%.

During 2018–2019, PV also recorded the most remarkable progress. The associated LCOE fell by 13% on average and reached $68 per MWh, which brings it closer to that of onshore wind power, for the plants commissioned in 2019. IRENA affirms that the trend will continue.

PV technology's competitiveness is also confirmed in rural off-grid applications. Indeed, as the LCOE drop associated with PV technology mainly owes to a 90% drop in the price of panels, it logically follows that the downward trend in production cost remains valid for small-scale PV projects, as is the case for this rural project. Another important advantage of choosing this technology is its adaptation to all project scales, which no other renewable technologies offer. This is great asset both for the solar installation sizing and for possible future extension.

IMAGE 3 Small-scale RE installations that are well adapted to communities' needs can have multiple, wide-reaching benefits. Local projects that enhance the provision of clean water and energy in rural Morocco, two resources that traditionally rely upon the labor women and girls who fetch water and gather fuelwood, free up a considerable amount of women and girls' time, which directly enhances their participation in formal and informal education, cooperative formation, and other income-generating activities for human development.

53 IRENA 2021

5.3. Selection criteria and main characteristics of the site intended to accommodate the pilot project

Despite economic progress in Morocco, some regions still suffer from unemployment, illiteracy, and poverty, particularly in rural areas. In this investigation, the localities of Bouchane, Ouazzane, Sitti Fadma, Tinfidine, and Youssoufia were preselected based on socio-economic and environmental (climate constraints, water scarcity) criteria. Regarding local solar and wind resources, data collected from AMEE and IRESEN (Figure 36) enabled evaluation of sites' potential, as well as classification of the sites. As the graphs show, Youssoufia and Bouchane (located in Rhamna) showed advantageous (high and temporally regular) performance.

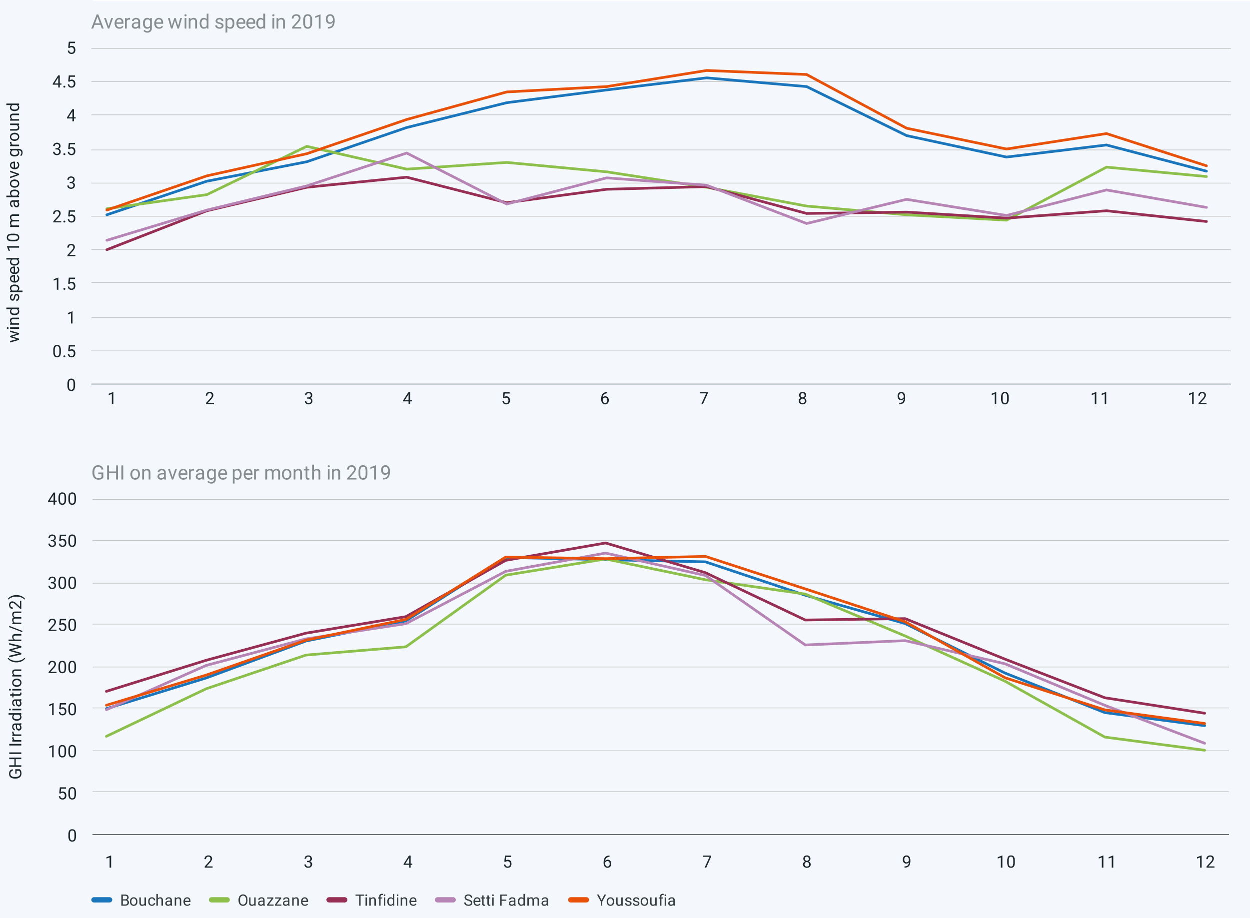


FIGURE 36 Wind and solar local profiles, throughout 2019 (data provided by IRESEN for this project)

The overall selection process, deploying weighted criteria (Figure 37), resulted in favor of the Youssoufia site, located in the Marrakech-Safi region, especially as the site has land that could be allocated to the project.

In consultation with the local stakeholders, it was decided to implement the pilot project in a rural agglomeration called Douar Lakdirate, in the territorial Commune of Jnane Bouih. Accounting for 34 households and 131 people, this *douar*[54] benefits locally from its location at the center of a group of *douars*: Sidi Hmed Moul Chaaba (56 households, 254 residents), Lakhoualka, (36 households, 170 residents), Zrouk el kouba (80 households, 320 residents), and Zourk koudia (45 households, 220 residents).

FIGURE 37 Selection criteria for the sites

By capitalizing on local renewable resources, the project aims to achieve a double objective of improving the population's living conditions while integrating a gender component, as well as supporting education for rural children. This last objective is reflected in the supply of drinking water to a school. Indeed, none of the schools in the Commune are connected to the drinking water network, but rather are only supplied periodically by tanks filled from water points set up in the *douars*. The beneficiary school proposed by the local representatives is called Al Joulane. Located about 1.5 km from the selected *douar*, the school currently has 105 students (almost equally boys and girls) and a staff of five. The local education and literacy indicators (Table 9) are striking for their levels compared with the required standards.

Indicator (%)	Male	Femeale	General average
Illiteracy rate	44.5	66	54.7
School enrollment rate for children aged 7 – 12	95.6	90.5	57.9
Level of education			
Primary	33.6	29.5	31.7
College secondary	8.7	2.7	5.8
Secondary qualification	1.6	0.7	1.2
Superior	0.7	0.4	0.5

TABLE 9 Local indicators of Illiteracy and education

54 *Douar* – A small village mainly consisting of a group of tents that encircle an open space.

These data reveal the sharp decline in the number of youth pursuing education after the primary level. In fact, nearly all the schools in the commune are primary, except for one secondary.

In terms of climate, average annual rainfall remains low (150–200 ml), thus classifying the region as semi-arid. Similarly, the drinking water supply program only benefits 70% of the local population, leaving approximately 530 households without water supply. Also notable is that access to drinking water is limited to domestic use and, according to local people's opinions, the amount of water per capita is inadequate for the actual needs. It also remains well below the World Health Organization (WHO) recommended standards. Similarly, the exclusive dependence of productive activities and livestock breeding on rainfall considerably limits farmers' prosperity. Indeed, only 80 hectares are irrigated, and 50 are dedicated to fruit trees.

Moreover, the electrification rate is about 96.76%. A total of 120 houses lack electricity and thus cannot satisfy their basic energy needs. The sum of these deficits impacts community's socio-economic development, as well as hygiene conditions, and encourages rural exodus.

The proposed project therefore intends to adopt a four-dimensional approach of water, clean energy, agriculture, and hygiene. This puts it in line with the new health challenges that result in the above-described food–RE–water–hygiene nexus approach.

6. Consistency of the project

The Decentralized Solar Pilot Project (DSPP) is intended to be integrated and inclusive. It modularity also allows for gradual implementation, evolving the facility as budgetary resources permit. This design will allow for progressive evaluation of the steps taken. The project addresses local energy issues based on the inclusive and participatory approach. The priorities were discussed with the target community. As a result, the first phase is devoted to generating and distributing drinking water to the *douar* and school, as well as to the joint coverage of the water needs of the nursery and collective bath (*hammam*). The next stages will concern creation of a nursery equipped with a greenhouse, extension of the solar plant to support productive activities (agricultural, commercial, public health, crafts, and community), and finally installation of a solar cooking set.

The health dimension of the project is particularly deployed through construction of the *hammam* and introduction of a solar cooking option.

Preliminary step
Electrification of the remaining non-electrified houses

Knowing that 120 households in the Jnane Bouih Commune are still not electrified, probably because of their ineligibility for the previous PERG phases, they are expected to benefit from this priority service that, additional to improving residents' quality of life, remains a catalyst for gender equality, including reduction of the school dropout rate of young rural girls.

The project's main objective is to promote decentralized SE as a support for the rural population's productive activities, health, and welfare services. Its main parts will be deployed gradually as follows.

Phase I
Solar energy for water production for the benefit of the douar, school, nursery, and collective hammam

This first part would be production and distribution of drinking water to the Lakdirate Douar and Al Joulane school, as well as to the plant nursery and *hammam*. As mentioned, the *douar* has a centralized water point, which presents a double weakness: households are not connected individually, just as the volume of water per resident is insufficient for real and priority needs. The option consisting of upstream reinforcement of the power source was rejected because of the difficulty in implementing it (administrative procedure, deadlines, etc.). Additionally, because of the 1.5-km distance separating the *douar* (where a main asset will be located) from the school, two solutions will be examined and compared, both economically and through the relevance of the autonomy of two targets.

Thus, the main steps for the first part of the pilot project will be as follows.

Dig a (main) well and equip it with a water pump
Considering the usual water depths in the locality, the hypothesis considering the deepest depth of about 120 m, serves as a buffer against worst-case scenarios. The water supply should ensure a monthly per-capita volume of at least 2 m³. Additionally, and to optimize the entire project's budget, the well's sizing, and that of the pump, must give coverage for the nursery and the collective *hammam* water needs, despite being planned for a later phase.

Given the approach integrating the FEWH nexus, the water extraction solution will be accompanied by systems that control the volume of water pumped, to limit it to the optimal needs for the applications (domestic, agricultural, public health, etc.)

Build a water reservoir
The target capacity ensures autonomy of at least 3 days, for current (*douar*, school) and future (nursery and *hammam*) water needs.

Install solar panels
The project favors that the panels be located on a common parcel of land. This arrangement gives them a triple function: the basic one (energy production) plus those of shading and protection of agricultural equipment, crops, animals, and/or plants. Indeed, unlike urban homes wherein solar installation is generally on the roof because of insufficient space elsewhere, rural farms have space beyond roofs, while needing multi-purpose shelters. Thus, the recommended arrangement places them on a parcel of municipal territory that local authorities made available to the project, within the framework of the project's participative partnership.

The suggested arrangement's other advantage is that the installation's services can be shared among multiple users. The solution, therefore, is suitable both for individual (panels in a private space) and collective (panels in a communal space) use for the whole community or multiple users (e.g., cooperative, neighboring farmers/artisans/traders).

As a distributed PV system, the equipment can be operated with or without a storage battery (if uninterrupted power is required). Suitable versions of the system may be adopted depending on the nature of the activities and the amount allocated to the investment.

As with other RE sources, PV suffers from intermittence. This project offers some optional solutions, including limiting use of the solar source to daytime productive activities (which constitute the majority of rural activities), storing excess energy produced in batteries to extend the solar power supply duration, adopting hybrid solutions with a backup diesel generator (as with PERG), or switching to the central power network, in the case of on-grid installations.

Connect beneficiaries (households, school, nursery) to the water well
Two options are being studies regarding the school water supply. One is to connect the school to the (main) well. This involves construction of trenches and their equipment with conduits, over a span of 1.5 km, which separates the school from the *douar* where the main well is located. The other option is to adopt an independent installation to produce and store water in the original place. This secondary installation includes a well, pump, water storage tank, and solar panels. All are scaled for the local school's needs only. Economic and site autonomy criteria will make it possible to decide between the two options.

Phase II
Creation of a nursery

A collective decision was made that the Jnane Bouih nursery would be located near the *douar* of Lakdirate. An inspiring model (Akrich) already exists among the achievements of the High Atlas Foundation, in partnership with the professional sector (Fenelec). Operation and management of the future nursery will be entrusted to the commune's women. This gender dimension of the project aims to develop rural women's productive activities and managerial capacities, and create sustainable incomes benefiting them.

Phase III
Solar energy for heating water and air

The rural citizens use one of the following options for bathing.

- A private bathroom, by allocating a specific space inside their house, but generally not arranged professionally. Along with the lack of comfort, the installation's lack of safety, and the risks associated with its supply of wood, gas, or animal residues, the process exposes users to health risks while negatively impacting the environment.
- A public bath, located in the nearest village or urban city, which requires rural inhabitants to transit from their *douar* to the nearest city. This option is obviously affected by the availability of the road infrastructure and regulation of transport logistics. Even with those required conditions, however, the option becomes complicated, or even impossible, during cold seasons. Another key disadvantage is health conditions that are not systematically ensured, as public baths are enclosed, hot spaces with high concentrations of people. These are known factors of bacteria proliferation and contamination.

In both of the above options, basic hygiene rules may be lacking, just as their peculiarities limit the rate of their use, to the detriment of hygiene. They also use wood or fuel/gas to heat the water and ground. Each process has major drawbacks, including deforestation, risk of gas leaks, and transmission of contagious diseases. This last fear has become more troubling with the emergence of the coronavirus and its variants.

The project, by locally creating a community bath (*hammam*), offers an intermediate-scale option, giving limited capacity and capitalizing on local clean energy resources. Hybrid solar panels (thermo-PV) providing both electricity and heat are suggested in overall installation. Hybrid installations generate electricity and heat water (Figure 38), or electricity and heated air. Double-sided panels by which electricity is produced on the front face while heat is produced on the rear face are an example of existing cogeneration technologies. Additional to the co-production of electricity and heat, the cogeneration process saves space by avoiding double installation. The technology also increases PV cells' efficiency by lowering their temperature, owing to the fluid circulating in the thermal part.

This results in higher PV electricity production than with a conventional PV collector having the same peak power, while producing heat.

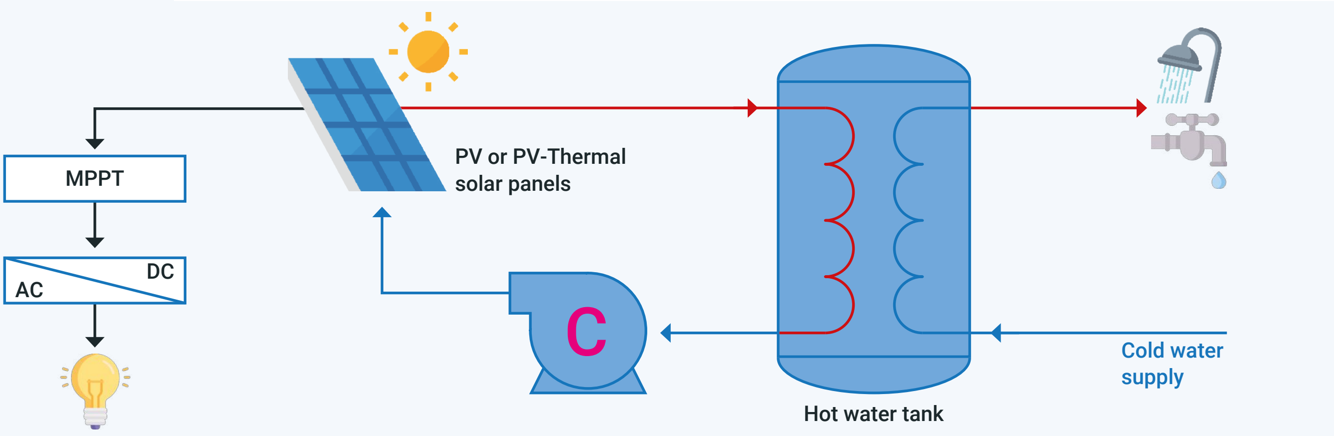


FIGURE 38 Solar cogeneration – Example of installation producing electricity and heating water

Beside saving space and enhancing panel efficiency, hybrid panels are estimated at just 40% higher cost than conventional solar panels. This makes their installation more competitive than with separate conventional PV panels and thermal panels. Also note that, depending on the technology, hybrid panels can produce heated air, which is useful for the community *hammam*, classrooms, greenhouses, poultry incubators, or air heaters to dry agricultural products or processed food.

The thermo-PV version would bring true added value to improve the health condition of rural citizens, especially as the recent health crisis has highlighted hygiene's crucial role in the health system.

Phase IV
Solar energy for cooking

The Tracking SDG 7: The Energy Progress Report (2021) report, edited on June 7, 2021, by five organizations (United Nations Economic and Social Affairs Department, IAE, World Bank, IRENA, and WHO) indicates that 66% of the world population in 2019 had access to clean cooking, while 2.6 billion people did not.[55] Based on the current trajectory, 28% of the world's people may still cook with traditional methods, such as charcoal, in 2030.

Use of SE in cooking presents economic, environmental, and social advantages. As rural households often use residues of trees from neighboring forests, livestock residues, or subsidized gas, the substitution of these means by solar resources preserves forests, prevents lung infections from wood or straw smoke, preserves health, and reduces gas costs.

Additionally, the mission of collecting and transporting wood or livestock residues is often assigned to women and young girls. Gains in both time and energy, achievable with the substitution of solar cooking systems, allow rural women to invest in beneficial activities and girls to learn and avoid dropping out of school, while preserving their health.

Phase V
Solar energy for productive activities

Through the previous phases of the project, PV was shown as not limited to electrification, which targets domestic uses, or at most, water pumping. The DSPP's ultimate objective is to extend the decentralized SE system's role to support rural productive activities and local services, to positively impact the socio-economic, environmental, and even health conditions of rural citizens.

As most rural activities occur during the daytime, energy needs are still aligned with times when access to sunshine is possible. This avoids additional costs and management of storage batteries. The following non-exhaustive list (Table 10) gives some examples of rural productive activities capable of being supported, in different sectors, by decentralized SE systems.

Agricultural activities	Community services	Commercial activities	Public services
• Irrigation	• Street lighting	• Solar kiosks	• Education
• Threshing	• Equipment repair (ICT and electronic devices, household appliances, transport equipment, …)	• Crafts	• Health services
• Drying of crops		• Carpentry	
• Grain milling		• Sewing	
• Milking		• Dry cleaning	
• Oil pressing		• Hairdressing	
• Egg incubation	• Well-being services		

TABLE 10 Examples of sectoral rural productive activities eligible for support by a decentralized solar solution

As solar PV energy is particularly suitable for pumping water, application of PV systems for irrigation is quite widespread in rural areas in different countries. In Morocco, replacing the diesel fuel or butane gas currently used for pumping water would reduce the burden of the subsidy abnormally levied on the compensation fund. Gas-oil generators, however, could be used as a backup solution or backup power supply in case of grid failure. Solar pumping also lets farmers receive less expensive and unlimited access to water during daylight hours. While this might increase agricultural productivity, it could also aggravate water resource depletion, even with efficient drip irrigation techniques, via a process called the "rebound effect." Hence, solar water pumping subsidies can lead to water resource depletion if they are not adequately regulated through authorization for groundwater use. This becomes a serious food security issue and endangers human well-being. When implementing solar energy for productive activities it is, therefore, essential to find sustainable, integrated solutions that maximize benefits and minimize trade-offs across sectors. Such schemes require enhanced cross-sectoral cooperation and decision-making processes that reflect the dynamic nature of complex systems. For solar pumping, cross-sectoral considerations include efficient irrigation techniques, sustainable groundwater management, optimized agricultural practices, community guidelines, and use of traditional knowledge. Technologies such as demand response technologies (e.g., smart grids and smart metering), which allow for real-time monitoring and communication between producers and consumers of electricity, hydraulic storage (basin) of excess pumped water, and chemical storage (batteries) to save excess electricity produced, can be part of the solution. They also extend autonomy of supply. Coupled with electronic and digital technologies, decentralized smart solar solutions help improve project performance. Use of decentralized SE systems for productive purposes is a genuine opportunity for off-grid households' sustainable development, if implemented in a sustainable, integrated way that maximizes benefits and minimizes trade-offs.

Example of technical needs for rural activities

Decentralized solar system sizes and technical specificities differ based on the applications and the budgets reserved to build them. Table 11 shows technical specifications as a general guideline.

Productive activity	Power range, in W
Irrigation	Surface water pumps: 75 – 1,500
	Submersible pumps: 0.45 – 22,000
Milking	1,100 (capacity: 20 cows/day)
Oil pressing	1,500 (capacity: 20kg/hr)
Poultry incubators	75 – 100 (capacity: 48 – 1000 eggs)
Husking, threshing, hulling	100 – 375 (capacity: 35 – 250 kg/hr)

TABLE 11 Technical specifications of certain productive activities (Sources: GIZ 2016, Dalberg 2018)

The cost of the installation thus depends on size and selected options (PV or hybrid panels, diesel backup, storage batteries, information technology control devices).

7. Expected impacts of the project

The above DSPP concept leads to expected positive impacts on the beneficiary communities regarding economy, society, environment, and health. Indirect benefits, such as improved literacy rates, encouragement of young girls' education, and development of community services can also be foreseen. Table 12 provides a partial list of expected benefits of the project.

Economic	Social	Environmental	Technical
• Omits cost of acquiring land and of expropriation procedures, as in network extension operations for rural electrification • Saves network infrastructure costs and associated maintenance • Saves electricity consumption costs (independence from the national grid) • Refocuses compensation fund (Caisse de compensation) aid on original household target to recover inherent loss from unintended butane gas use (in pumping water) • Avoids running costs associated with diesel fuel or butane gas • Promotes industrial integration: professional opportunities created for RE actors (engineers, manufacturers, installers, maintenance operators, technicians, and skilled workers) • Promotes public-private-partnership • Reinforces nutrition security • Improves rural GDP • Diversifies income sources with diversified rural productive activities • Strengthens existing activities • Develops agriculture • Fosters local services • Creates new economic activities • Expands businesses	• Reduces rural poverty • Increases social stability via job creation and reduced rural exodus • Stimulates migration from urban to rural areas (reversing the current trend) • Reduces unemployment of youth by providing new skills • Improves public health and well-being • Improved food, by diversifying crops and enhancing incomes • Promotes common services (commercial, social, educational, health and well-being, sports) • Makes growth inclusive • Promotes community synergy around sustainable projects • Develops new skills in workers	• Sustainable energy source • Reduces CO2 emissions • Fights climate change • Rationalizes water use • Accelerates fossil fuel phase-out • Contributes, in time, to achieving Sustainable Development Goals • Agricultural sector contributes to global energy efficiency objective (20% by 2030) • Promotes the green economy	• Makes implementation and use of RE easier • Centralized RE production projects' completion takes months, not years • Decentralized RE integration systems put no constraints on grid • Partial or total energy autonomy • Rural population introduced to green energy technologies (implementation, operations and maintenance, reparation) • Distributed RE systems more resilient in crises • Hybrid solar panels save space (and enhance PV cells' efficiencies, with some cogeneration technology)

TABLE 12 Expected impacts of the decentralized solar project

8. Conclusion

Morocco's electricity prices, compared with those in the Middle East or North Africa, are known to be high. Reducing consumption from centralized sources can create savings. Use of PV installations as shelters for stables or agricultural greenhouses poses a viable alternative, just as it can contribute to achieving national objectives, as defined by the country's NDC, aiming to increase RE capacity to 50% of the electric mix by 2025. Morocco's solar resources are plentiful and suitable for solar PV. The technology is also mature. SE offers several advantages for rural communities because, along with avoiding the running costs associated with diesel fuel or butane gas, it is clean, safe, and independent from road access. PV installations, for their part, require low maintenance. Promoting local employment and acquisition of new skills could also have a socially beneficial impact by entrusting the installation and maintenance to local residents.

[43] IRENA (2015), Africa 2030: Roadmap for a Renewable Energy Future. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Africa_2030_REmap_2015_low-res.pdf

[44] ESMAP (2019), Energy Sector Management Assistance Program (ESMAP) Annual Report 2019. Available at: https://documents1.worldbank.org/curated/en/596691580942442131/pdf/Energy-Sector-Management-Assistance-Program-ESMAP-Annual-Report-2019.pdf

[45] ESMAP (2020), Energy Sector Management Assistance Program (ESMAP) Annual Report 2020. Available at: https://documents1.worldbank.org/curated/en/712171609756525808/pdf/Main-Report.pdf

[46] Pais, G., Jayaram, K., van Wamelen, A. (2020), Safeguarding African food systems through and beyond the crisis: Understanding the impact of COVID-19 on African agriculture—and how governments and private-sector actors can respond, McKinsey & Company. Available at: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Middle%20East%20and%20Africa/Safeguarding%20Africas%20food%20systems%20through%20and%20beyond%20the%20crisis/Safeguarding-Africas-food-systems-through-and-beyond-the-crisis-vF.pdf

[47] RES4Africa Foundation (2019), Africa's future counts: renewables & the water-energy-food nexus in Africa. Available at: https://static1.squarespace.com/static/609a53264723031eccc12e99/t/60ee0f84115d504d3a82b734/1626214286904/RES4Africa_flagship_2019.pdf

[48] Laabid, M. (2018), *Commandé par l'Office national des pêches: Un projet pour réduire les émissions CO_2 porte ses fruits à Boujdour* (in French), Aujourd'hui Le Maroc. Available at: https://aujourdhui.ma/economie/commande-par-loffice-national-des-peches-un-projet-pour-reduire-les-emissions-co2-porte-ses-fruits-a-boujdour

[49] La Commission Spéciale sur le Modèle de Développement (2021), The New Development Model: Releasing energies and regaining trust to accelerate the march of progress and prosperity for all, General Report. Available at: https://www.csmd.ma/documents/CSMD_Report_EN.pdf

[50] MEME & MASEN (2021), *Programme d'allocation de capacités d'environ 400 MWdc dans des sites qualifiés et prééquipés pour le développement de projets photovoltaïques « PV » dans le cadre de la Loi N° 13-09* (in French). Available at: https://www.cleantech-alps.com/multimedia/docs/2021/01/AVIS_Projet_Noor_PVII_Loi_1309_vf.pdf

[51] MASEN (2021), *Noor PV II: lancement d'un nouvel appel à projets* (in French). Available at: https://www.masen.ma/fr/actualites-masen/noor-pv-ii-lancement-dun-nouvel-appel-projets

[52] Gharbaoui, H. (2021), *Energies renouvelables moyenne tension: NOOR PV II. Après l'espoir, la déception* (in French), Médias 24. Available at: https://www.medias24.com/2021/07/18/energies-renouvelables-moyenne-tension-noor-pv-ii-apres-lespoir-la-deception/

[53] IRENA (2021), Power Generation Costs in 2020. Available at: https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

[54] "Definition of douar." Merriam-Webster Dictionary. https://www.merriam-webster.com/dictionary/douar

[55] IRENA (2021), Tracking SDG 7: The Energy Progress Report 2021. Available at: https://www.irena.org/publications/2021/Jun/Tracking-SDG-7-2021

Chapter VII CONCLUSION

Decentralized SE projects contribute to developing resilient and inclusive societies, and to accelerating the shift toward sustainable and decarbonized economies. Decentralized RE systems reduce reliance on the grid and on electricity costs, and enhance reliability. The project discussed herein aims to strengthen Moroccan leadership in RE and contributes to actions linked to the country's commitment to the climate. It does this while aligning with development objectives focused on reducing social and economic inequalities. The DSPP proposed within this investigation's framework highlights potentially productive outcomes that decentralized PV systems can support. The "passive" role (residential consumption) usually assigned to PV systems is revised to make them vectors of productive activities that positively impact the beneficiary community.

By targeting rural areas, the project intends to:

- Capitalize on the socio-economic weight of the agricultural sector, the largest employer nationally and a substantial contributor to GDP
- Boost a participatory and inclusive dynamic around sustainable projects
- Support local populations' efforts by orienting use of decentralized SE systems toward development of productive activities and community services
- Validate local human potential via stimulation of job creation and emergence of new professional profiles among women and young people
- Enhance health through hygiene and environmental measures
- Reinforce access to education by upgrading essential services

Using the FEW nexus as a basic concept, the project focuses on clean energy and integrates an additional component (hygiene), for a more comprehensive nexus: FREWH.

Concerning the approach, the project's sustainability involves it being taken over by the concerned community. For this, an inclusive and participatory approach is adopted and recommended throughout the process – from identification of local needs to operation of facilities – including project design and implementation. Combined efforts between private and public sectors, territorial entities, NGOs, and citizens can develop the required community synergies around collective activities and locally crystallize some of the global objectives of sustainable development. Financial incentives can also impel a true dynamic of RE decentralization, both in rural and urban areas.

In terms of profitability, along with helping curb the rise in global temperatures, ramping up investment in RE would effectively pay for itself over the long term.

With the opening of the low-voltage grid to electricity injection in perspective, incomes of rural citizens with solar on-grid installations could be improved, if the authorized rate of the excess produced energy is enhanced. The long-awaited regulatory measure would boost the overall ecosystem of the SE sector (manufacturers, installers, and individuals) and transform the status of users from "consumers" to "consumer-actors." If sufficiently mainstreamed, decentralized SE projects can contribute to developing resilient, inclusive societies, accelerating the shift toward sustainable and decarbonized economies, and bringing us closer to the ultimate goal of 100% renewables within optimal deadlines.

FIGURES

Figure 1 IEA, Change in electricity demand in 2020 and 2021 by region. Available at: https://www.iea.org/data-and-statistics/charts/change-in-electricity-demand-in-2020-and-2021-by-region

Figure 2 WEF (2021), Fostering Effective Energy Transition 2021 edition, p. 23. Available at: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf

Figure 3 The World Bank (2020), World map of direct normal irradiation, Global Solar Atlas 2.0, Solar resource data: Solargis. Available at: https://solargis.com/maps-and-gis-data/download/world

Figure 4 IEA (2019), CO2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2010-2050s. Available at: https://www.iea.org/data-and-statistics/charts/co2-emissions-reductions-by-measure-in-the-sustainable-development-scenario-relative-to-the-stated-policies-scenario-2010-2050

Figure 5 IRENA (2020), Global Renewables Outlook: Energy transformation 2050 (Edition: 2020), p. 29. Available at: https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_Summary_2020.pdf?la=en&hash=1F18E445B56228AF8C4893CAEF147ED0163A0E47

Figure 6 LAZARD (2020), Lazard's Levelized Cost of Energy Analysis – Version 14.0, p. 8.
Available at: https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf

Figure 7 IRENA, Trends in Renewable Energy Statistics Time Series. Available at: https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Statistics-Time-Series

Figure 8 IRENA, Trends in Renewable Energy by Region. Available at: https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Regional-Trends

Figure 9 IRENA (2020), Global Renewables Outlook: Energy Transformation 2050 (Edition: 2020) , p. 30.
Available at: https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_Summary_2020.pdf?la=en&hash=1F18E445B56228AF8C4893CAEF147ED0163A0E47

Figure 10 AMEE (2013), Energy efficiency in buildings. Available at: https://www.amee.ma/en/node/118

Figure 11 Habachi, R., Touil, A., Abdellah, B., Charkaoui, A. (2019) Recommendations and solutions to remove some barriers to the deployment of smart grid in Morocco. *International Journal of Power Electronics and Drive Systems 10* (2). Available at: https://www.researchgate.net/publication/331687786_Recommendations_and_solutions_to_remove_some_barriers_to_the_deployment_of_smart_grid_in_Morocco

Figure 12 **(a) & (b):** UNFCCC (2016), Morocco Nationally Determined Contributions under the UNFCCC, Distribution of the expected mitigation effort by sector to achieve the overall target (with AFOLU), p. 13. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Morocco%20First%20NDC-English.pdf

Figure 13 UNFCCC (2016), Morocco Nationally Determined Contributions under the UNFCCC, Distribution of the expected mitigation effort in energy generation and consumption for a variety of purposes to achieve the overall target, p. 14. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Morocco%20First%20NDC-English.pdf

Figure 14 African Development Bank Group (2020), Morocco Economic Outlook. Available at: https://www.afdb.org/en/countries/north-africa/morocco/morocco-economic-outlook

Figure 15 IMF (2020), World Economic Outlook, April 2020: The Great Lockdown, p. 132. Available at: https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Figure 16 RES4MED (2018), Country Profile Morocco 2018, Renewable Energy Solutions for the Mediterranean, pp. 32–33. Available at: https://www.res4med.org/wp-content/uploads/2018/06/Country-profile-Marocco-2.pdf

Figure 17 IEA (2019), Energy Policies Beyond IEA Countries: Morocco 2019, p. 23. Available at: https://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/Energy_Policies_beyond_IEA_Contries_Morocco.pdf

Figure 18 MEME (2020), *Secteur de l'énergie chiffres clés Decembre 2020* (in French), p. 8. Available at: https://www.observatoirenergie.ma/wp-content/uploads/2021/01/Chiffres-cl%C3%A9s-D%C3%A9cembre-2020.pdf

Figure 19 MEME (2020), *Secteur de l'énergie chiffres clés Decembre 2020* (in French), p. 8. Available at: https://www.observatoirenergie.ma/wp-content/uploads/2021/01/Chiffres-cl%C3%A9s-D%C3%A9cembre-2020.pdf

Figure 20 IEA (2020), Electricity generation by source in Morocco. Source data Available at: https://www.iea.org/countries/morocco

Figure 21 The World Bank (2020), World map of direct normal irradiation, Global Solar Atlas 2.0, Solar resource data: Solargis. Available at: https://solargis.com/maps-and-gis-data/download/world

Figure 22 The World Bank (2020), Horizontal Global Irradiation in Europe, Global Solar Atlas 2.0, Solar resource data: Solargis. Available at: https://solargis.com/maps-and-gis-data/download/europe

Figure 23 BP (2021), Statistical Review of the World Energy 2021, 70th Edition, Shares of global primary energy, p. 12. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Figure 24 BP (2021), Statistical Review of the World Energy 2021, 70th Edition, Regional consumption pattern 2020, p. 12. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Figure 25 WEF (2021), Fostering Effective Energy Transition 2021 edition, p. 14. Available at: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf

Figure 26 WEF (2021), Fostering Effective Energy Transition 2021 edition, p. 16. Available at: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf

Figure 27 IRENA (2020), Global Renewables Outlook: Energy transformation 2050 (Edition: 2020), p. 31. Available at: https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_Summary_2020.pdf?la=en&hash=1F18E445B56228AF8C4893CAEF147ED0163A0E47

Figure 28 ENSAE Alumni & IP Paris (2019), Available at: *Stratégies énergétiques: cas du Royaume du Maroc* (in French). Available at: https://www.ensae.org/fr/news/strategies-energetiques-cas-du-royaume-du-maroc-761

Figure 29 CESE (2020), *Avis du Conseil Economique, Social et Environnemental Auto-saisine n°45/2020 Accélérer la transition énergétique pour installer le Maroc dans la croissance verte* (in French). Available at: http://www.cese.ma/media/2020/11/Av-transitionEnergetique-f-1.pdf

Figure 30 EA (2020), SDG7: Data and Projections, IEA, Paris. Available at: https://www.iea.org/reports/sdg7-data-and-projections

Figure 31 IRENA (2015), Africa 2030: Roadmap for a Renewable Energy Future. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Africa_2030_REmap_2015_low-res.pdf

Figure 32 Bloc diagram of the installation

Figure 33 IRENA (2020), Renewable power generation costs in 2019: key findings, p. 1. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Costs_2019_EN.pdf?la=en&hash=BFAAB4DD2A14EDA7329946F9C3BDA9CD806C1A8A

Figure 34 RES4Africa Foundation (2020), Connecting the dots: Why only 2% of global RE in Africa? p. 18. Available at: https://static1.squarespace.com/static/609a53264723031eccc12e99/t/60ec6a55a29ebd68f4fd315e/1626106473933/RES4Africa-Foundation-Connecting-the-Dots.pdf

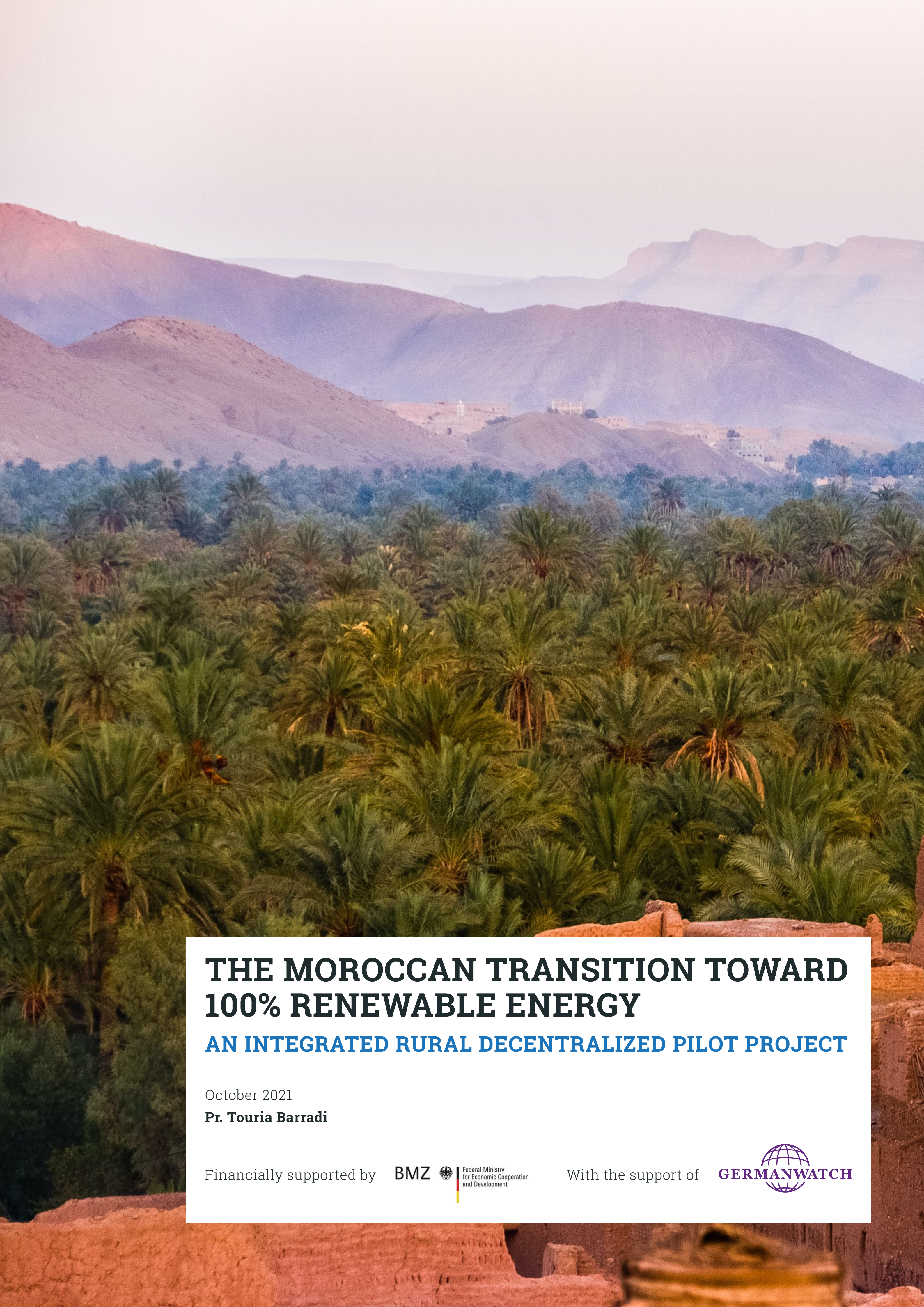
Figure 35 Bennouna, A. (2019), Trois décennies d'énergie solaire photovoltaïque au Maroc (in French), EcoActu, p. 2. Available at: https://www.researchgate.net/publication/337731175_Trois_decennies_d%27energie_solaire_photovoltaique_au_Maroc

Figure 36 IRESEN (2020). Wind and solar local profiles, throughout 2019 (data provided by IRESEN for this project).

Figure 37 Selection criteria of the sites

Figure 38 Solar cogeneration – Example of installation producing electricity and heat water

TABLES



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AN INTEGRATED RURAL DECENTRALIZED PILOT PROJECT

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Pr. Touria Barradi

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