May 2023
Regional Programme Energy Security and Climate Change Middle East and North Africa

KONRAD ADENAUER STIFTUNG

REPORT

The State of Energy in Morocco

Country report – Energy in Morocco 2022

Amin Bennouna

INDEX

FIGURES INDEX

1. Introduction

1.1. Sources of information

Except when mentioned, all sources of data are official:

- international for income [1], for a uniform treatment of the series,
- national for energy data[2, 3, 4, 5, 6, 7].

Readers can refer to the following chronological list of articles and books about energy in Morocco : 8 (1993 & 2002), 9 (1994), 10 (2002), 11 (2002), 12 (2006), 13 (2011), 14 (2011), 15 (2012), 16 (2012), 17 (2012), 18 (2014), 19 (2014), 20 (2015), 21 (2015), 22 (2015), 23 (2015), 24 (2015), 25 (2015), 26 (2015), 27 (2016), 28 (2016), 29 (2016), 30 (2017), 31 (2017), 32 (2017), 33 (2018), 34 (2018), 35 (2019), 36 (2019), 37 (2019), 38(2021).

1.2. Relationship between income and energy in the world

Figure **1** (year 2014, 126 countries data) shows how energy consumption and income are not independent[39].

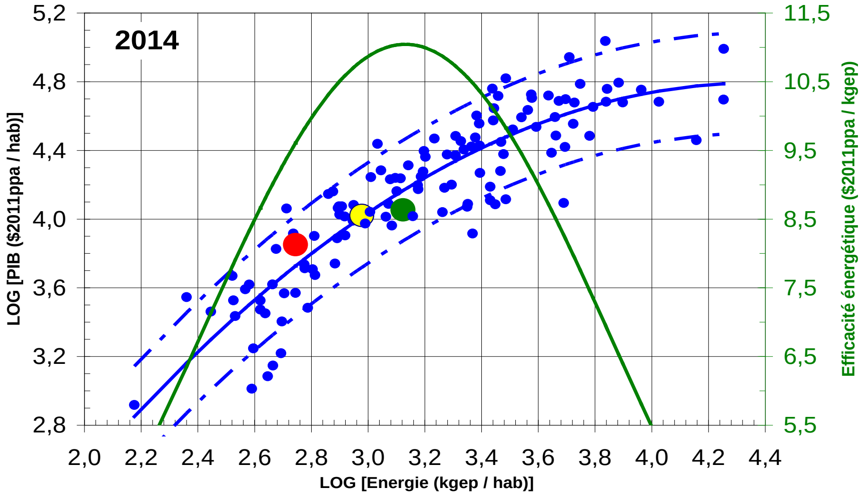


Figure 1 2014 GDP ($2011 at PPP) and energy in 126 countries

Inequality between nations shows a relationship between income and energy. Deviations from the average curve are due to national specificities: structure of GDP, geography, population density, climate as well as socio-cultural uses. ranks rather well.

Figure 2 shows how Morocco's energy consumption has increased relatively much more than its North West African neighbors (a) and that, despite this, its global energy efficiency ranking has deteriorated less than among its same neighbors over the same period (b). The per capita consumption data (a) come from the University of Oxford website[40] while the data used for the ranking (b) comes from the World Bank website[41]. Morocco's energy efficiency (red circle ●) ranks rather well.

a

b

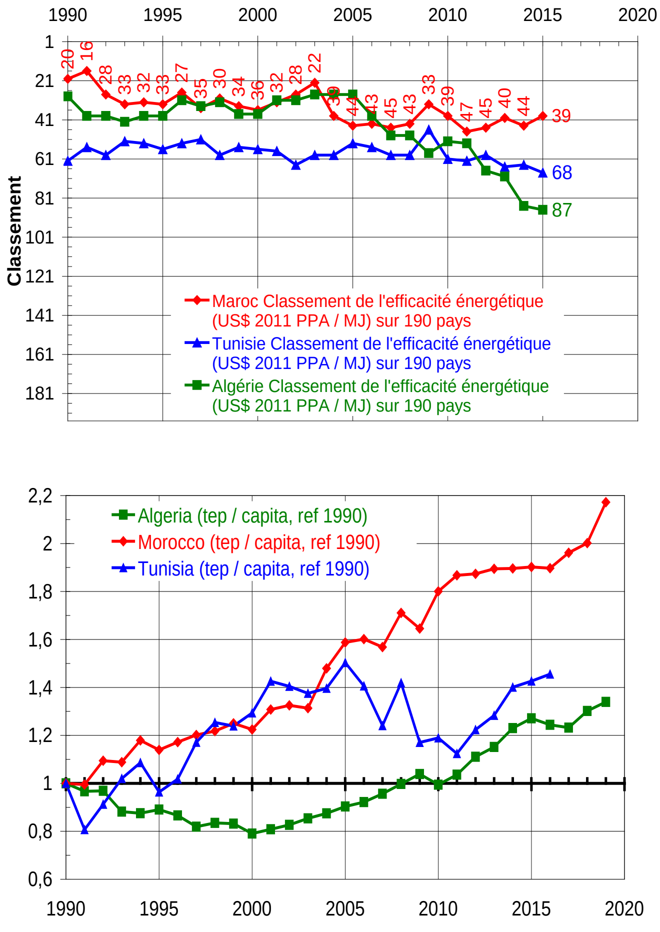


Figure 2 Evolution of energy per capita and energy efficiency rankings

In the energy efficiency rankings, Morocco was around 30th between 1995 and 2000 and then lost about 10 ranks due to the acceleration of the domestic component of rural electrification. However, the increase in revenue generated by the grid extension has made up for the loss of energy efficiency due to domestic consumption since 2006. Meanwhile, Algeria and Tunisia have fallen further down the rankings, as shown in the graph on the Figure 2-b.

1.3. Total energy consumption in Morocco in 2021

Figure **3** shows the breakdown of total energy consumption in Morocco from primary to final.

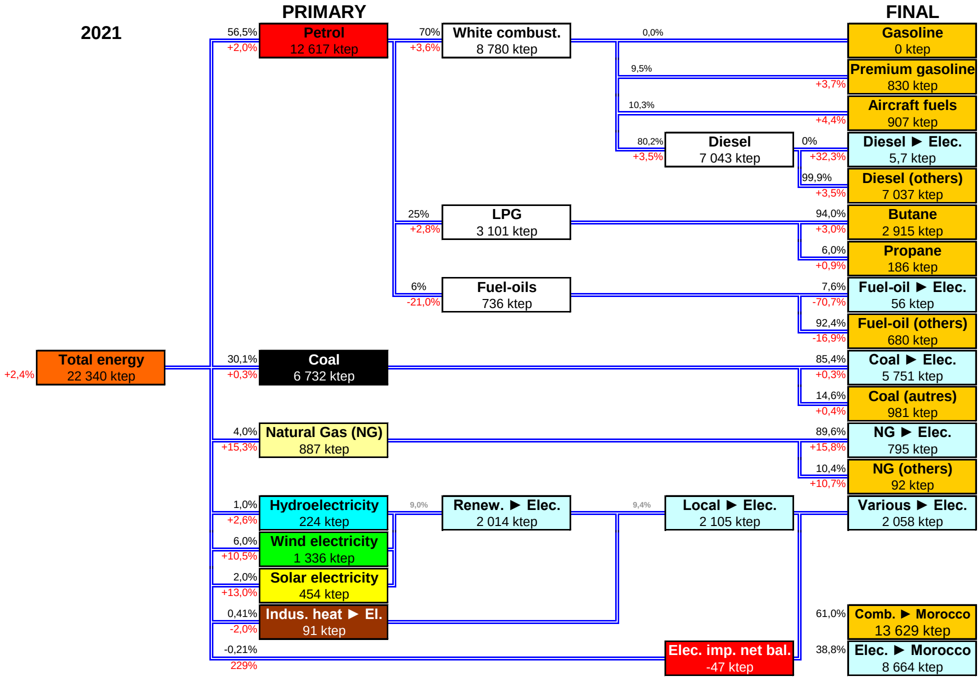


Figure 3 Total energy consumption in Morocco in 2021

The percentage written in blue above the line is the share of the following element while the one written in red with a sign is that of its annual variation. In 2021, Morocco used 22,340 millions of tons of oil equivalent (Mtoe) of which 8.664 as electricity and 13.629 as other non-electric final energy products.

2. Demand and emissions of energy in Morocco

2.1. The energy flow diagram of Morocco in 2021

Figure 4 shows the inputs of the simplified energy flow diagram in Morocco in 2021: in-puts are represented by blue arrows while outputs are represented by red arrows.

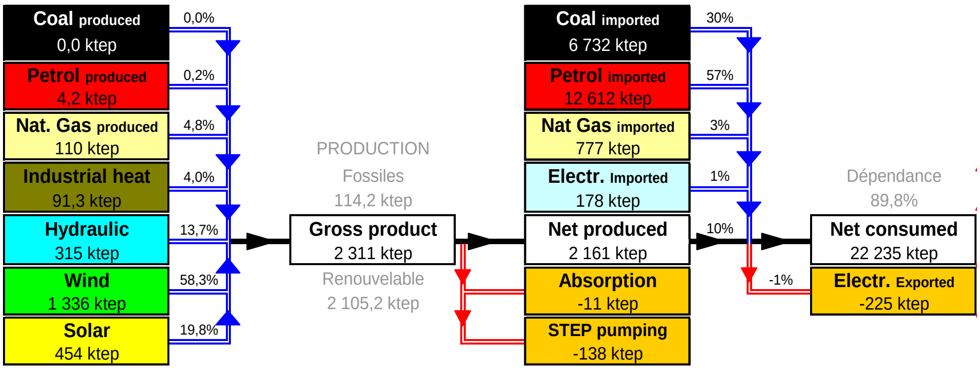


Figure 4 The input side of the energy flow diagram of Morocco in 2021

It is clear that production, however diversified it may be, covers only a small part of consumption: in 2021, Morocco had a net production of 2.311 Mtoe covering only 10.2% of its needs.

2.2. Satisfaction of the energy demand in Morocco till 2030

Figure 5 shows the backward and probable forward-looking segmentation of energy demand in Morocco. Fuels include those taken for electricity generation.

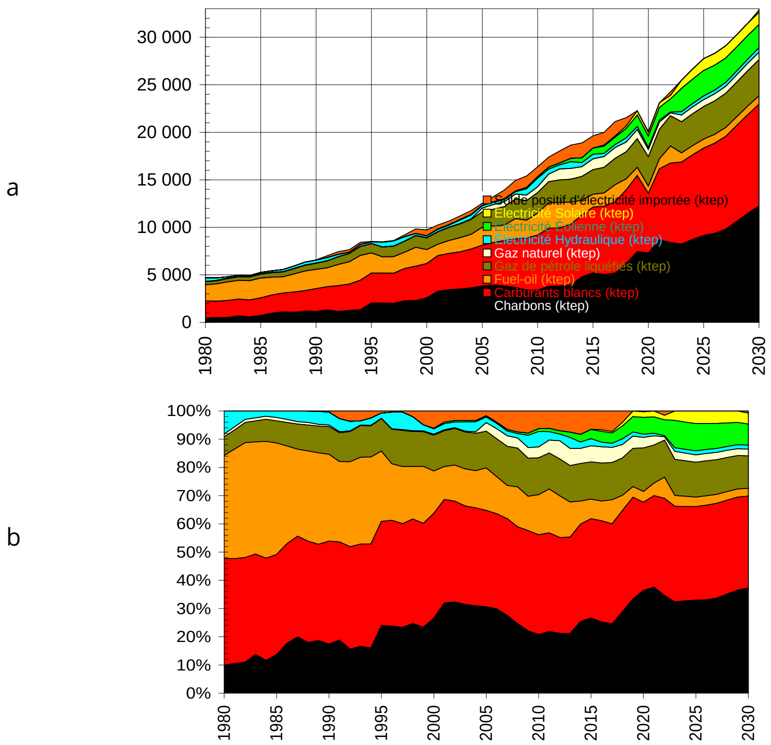


Figure 5 Retrospective evolution and forecast of energy demand segmentation

Year 2020 shows a net decrease in all components, with the exception of fuel oil, which decreased quickly after the removal of its subsidy to the National Authority for Electricity and Drinking Water (ONEE) end of 2014. The coal consumption decrease is not visible in the graphs because it should not take place before 2045, at the end of the PPA with two big private coal-fired electricity plants that generate around 24 TWh.

2.3. Greenhouse gases emissions from energy in Morocco till 2030

In 40 years (1980-2020), greenhouse gas (GHG) emissions have increased fivefold to reach nearly 63 million tons of CO_2 equivalents in 2020.

Pending a comprehensive capital program supported by the 2050 new long-term low-carbon strategy[42] Figure 6 shows the history and likely evolution of greenhouse gas emissions by 2030 as a result of the current knowledge of the electric equipment program and a certain evolution of the different components of non-electric final energy. Apart from a peak in 1993-1994, the share of GHG emissions from fuel oil has tended to decrease in value and share.

Between 1980 and 2020, the share of GHG emissions from solid and liquid fossil fuels has steadily eroded in favor of gaseous fuels (natural gas and liquefied petroleum gases). The share of emissions from liquefied gases is steadily increasing, due to butane.

a

b

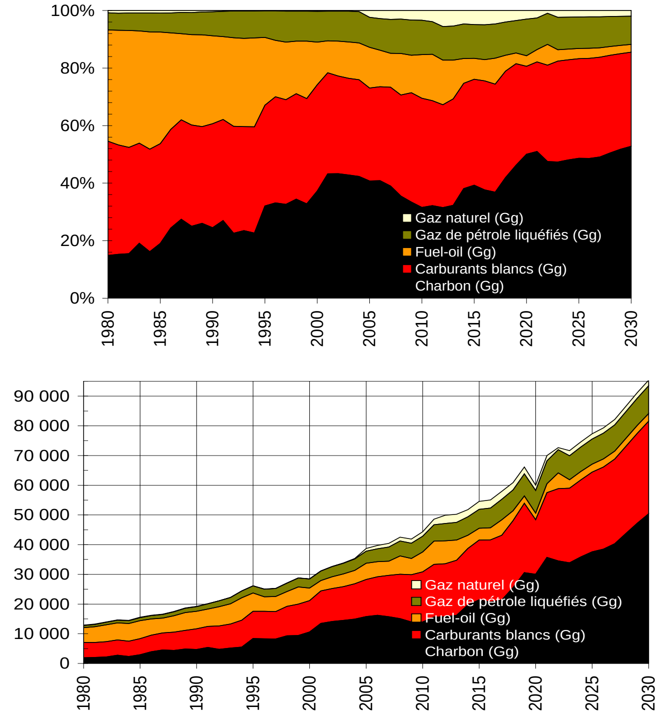


Figure 6 Retrospective and forecast of greenhouse gas emissions segmentation

Although coal's share of greenhouse gas emissions peaked in 1987, it trended upward between 1984 and 2001, mostly due to coal-fired power generation, but this share is not expected to increase after 2019. The share of white fuels (diesel, gasoline and super) remained almost constant until 2006 when it started to increase.

3. Demand and emissions of electricity in Morocco

3.1. The electricity flow diagram of Morocco in 2021

Figure 7 shows the inputs to the electricity flow diagram in Morocco in 2021: blue arrows is represent inputs while red arrows represent outputs. Powers shown in the left of the left rectangles stand for the installed power capacities for the different sources.

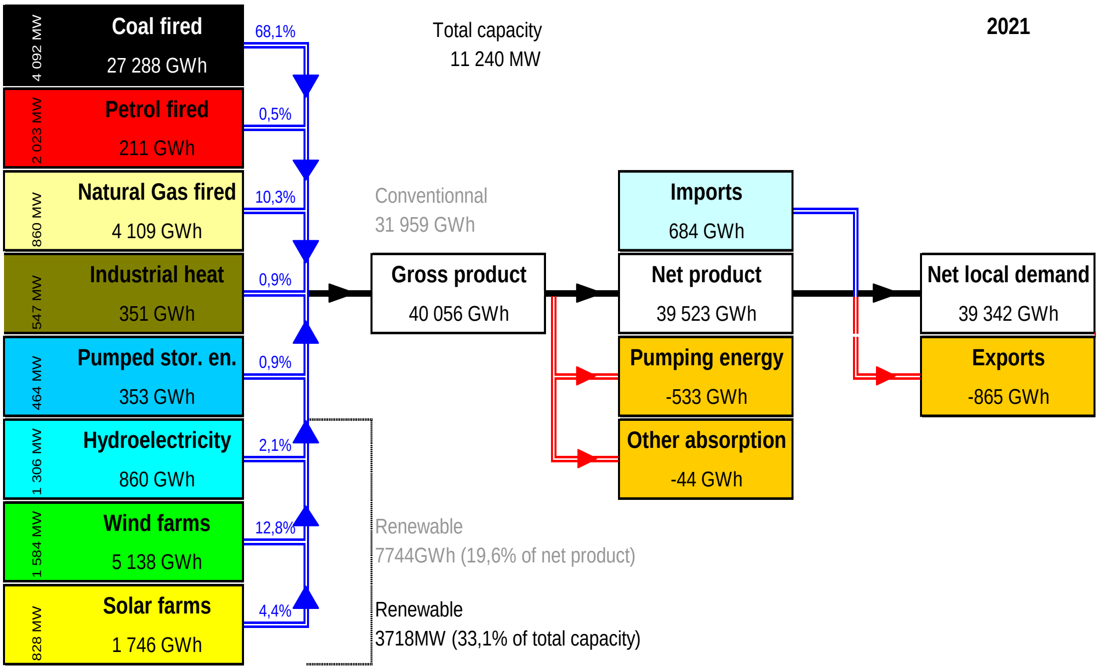


Figure 7 The input side of the electricity flow diagram of Morocco in 2021

The percentage written in blue above the line is the share of the following element while the one written in red with a sign is that of its annual variation. In 2021, Morocco had a net production of electricity of 39.523 TWh among which 0.865 exported.

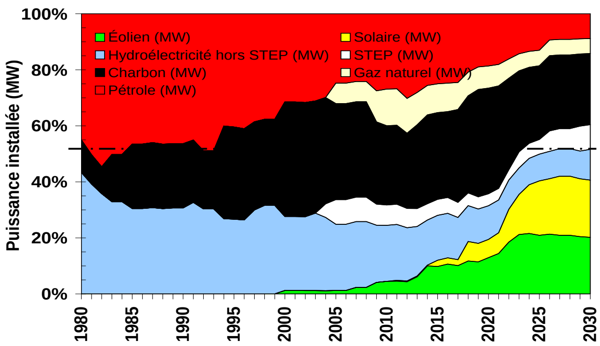
ONEE and the Ministry still unduly consider as "renewable", the capacity and productions of the Pumped Storage Power Station (STEP of Afourer).

3.2. Satisfaction of the electricity demand in Morocco until 2030

Presented at the COP22, the revision of the 2008 National Energy Strategy has set a new target of 52% of the total installed capacity of electricity generation from renewable sources.

Figure 8 shows the retrospective and probable forecasted evolution to 2030 of the segmentation of electric generation capacities (a) and their structure (b)

a



b

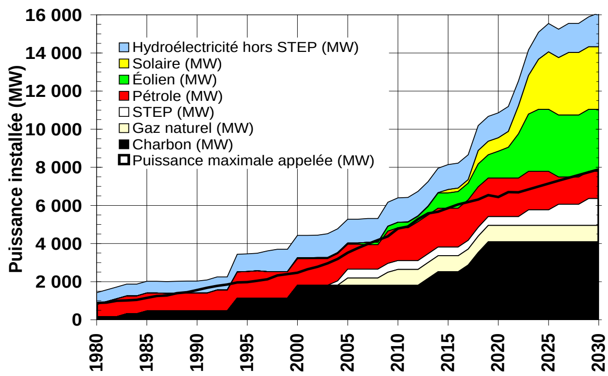


Figure 8 Retrospective and prediction of power segmentations

Figure 8 is based on the current knowledge of Morocco's 2030 electricity generation equipment plan, a summary of which can be found in another article[43] . Although the color code is identical in both graphs of Figure 8, in the figure 8-a , the low intermittent sources are placed at the bottom while in figure 8-b, renewable are placed at the bottom. Power plants using renewable sources (wind, solar and conventional hydro) should be close to 52% from 2027-2028. The self-generation of solar electricity, whose capacity is estimated at 645 MW by 2030 on the basis of the National Energy Strategy, could contribute significantly[44] at "peak" hours (during the day), but provided that it is encouraged instead of discouraged[45].

Figure 9 shows the retrospective evolution and the forecast to 2030 of the segmentation of the electricity produced from the electricity generation capacities (a) and their structure (b). Figure 9-a shows the generation deficit composated by electricity import.

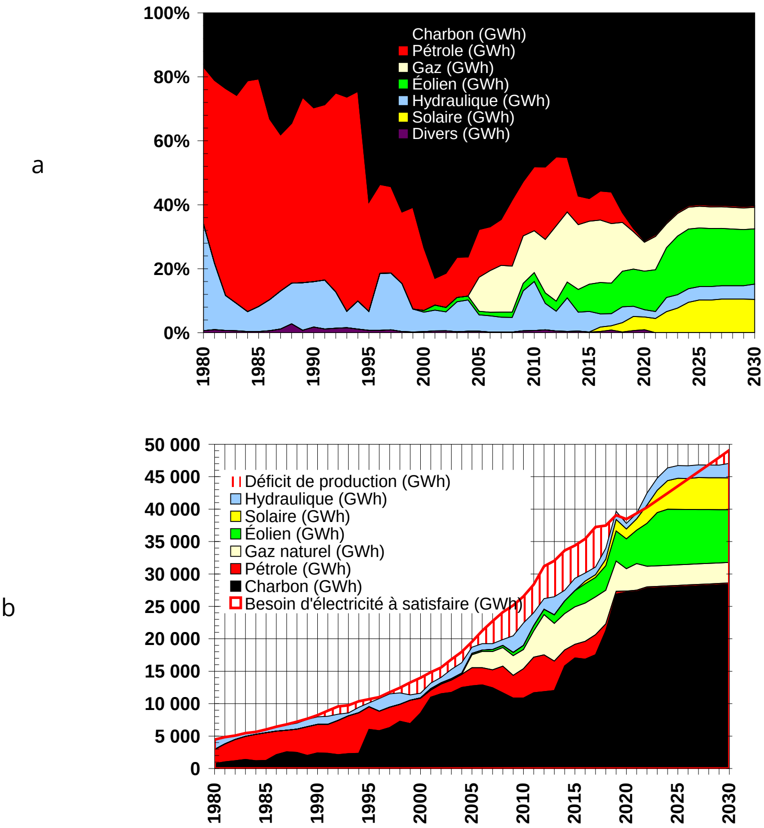


Figure 9 Retrospective and forecast segmentation of the electricity production

The figure 9-a chart bottom starts with fossil sources while the figure 9-b chart bottom starts with renewable ones.

3.3. Greenhouse gases emissions from electricity

3.3.1 Greenhouse gases emissions from electricity in Morocco until 2030

Figure **10** shows the historical and forecast evolution of greenhouse gas emissions from electricity produced in Morocco. The dominance of the coal contributions is obvious.

a

b

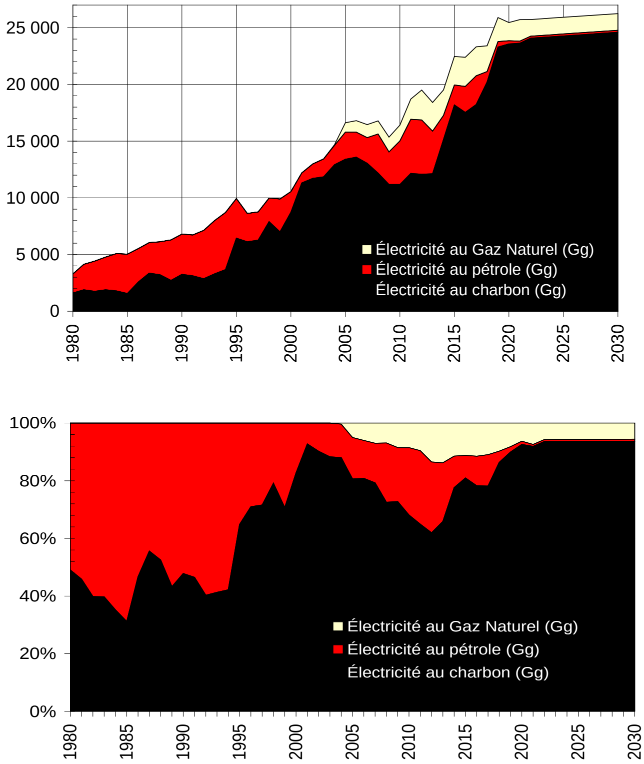
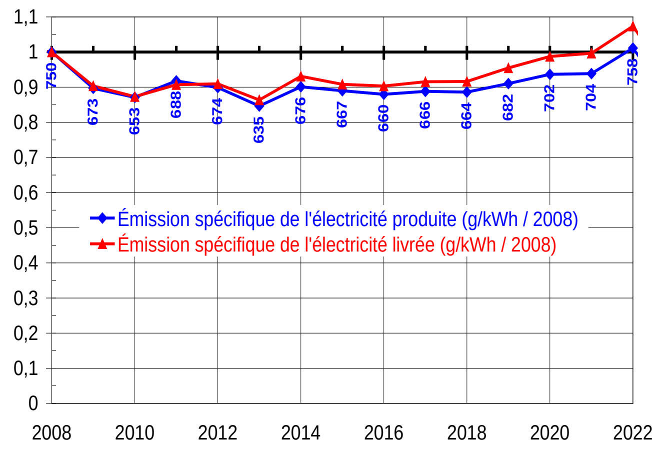


Figure 10 Retrospective and forecast segmentation of greenhouse gas emissions by electricity production

The graph on Figure 11-a shows the evolution of GHG emissions for each kWh produced in Morocco (in blue) or distributed (in red). The graph on the Figure 11-b shows the evolution of GHG emissions in relation to 2008 (reference year for the National Energy Strategy): they were calculated considering that each kWh of electricity counts for 950 grams of equivalent CO_2 when generated from coal, 770 grams when generated from coal petrol and 370 grams when generated from natural gas.

The rise from six hundred to seven hundred grams is mainly due to the commissioning of the Safi coal-fired power plant in June 2018. The values of the reference year 2008 (establishment of the National Energy Strategy) we exceeded in 2022, due to the total shutdown of the natural gas power plants of Tahaddart and Ain Beni Mathar between November 2021 (no more Algerian natural gas) and May 2022 and the replacement of their contribution by the production of power plants from the ONEE running on oil or coal.

a



b

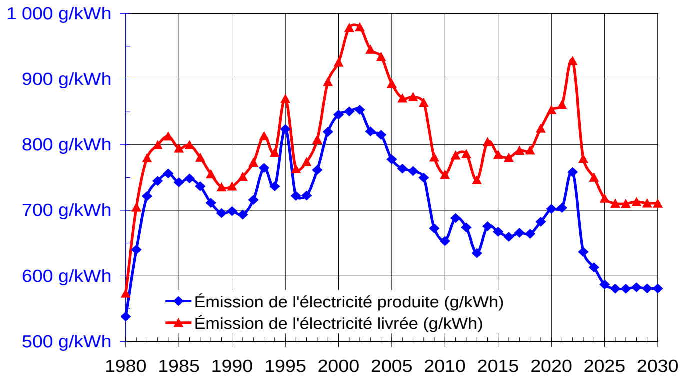


Figure 11 Absolute and relative change in GHG emissions per kWh produced or distributed

Unit emissions are slowly decreasing thanks to the introduction of electricity from renewable sources, but there will be no sharp drop before the end of the Power Purchase Agreement (PPA) contracts of private coal producers (2044).

3.3.2 Impact of electric mobility in Morocco on GHG emissions

Figure 12 shows the conversion chains ending at the mechanical work delivered to the wheels through the entire mechanical transmission of a vehicle with a combustion engine (in black) with an electric motor which batteries are charged in Morocco (in red), in Spain (in yellow) or in France (in blue)[46].

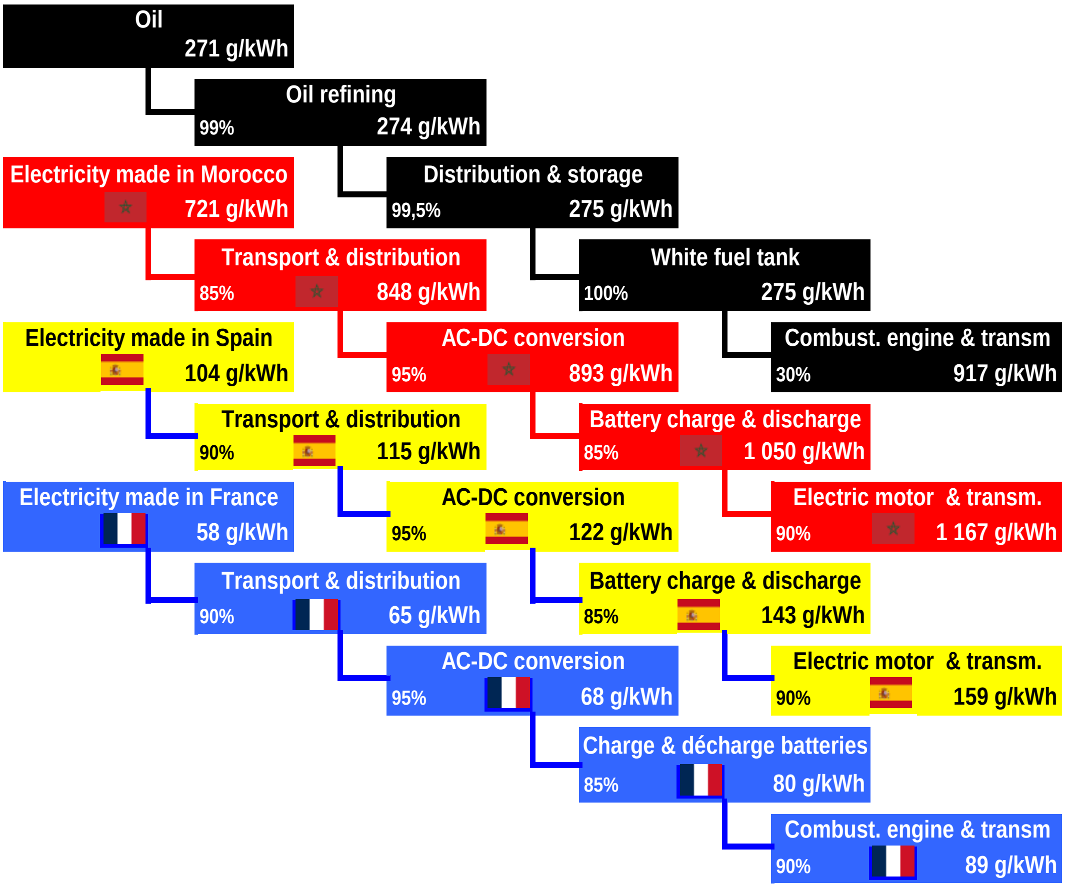


Figure 12 Energy conversion from the origin to the mechanical work supplied to the wheels of a vehicle

It turns out that, with 1'224 grams of equivalent CO_2 per kWh at the wheel, the use of an electric car recharged on the Moroccan electricity grid would pollute:

- more than a quarter more than a vehicle powered by a recent diesel engine (917 grams of equivalent CO_2 per kWh at the wheels),
- more than seven times more than an electric vehicle powered by batteries re-charged on the Spanish electricity network (159 grams of equivalent CO_2 per kWh at the wheels),
- more than twelve times more than the same recharged on the French electricity network (89 grams of equivalent CO_2 per kWh at the wheels).

The differences transcend calculation uncertainties and small yearly variations.

The huge gap between greenhouse gas emissions by electricity produced in France (58 g/kWh) and that produced in Morocco (721 g/kWh) comes, of course, from the difference in the mix of technologies for the production of electrical energy (commonly referred to as an electric "mix"). None of three countries is self-sufficient in fossil fuels: coal, oil, natural gas and uranium.

4. Energy production and dependence in Morocco

4.1. Local energy production in Morocco

Even though there are some recent natural gas findings, we can still say that, for the moment, Morocco has found very few hydrocarbons.

Figure 13 shows the evolution of the segmentation of locally produced energy: electricity from renewable sources (green), local fossil fuels (beige) and electricity from industrial heat (light blue). It should be noted that while the latter is present in the electricity data, it is almost always ignored in national balances of local energy production. The graph on figure 13-a represents their values converted into tons of oil equivalent, while the graph on the figure 13-b shows their respective shares.

a

b

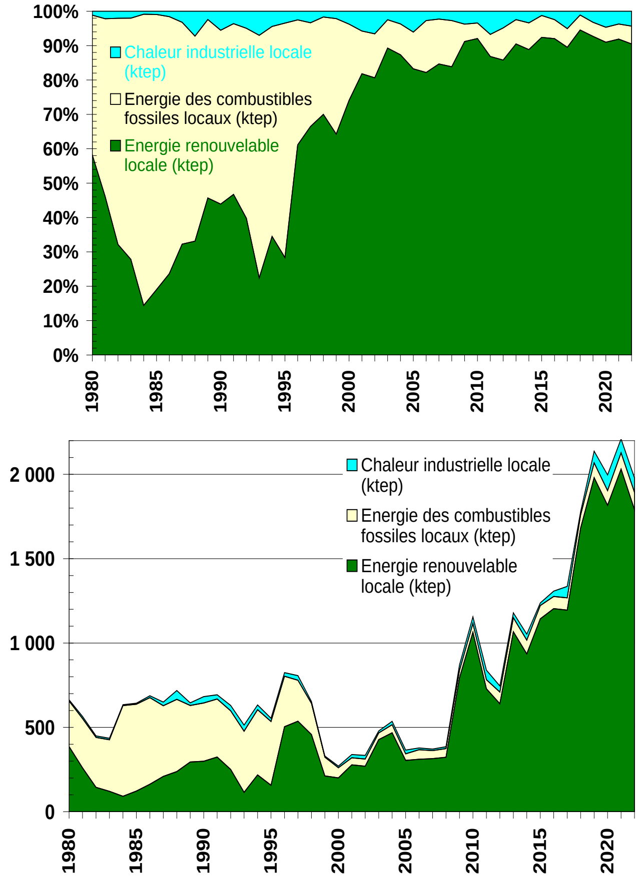


Figure 13 Evolution of the segmentation of locally produced energy

The lower graph allows saying that, for the time being, Morocco produces essentially renewable energy.

4.2. Energy dependence of Morocco

Figure 14 shows the evolution of the energy segmentation into imported and local energy: imported energy (red), electricity from renewable sources (green), electricity from industrial heat (light blue) and local fossil fuels (beige). The graph on figure 14-b represents their values converted into tons of oil equivalent while the lower graph 14-a shows their respective shares.

a

b

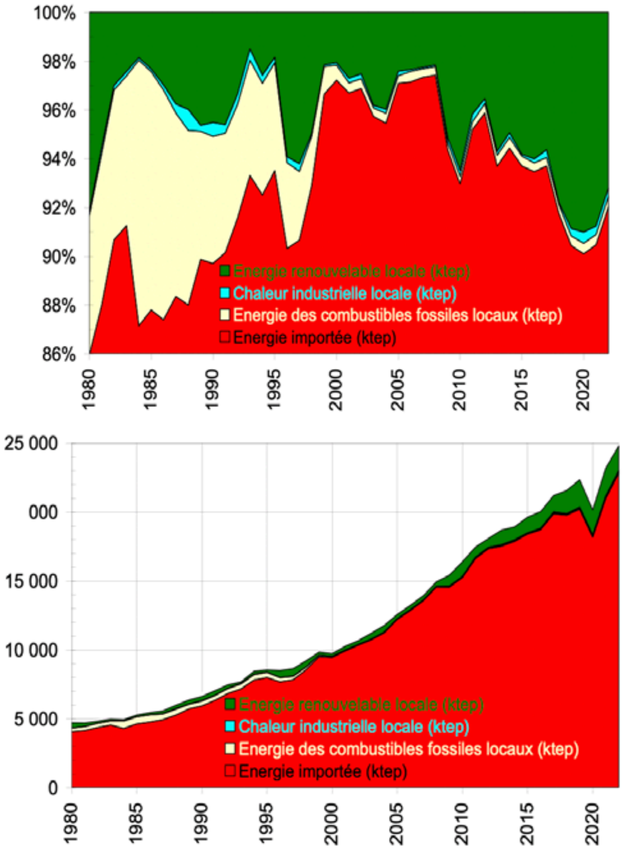


Figure 14 Evolution of energy segmentation into imported and local energy

Although oscillations due to variations in hydroelectric production (caused by rainfall fluctuations), energy dependence never went below 86% in the last 40 years. It exceeded 95% after 1999 (abandonment of coal mining in Jerada) and the gradual increase in demand met by imports. Since 2008, investments in renewable are slowly eroding the energy dependency index, albeit very erratically. The graph 14-a (ordinate origin at 86%) allows us to make at least the statement that Morocco is one of the most energy-dependent countries and that his little energy independence is almost fully due to renewable energy.

Figure 15 shows the evolution of annual electricity production from fossil fuels (in black) or from renewable sources (in green): both related to those of the same reference year 2008.

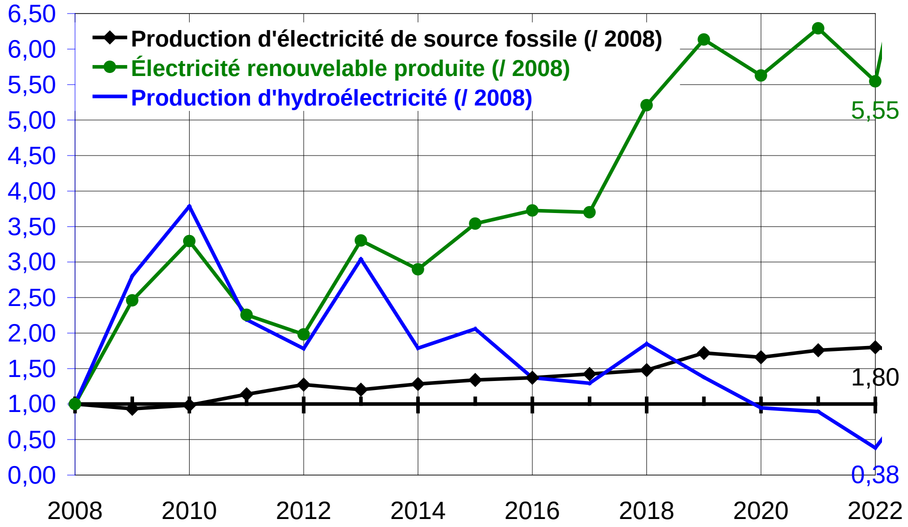


Figure 15 Evolution of fossil energy and renewable electricity production

While the production of electricity from fossil fuels has only multiplied by 1.80 between 2008 and 2022, the production of electricity from renewable sources has multiplied by 5.55 during the same period. Moreover, this was while hydroelectricity lost 62% of its production (see the blue curve). This shows clearly the effort done in the country to push towards renewable energy.

4.3. Energy cross-borders infrastructures and flows

4.3.1. Natural gas

Figure 16 shows main of the North African natural gas networks (circles show the crossing of borders).

Figure 16 Map showing North African natural gas networks (circles show the crossing of borders)

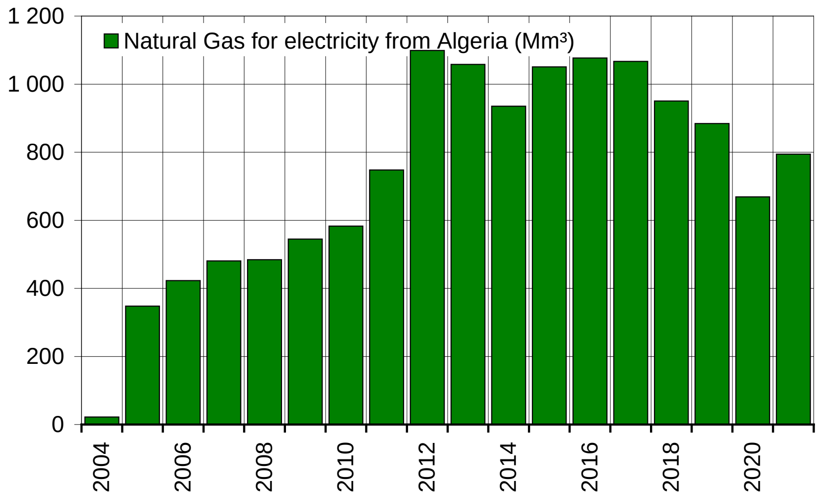


Figure 17 Evolution of the Moroccan imports of natural gas from Algeria

Imports of Algerian natural gas to Morocco went through the "*Gazoduc Maghreb Europe*" (GME) which, on November 1996, started delivery to Spain through the Moroccan territory and below the Gibraltar straight. However, after the end of the 25 years' contract, Algeria decided to stop all deliveries through the GME at the end of October 2021:

- Morocco had to stop its two natural gas plants (860 MW) which were generating up to 15.2 % of Moroccan net production of electricity on 2018[47, 48].
- Spain had to face a deficit of supply [49] from Algeria of a bit less than a billion cubic meters of natural gas in 2021 but probably 15% of its needs in 2022 (7-8 billion cubic meters).

4.3.2. Electricity

Figure 18 shows main parts of the North African power grid and the circles show the crossing of borders.

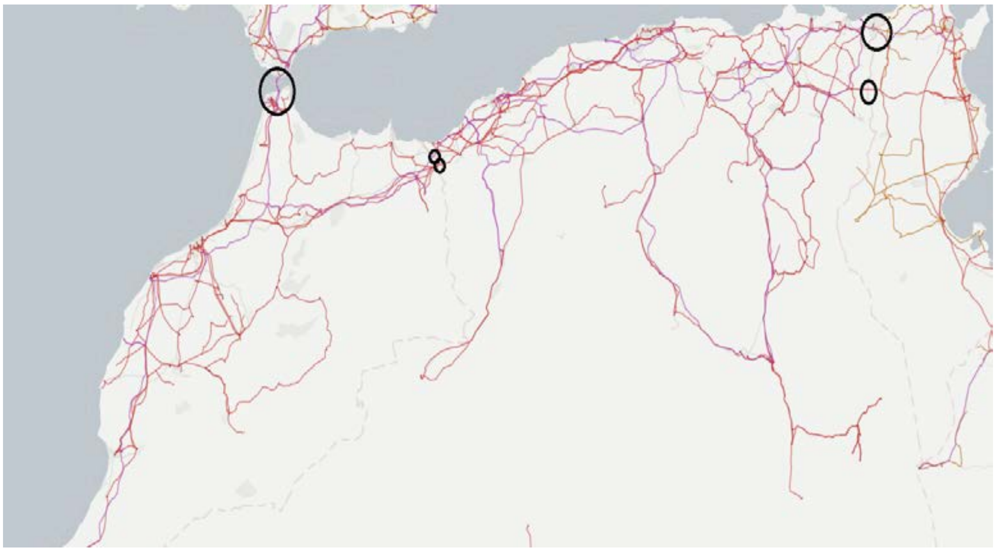


Figure 18 Map showing North African electricity power grids (circles show the showing the crossing of borders)

Figure 19 shows the evolution of the imports and exports of electricity through the interconnections with Algeria and Spain. The contract relating to electricity exchanges with Morocco is completely commercial with Spain, whereas it is limited to mutual assistance with Algeria. Consequently, exchanges with Algeria (12.56 TWh over 1988-2021) represented only 13.8% of the total electricity exchanges. During the period when Morocco was under-equipped (2007-2018), net imports from Spain provided up to 18.3% of the net electricity called up by the Moroccan network in 2009, but since 2019 the balance has been restored.

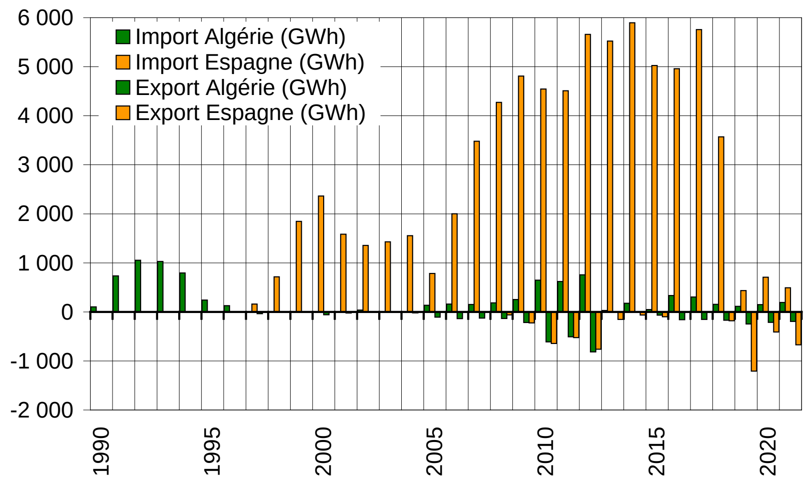


Figure 19 Evolution of the imports and exports of electricity through the interconnections with Algeria and Spain

5. Renewable energy adoption, storage and transportation

5.1. The 2008 National Energy Strategy (SEN)

Figure 22 shows a summary of the electrical power capacities provided for by the 2008 SEN and amended in 2016 during COP22.

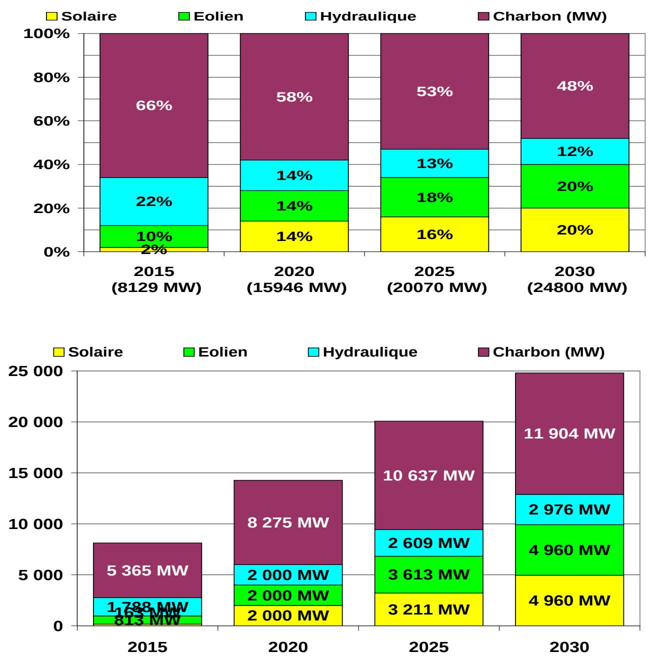


Figure 20 Electrical capacities planned by the 2008 National Energy Strategy

Even if its breakdown (coal, natural gas and oil) is not represented, the total capacity based on fossil fuels complies with the SEN. However, the following elements can be found in Figure 21:

- For the 3 times 2,000 MW which were planned by the SEN in hydraulic, wind and solar power to be able to accumulate 42% of the total installed power, it would have had to reach 15,946 MW in 2020 when we do not were only at 3,816 MW (instead of 6,000 MW) out of a total of 10,867 MW. If, in the end, the electricity consumption did not increase enough to need such capacities, the predicted 42% of electric capacity was not there either.

- The 52% of electric capacity planned for 2030 and for which Morocco committed in 2016 during COP22 are declined in the form 20% wind, 20% solar and 12% hydraulic.

It is clear that an equipment plan must be clearly defined for 2030 and new objectives for beyond, that is to say 2040 or 2050. To convince on this, **Figure 21** shows a comparison of the 2008 SEN forecasts (baseline in blue, disruptive in red and with energy efficiency in brown) with reality and new forecasts (in green).

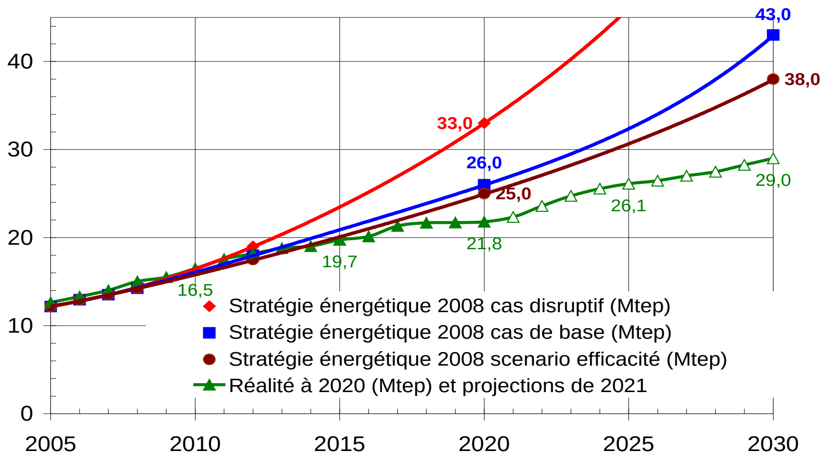


Figure 21 SEN energy consumption scenarios and new forecasts

The 21.8 Mtoe consumed in 2020 not having even reached the 25 Mtoe forecast by the "energy efficiency" scenario, it is clear that the forecasts made within the framework of the 2008 SEN were largely overestimated and that it is necessary to update them and extend them beyond 2030.

5.2. Electricity storage plants and projects

For the time being, Morocco has only one Pumped Storage Power Station in Afourer (464 MW) operating since 2005 but another one (350 MW) should be commissioned on 2023 near the Abdelmoumen dam.

In February 2021, Morocco also established a roadmap for green hydrogen[50] which, subject to competitive cost, could also be used for transport or energy storage before electricity production.

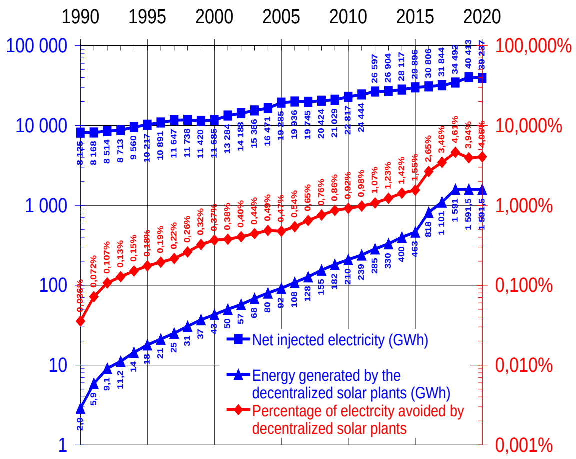
5.3. Off-balance-sheet renewable energies

Off-balance sheet energy is a part of energy efficiency because self-production energies, that do not pass through the economic circuits, contribute to increase the economic energy efficiency since, however real they may be, they do not appear in its denominator: self-consumption of solar water heaters or photovoltaic installations that reduce the call for one or more of the energy products of the national balance sheet.

5.3.1. Decentralized solar energy

Figure **22** recalls the maximum annual power on the electrical grid for the period 1990-2020 (in blue squares referring to the figure 22-a logarithmic scale) as well as the power generated at noon by decentralized solar thermal and photovoltaic (in blue triangles referring to the logarithmic scale in figure 22-a) as well as the savings in power demand that this represents at noon (in red diamonds referring to the logarithmic scale in figure 22-b).

a



b

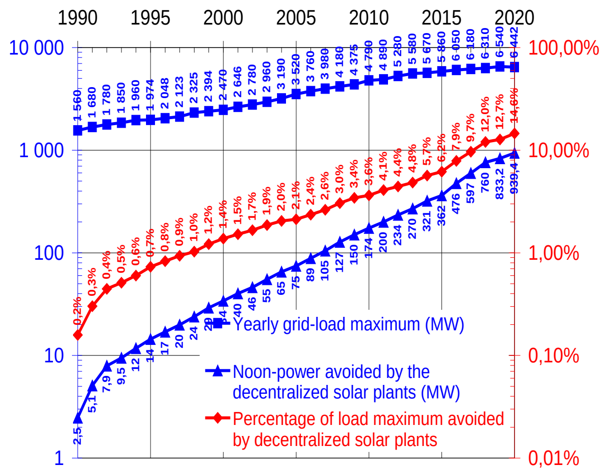


Figure 22 Evolution of electricity avoided by all decentralized solar

Energy efficiency in lighting that reduces night-time electricity demand (by 1,231 MW in power and 764 GWh per year in energy) is perfectly complementary with decentralized solar energy systems that reduce daytime electricity demand (by 939 MW and 1,591 GWh per year). Unfortunately, neither of these two elements is visible in the national energy accounting.

5.3.2. Biomass energy (gross estimations)

Figure 23 shows the estimated evolution of figures related to wood energy consumption.

a

b

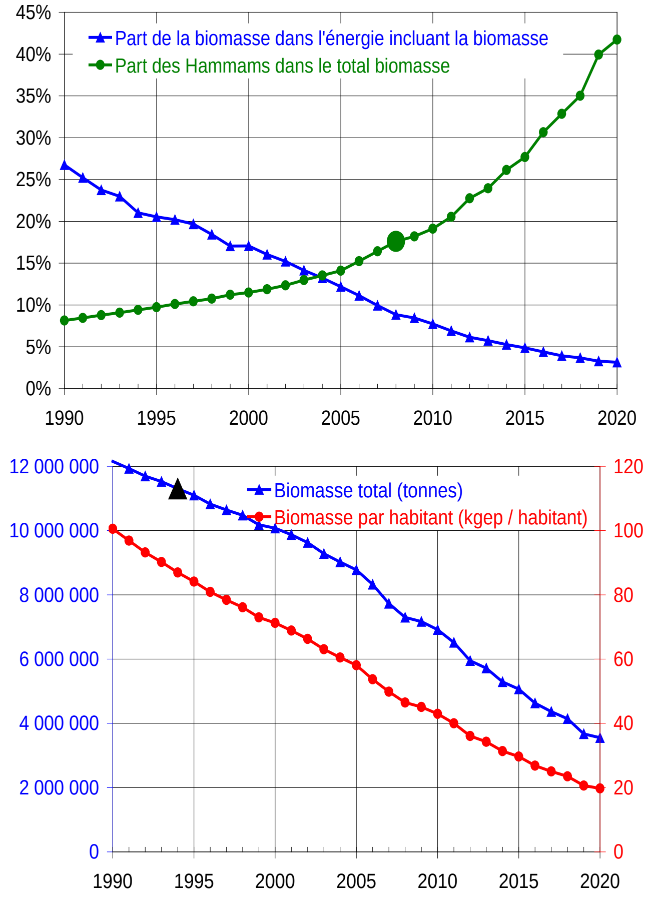


Figure 23 Calculated evolution of elements related to wood energy consumption

This is the most questionable part of this document. The only real data are: the 1994 figure on the figure 23-b (enlarged **black** triangle) which results from a previous work[51] and the 2008 figure in graph 23-a (green circle enlarged) which results from a study on Hammams in Morocco. The extrapolations are based on the conservation of residential thermal energy needs per capita with a transfer from wood energy to butane:

- Since removals are not under the control of the forestry services, it is difficult to know the precise value of these consumptions,
- From the 1994 data only and without additional safeguards, we assumed that the useful thermal energy of wood (50% efficiency) was replaced by that of butane (65%).

Despite this, we wanted to visualize what would be the degree of decrease of the call for biomass if this scenario were valid. This decrease would be good news for Moroccan forests, because without it, the effect of the butane subsidy on the fight against deforestation would be zero. In the substitution model, we find that subsidizing butane gas would have reduced forest biomass consumption by barely 30% in 20 years. Harvesting continues to put too much pressure on the forest estate. There is a need to establish a reliable database and to put in place a national renewable biomass energy plan.

The green curve is obtained by extrapolating backwards from the 2008 data (magnified in the figure) and then normalizing to the annual biomass total. This extrapolation is itself obtained by assuming constant per capita wood energy needs in the Hammams.The blue curve in figure 23-a is obtained by normalizing the annual total in toe of (conventional energy + biomass).

Despite these reservations, as conventional energy consumption increases and biomass consumption decreases, the share of biomass in the total can only decrease rapidly. Thus, within the applicability limit of the biomass/butane substitution model, the share of biomass in total energy would have fallen by a little more than half between 1990 and 2008. On the other hand, the share of Hammams in biomass would have almost doubled during the same period.

5.4. Evolution of the legal and regulatory framework in favor of renewable

Text	Object
Law 13/09	Promote the production of energy from renewable sources, its marketing and export by public or private entities and gives the right to produce, by an operator, electricity from renewable energy sources on behalf of a consumer connected to the national MV, HV and VHV electricity grid.
Law 58/15	Modifies and completes Law 13-09 on renewable energy. Allows the increase of the installed capacity threshold for hydro power projects from 12 to 30 MW, gives the possibility of selling the surplus of renewable energy produced and opens the electricity market of renewable sources (LV).
Decree 2-10-578	Makes it possible to establish and to stop the procedures related to the modalities and conditions of the constitution and the deposit of the file of request for authorization and in application of the law n° 13-09 relating to the renewable energies.
Law 57/09	Creates the new company "Moroccan Agency for Solar Energy" (MASEN) and defines its missions for the realization of the 2000 MW solar program.
Law 37/16	Amends and completes the law 57-09. MASEN becomes "Moroccan Agency for Sustainable Energy". Extents MASEN's missions to include the realization of power generation plants from all current and future renewable energy resources (except pumped storage stations, power generation facilities intended for the peak and stability of the national electrical system and power generation facilities from renewable energy sources governed by the provisions of Law No. 13-09 on renewable energy).
Decree 2-15-772	Regulates access to the national medium-voltage electricity network.

Law 47/09	Published in 2011 and provides for compliance with requirements in terms of minimum energy performance of buildings as well as those of appliances and equipment running on energy offered for sale on the national territory, the conditions for the creation of energy service companies, the obligation of periodic energy audit and energy impact study for major urban development projects and building construction program projects, the introduction of technical control.
Law 16/09	Creates the National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE) which replaces CDER. Considering the importance of energy efficiency in the framework of the energy strategy, ADEREE's missions will be focused on strengthening energy efficiency.
Law 39/16	Creates the Moroccan Agency for Energy Efficiency, which replaces ADEREE, and sets the allocation of energy efficiency to the agency in order to exploit the significant potential for energy efficiency in all economic sectors.
Decree 1-10-17	Decree 1-10-17 relates to the mandatory energy audit and the accreditation of auditing bodies
Decree 2-13-874	Approves the general building regulations setting the rules for energy performance of buildings and establishing the National Committee for Energy Efficiency in Construction. Aims to reduce energy consumption in the building due to heating and air conditioning according to the climatic zoning and improve the thermal comfort of the building.
Decree 1-63-226	Decree 1-63-226 creates the National Office of Electricity
Law 38/16	Law No. 38-16 amends and supplements Article 2 of Decree 1-63-226
Law 40-09	Relates to the creation of the Office National de l'Électricité et de l'Eau Potable (ONEE), a merger of the former ONE and the former ONEP. Specifies the entities to which activities are entrusted. Indeed, electricity production is ensured by ONEE, the private sector on behalf of MASEN within the framework of a PPA or by the private sector within the framework of self-production or within the framework of the law on renewable energies, electricity transmission is a monopoly of the national grid operator (ONEE) and electricity distribution is shared between the ONEE, the Régies Communales de Distribution and the Concessionnaires Délégués.
Law 48/15	Defines the regulation of the electricity sector and creates the National Electricity Regulation Authority. It ensures the proper functioning of the free market for electricity produced from renewable sources and regulates the access of self-generators to the national transmission network.
Order 3851-21	Joint order of the Minister of Energy Transition and Sustainable Development and the Minister of the Interior setting the trajectory for the next ten years, from 2022 to 2031, composed of envelopes for the injection of electrical energy produced from renewable energy sources to the MV grid.

Project of Law 40/19	Draft law amending and supplementing Law No. 13-09 on Renewable Energies as amended and supplemented by Law 58/15 (not yet passed to Parliament in March 2022)
Project of Law 82/21	Bill on self-generation of electrical energy (not yet passed to Parliament in March 2022).

6. Conclusions

Morocco is a country very heavily dependent on imports and "under-energized". Its major assets are: good overall energy efficiency and low intensity of GHG emissions per unit of GDP, even if its electricity is still strongly polluting. However, the international environment poses serious threats to its economic energy efficiency without having offered it opportunities, unless solar and wind electricity come to offer it in the future.

Although the recovery of the Moroccan Saharan Provinces, after the decolonization by Spain in 1975, poisons the relations with the immediate neighbors, Morocco has no other solution than to cooperate with them and to develop renewable energies which are its only resource of proven energy. This will take time and the management of the energy transition period will not be smooth.

For the grid electricity, big renewable plants are balancing, but very progressively, the pollution of the coal fired electricity plants which should not be stopped before 2044 (purchase power agreement with take-or-pay clauses).

For the time being, biomass renewable energy has still not been fully exploited. Despite this, the combination of decentralized solar photovoltaic energy combined with drip irrigation has strongly contributed to:

- securing agricultural production and farmers' income while avoiding water wastage,
- to decrease the dependence of the country's agricultural GDP on rainfall,
- to widen the exploitable surfaces for agriculture,
- to the country's food independence.

References

[1] Banque Mondiale, https://donnees.banquemondiale.org/pays/maroc?view=chart

[2] Royaume du Maroc, Ministère de l'Énergie, des Mines et de l'Environnement, Portail des statistiques de l'Observatoire Marocain de l'Énergie (OME), https://www.observatoirenergie.ma/data/

[3] Royaume du Maroc, Ministère de l'Economie, des Finances, et de la Réforme de l'Administration, Direction des Etudes et des Prévisions Financières (DEPF), Notes de Conjoncture, http://depf.finances.gov.ma/etudes-et-publications/note-de-conjoncture/

[4] Royaume du Maroc, Ministère de l'Economie, des Finances, et de la Réforme de l'Administration, Direction du Trésor et des Finances Extérieures (DTFE), Notes de Conjoncture, https://www.finances.gov.ma/fr/Nos-metiers/Pages/notes-conjoncture.aspx

[5] Royaume du Maroc, Bank Almaghrib, Revue de la Conjoncture Economique, http://www.bkam.ma/Publications-statistiques-et-recherche/Documents-d-analyse-et-de-reference/Revue-de-la-conjoncture-economique

[6] Haut Commissariat au Plan, Annuaire Statistique du Maroc, Version électronique après 2013 https://www.hcp.ma/downloads/Annuaire-statistique-du-Maroc-version-PDF_t11888.html, Version papier ou scannées avant 2013 https://cnd.hcp.ma/

[7] Direction Générale des Collectivités locales, Ministère de l’Intérieur, Informations sur les Régies et les Services Concédés dans "Décentralisation en chiffres" (pour 2014-2015) et "Collectivités locales en chiffres" (pour les années antérieures), https://www.collectivites-territoriales.gov.ma/fr/statistiques

8 M. Rodot, A. Benallou, "Solar Electricity for Rural Development", First Edition (ISSN 2ème edition 978-2-913620-13-1) by the Institute of Energy of the Countries in Common Use of French (IEPF) with the support of the Agency of Cultural and Technical Cooperation (1993 and 2002)

9 Abdelaziz Bennouna, "*Towards an Energy Exporting Morocco*" (in Arabic, " نحو مغرب مصدر للطاقة"), (ISBN 9981-9790-07), Self-Published printed by Dar Nachr Almaghribya (1994)

10 Mohammed Belhaj, "*Vehicle and fuel demand in Morocco*", Energy Policy 30 (2002) 1163-1171, https://doi.org/10.1016/S0301-4215(02)00008-3

11 Saul Samir, "*L'électrification du Maroc à l'époque du protectorat*", In: Outre-mers, tome 89, n°334-335, 1er semestre 2002. L'électrification outre-mer de la fin du XIXe siècle aux premières décolonisations. pp. 491-512, https://doi.org/10.3406/outre.2002.3952

12 R. Gutiérrez, R. Gutiérrez-Sànchez, A. Nafidi, "*Electricity consumption in Morocco: Stochastic Gompertz diffusion analysis with exogenous factors*", Applied Energy 83 (2006) 1139-1151, http://dx.doi.org/10.1016/j.apenergy.2005.11.007

13 Kerstin Fritzsche, Driss Zejli, Dennis Tänzler, "*The relevance of global energy governance for Arab countries: The case of Morocco,*" Energy Policy 39 (2011) 4497-4506, http://dx.doi.org/10.1016/j.enpol.2010.11.042

14 Kerstin Fritzsche, Driss Zejli, DennisTänzler, "*The relevance of global energy governance for Arab countries: The case of Morocco*," Energy Policy 39 (2011) 4497-4506, http://dx.doi.org/10.1016/j.enpol.2010.11.042

15 Bernhard Brand, Amine Boudghene Stambouli, Driss Zejli, "*The value of dispatchability of CSP plants in the electricity systems of Morocco and Algeria*," Energy Policy 47 (2012) 321-331, http://dx.doi.org/10.1016/j.enpol.2012.04.073

16 Rafael de Arce, Ramon Mahia, Eva Medina, Gonzalo Escribano, *"A simulation of the economic impact of renewable energy development in Morocco*," Energy Policy 46 (2012) 335-345, http://dx.doi.org/10.1016/j.enpol.2012.03.068

17 Abdelkrim Rimi, Yassine Zarhloule, Alae Eddine Barkaoui, Antonio Correia, Julio Carneiro, Massimo Verdoya, Francis Lucazeau, "Towards a de-carbonized energy system in north-eastern Morocco: Prospective geothermal resource," Renewable and Sustainable Energy Reviews 16 (2012) 2207- 2216, http://dx.doi.org/10.1016/j.rser.2011.12.008

18 N. Belakhdar, M. Kharbach, M.E. Afilal, *"The renewable energy plan in Morocco, a Divisia index approach,"* Energy Strategy Reviews 4 (2014) 11-15, http://dx.doi.org/10.1016/j.esr.2014.06.001

19 A. Ghezloun, A. Saidane, N. Oucher, "*Energy policy in the context of sustainable development: Case of Morocco and Algeria*," Energy Procedia 50 (2014) 536 - 543, http://dx.doi.org/10.1016/j.egypro.2014.06.065

20 A. Allouhi, A. Jamil, T. Kousksou, T. El Rhafiki, Y. Mourad, Y. Zeraouli, *"Solar domestic heating water systems in Morocco: An energy analysis*,*"* Energy Conversion and Management 92 (2015) 105-113, http://dx.doi.org/10.1016/j.enconman.2014.12.055

21 Alaa Alhamwi, David Kleinhans, Stefan Weitemeyer, Thomas Vogt, "*Moroccan National Energy Strategy reviewed from a meteorological perspective*," Energy Strategy Reviews 6 (2015) 39-47, http://dx.doi.org/10.1016/j.esr.2015.02.002

22 T. Kousksou, A. Allouhi, M. Belattar, A. Jamil, T. El Rhafiki, A.Arid, Y. Zeraouli, "*Renewable energy potential and national policy directions for sustainable development in Morocco*," Renewable and Sustainable Energy Reviews 47 (2015) 46-57, http://dx.doi.org/10.1016/j.rser.2015.02.056

23 Amine Allouhi, Tarik Kousksou, Abdelmajid Jamil, Tarik El Rhafiki, Youssef Mourad, Youssef Zeraouli, *"Economic and environmental assessment of solar air-conditioning systems in Morocco*,*"* Renewable and Sustainable Energy Reviews 50 (2015) 770-781, http://dx.doi.org/10.1016/j.rser.2015.05.044

24 T. Kousksou, A. Allouhi, M. Belattar, A. Jamil, T. El Rhafiki, Y. Zeraouli, *"Morocco's strategy for energy security and low-carbon growth*,*"* Energy 84 (2015) 98-105, http://dx.doi.org/10.1016/j.energy.2015.02.048

25 Alaa Alhamwi, David Kleinhans, Stefan Weitemeyer, Thomas Vogt, *"Moroccan National Energy Strategy reviewed from a meteorological perspective*,*"* Energy Strategy Reviews 6 (2015) 39-47, http://dx.doi.org/10.1016/j.esr.2015.02.002

26 T. Ksouksou, A. Jamil, T. Elrhafiki, "*Renewable energies for electricity production: the case of Morocco*", edited by IRESEN, ISBN 978-9954-9360-1-6

27 L. Boughamrane, M. Boulaid, A. Tihane, A. Sdaq, K. Bouabid, A. Ihlal, "Comparative Analysis of Measured and Simulated Performance of the Moroccan First MV Grid Connected Photovoltaic Power Plant of Assa, Southern Morocco", J. Mater. Environ. Sci. 7 (11) (2016) 4064-4072, https://www.jmaterenvironsci.com/Document/vol7/vol7_N11/434-JMES-2663-Boughamrane.pdf

28 Amin Bennouna, Charaf El Hebil, "*Energy needs for Morocco 2030, as obtained from GDP-energy and GDP-energy intensity correlations*," Energy Policy 88 (2016) 45-55, http://dx.doi.org/10.1016/j.enpol.2015.10.003

29 Jens Marquardt, Karoline Steinbacher, Miranda Schreurs, "*Driving force or forced transition?: The role of development cooperation in promoting energy transitions in the Philippines and Morocco*," Journal of Cleaner Production 128 (1) (2016) 22-33, http://dx.doi.org/10.1016/j.jclepro.2015.06.080

30 Ahmed Alami Merrouni, Abdel-Ilah Amrani, Ahmed Mezrhab, "*Electricity production from large scale PV plants: Benchmarking the potential of Morocco against California, US*, "Energy Procedia 119 (2017) 346-355, http://dx.doi.org/10.1016/j.egypro.2017.07.118

31 Ibitissam Fellak, Mohammed El Ganaoui, Abdelaziz Mimet, Abdellah Maalouf, *"The solar domestic water heating system in the six Moroccan climate zones*,*"* Energy Procedia 139 (2017) 180-185, http://dx.doi.org/10.1016/j.egypro.2017.11.193

32 Sharlissa Moore, *"Evaluating the energy security of electricity interdependence: Perspectives from Morocco,"* Energy Research & Social Science 24 (2017) 21-29, http://dx.doi.org/10.1016/j.erss.2016.12.008

33 Mohammed Kharbach, Tarik Chfadi, *"Oil prices and electricity production in Morocco,"* Energy Strategy Reviews 22 (2018) 320-324, https://doi.org/10.1016/j.esr.2018.10.006

34 N. Aarich, N. Erraissi, M. Akhsassi, A. Bennouna, A. Asselman, A. Barhdadi, L. Boukhattem, A. Cherkaoui, Y. Darmane, A. Doudou, A. El. Fanaoui, H. El. Omari, M. Fahoume, M. Hadrami, D. Moussaid, B. Hartiti, A. Ihlal, M. Khaidar, A. Lfakir, K. Loudiyi, M. Mabrouki, M. Raoufi, A. Ridah, R. Saadani, I. Zorkani Aboufirass, "*Photovoltaic DC yield maps for all Morocco validated with ground measurements*", Energy for Sustainable Development (ISSN: 2352-4669), 12 (2018) Pages 158-169, https://DOI.ORG/10.1016/j.esd.2018.10.003

35 Younes El Khchine, Mohammed Sriti, Nacer Eddine El Kadri Elyamani, "*Evaluation of wind energy potential and trends in Morocco*," Heliyon 5 (2019) e01830, https://doi.org/10.1016/j.heliyon.2019.e01830

36 Roberto Cantonia, Karen Rignall, "*Kingdom of the Sun: a critical, multiscalar analysis of Morocco's solar energy strategy*," Energy Research & Social Science 51 (2019) 20-31, https://doi.org/10.1016/j.erss.2018.12.012

37 Roberto Cantonia, Karen Rignall, *"Kingdom of the Sun: a critical, multiscalar analysis of Morocco's solar energy strategy,"* Energy Research & Social Science 51 (2019) 20-31, https://doi.org/10.1016/j.erss.2018.12.012

38 A. Bennouna, "The increasingly important role of decentralized solar energy in Morocco", Applied Journal of Environmental Engineering Science (ISSN: 2509-2065), 7-1 (2021) Pages 18-41, https://DOI.ORG/10.48422/IMIST.PRSM/ajees-v7i1.24354

39 World Bank, World Development Indicators, https://databank.banquemondiale.org/source/world-development-indicators

40 Global Change Data Lab, Oxford Martin School, University of Oxford (UK), "Our world in data", https://ourworldindata.org/charts

41 World Bank, https://donnees.banquemondiale.org/indicator/EG.EGY.PRIM.PP.KD

42 Ministère de la Transition Energétique et du Développement Durable, Département du Développement Durable, "*Stratégie Bas Carbone à Long Terme (Maroc 2050)*", Octobre 2021, UNFCCC Sites and platforms, https://unfccc.int/sites/default/files/resource/MAR_LTS_Dec2021.pdf

43 Amin BENNOUNA, "*No need for new thermal power plants - neither coal nor fuel oil nor natural gas*", Webmagazine EcoActu, 19 April 2021, https://www.ecoactu.ma/nul-besoin-de-nouvelles-centrales-thermiques-electriques/

44 Amin BENNOUNA, "*Three decades of solar photovoltaic energy in Morocco*," EcoActu Webmagazine, 03 December 2019, https://www.ecoactu.ma/trois-decennies-denergie-solaire-photovoltaique-au-maroc/

45 Amin BENNOUNA, "*L'inapplicable Projet de Loi marocain relatif à l'autoproduction d'électricité*", Webmagazine EcoActu, November 15, 2021, https://www.ecoactu.ma/linapplicable-projet-de-loi-82-21-relatif-a-lautoproduction-delectricite/#:~:text=R%C3%A9uni%20le%20jeudi%2011%20novembre,du%20mardi%2002%20Novembre%2021

46 Amin Bennouna, "*La majorité véhicules électriques du Maroc contribuent plus qu'ailleurs au réchauffement climatique*", Webmagazine EcoActu 4 March 2022, https://www.ecoactu.ma/vehicules-electriques-rechauffement-climatique/

47 A. Bennouna, "*Quid si l'Algérie ne livrait plus nos centrales électriques en gaz naturel ?*", Webmagazine EcoActu, 22 September 2021, https://www.ecoactu.ma/algerie-centrales-electriques-gaz-naturel/

48 A. Bennouna, "*Pas de gaz naturel algérien ? – Pas de problème, le Maroc continue à exporter de l'électricité !*", Webmagazine EcoActu, 03 February 2022, https://www.ecoactu.ma/gaz-naturel-algerien-maroc-ectricite/

49 A. Bennouna, "*Le contexte énergétique de l'adieu du gouvernement espagnol à un certain Mohamed Ben Battouche*", Webmagazine EcoActu, 22 March 2022, https://www.ecoactu.ma/contexte-energetique-mohamed-ben-battouche/

50 Ministère de l'Énergie, des Mines, de l'Eau et d'Environnement, "Feuille de route de l'hydrogène vert - Vecteur de transition énergétique et de croissance", Document written on February 2021 by the MEMEE, https://www.mem.gov.ma/Lists/Lst_rapports/Attachments/36/Feuille%20de%20route%20de%20hydrog%C3%A8ne%20vert.pdf

51 Driss OUKASSOU, "*Informations sur le bois énergie au Maroc, inventaire*", Direction du Développement Forestier, Ministère Chargé des Eaux et Forêts (1995) http://www.fao.org/DOCREP/003/Y2714F/y2714f15.htm

Imprint

The author

Amin Bennouna

Born in 1956, Amin BENNOUNA teaches Physics since 1980, won a Moroccan National Research Prize Distinction in 2009, led two energy companies (to 2005 and to 2018) and held several positions in the Moroccan Solar Industry Association from 1996 until 2016. He presently coordinates a network of 250 Moroccan energy researchers after having led an 'Innoproject' solar energy research carried by all the Moroccan Universities with IRESEN funds (2014-2018), and after having managed two multilateral European 'Med-campus' projects with EU funds (1990-1994). After having built an energy scenario (2007) for Morocco'2030 and signed more than 200 papers, he is presently updating his "Monograph of energy in Morocco" (first edition in 2011).

Konrad-Adenauer-Stiftung e. V.

Regional Programme Energy Security and Climate Change
Middle East and North Africa
www.kas.de/remena
info.remena@kas.de