Journal of Energy Storage 32 (2020) 101806

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

Towards a large-scale integration of renewable energies in Morocco

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ARTICLE INFO

Keywords:
Renewable energy integration
Energy storage
Power to X
Morocco
Thermal energy storage
Concentrated solar power

ABSTRACT

Renewable energies are a sustainable, unlimited and decarbonised solution to address future energy challenges. In this context, Morocco has a considerable advantage to position itself on this promising market. Furthermore, renewable energies have been highlighted as a key strategic source for the country's green growth. Morocco has adopted the renewable energy path through a strategy targeted on the development of solar, wind and hydroelectric power to boost its energy policy by adapting it to the challenges posed by today's world. Nowadays, Morocco is facing a challenge to reach 52% by 2030 of its total renewable energy capacity, which will exceed 42% by the end of 2020. The main objective of this paper is to study a scenario for 2030 for the Moroccan electricity system and to identify the challenges that need to be addressed in order to accelerate the integration of renewable energies in the Moroccan energy mix and to achieve a possible export of such green energy towards Europe.

1. Introduction

The challenge of responding to the world's climate change is a worldwide environmental problem that will impact all countries around the globe. Environmentalists alert international society and businesses that natural resources will run out faster than anticipated [1]. Indeed, energy demand in developed and developing countries is rising dramatically. By 2030, 40% and 50% increases in energy consumption is expected in Europe and in the USA, it will be doubled in India and it's expected to triple in China [2]. Since then, the global world interests to increase the use of renewable energy sources and reduce the GHGE as a key solution.

The use of renewable energy sources (RES) can contribute to the decarbonization of the power system and to ensure a sustainable energy supply throughout the world [3,4]. Over the past century, the share of renewable energy in the energy mix of many developed countries has increased considerably and this trend is expected to continue in the future [5]. Many governments around the world have directed their transition policies to more sustainable and accessible energy systems [6–9]. In Morocco, electricity consumption demand increases at an annual average of 7%, since 2002 [10]. The electrical power production industry in Morocco is facing challenges involved with sustained growth of demand, added to environmental protection requirements, that's why energy security [11] and mitigation of emissions and environmental pollution are identified as the main motivating forces for the transformation of the existing electricity power supply system to a sustainable form of electricity [12–17].

At COP 21 conference held in Paris, Morocco is promising an optimistic and binding deal. It is in this perspective that the Moroccan government has launched a holistic plan to boost the percentage of renewable energy in the energy mix and substantially increase energy efficiency. Goals have been established to increase the percentage of renewable energy electricity generation capacity (42% by 2020 and 52% by 2030 – see **Fig. 1**) and objectives to decrease energy

Abbreviations: GHGE, Green House Gas Emissions; RES, Renewable energy sources; SDGs, Sustainable Development Goals; TOE, Tonne Oil Energy; MASEN, Moroccan Agency for Solar Energy; CSP, Concentrated Solar Power; PV, Photovoltaic; ONEE, National Agency for Electricity and Water; PETS, Pumped Energy Transfer Station; IRESEN, Institute of Research on solar energy and New Energies; IPPs, Independent Power Producer's Electricity.; LNG, Liquefied natural gas; CCGTs, Combined Cycle Gas Turbines; SG, Smart Grid; SET Roadmap, Roadmap for Sustainable Electricity Trade; WWTP, Waste Water Treatment Plan; PtX, Power to X; PtH, Power-to-Hydrogen; MSF, Multi-Stage Flash; MED, Multi-Effect Distillation; RO, Reverse Osmose; ED, Electro Dialyses; MVC, Mechanical Vapor compression; TVC, Thermo-Vapor compression; BWRO, Brackish Water Reverse Osmose; SWRO, Sea Water Reverse Osmose; V2G, Vehicle to Grid; RETs, Renewable energy technologies; RE, Renewable Energy; EU, European Union; R&D, Research and Development

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https://doi.org/10.1016/j.est.2020.101806
Received 27 May 2020; Received in revised form 4 August 2020; Accepted 25 August 2020
Available online 02 September 2020
2352-152X/

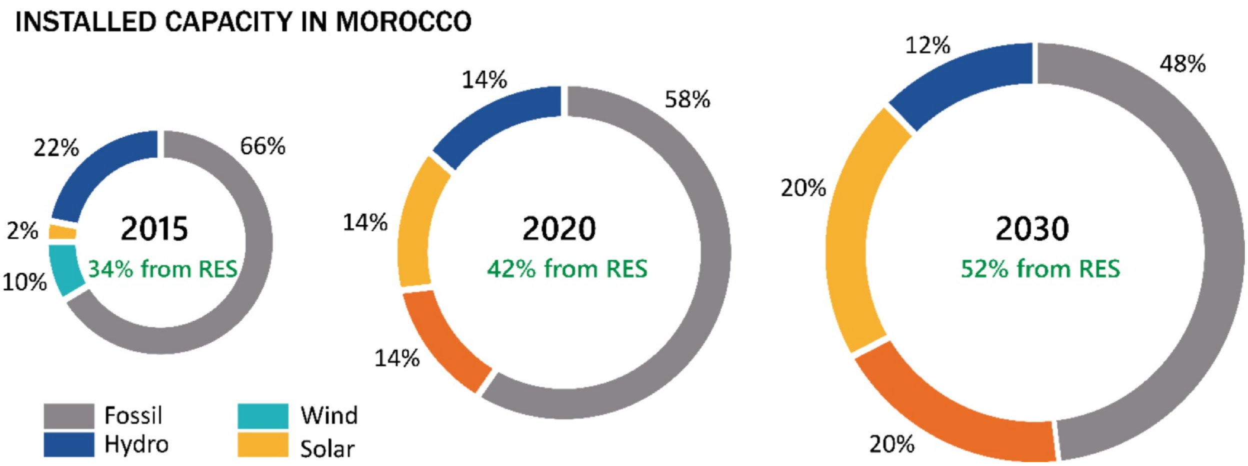

Fig. 1. Installed capacity in Morocco.

consumption by 12% by 2020 and 15% by 2030 through energy efficiency enhancements [18–21]. For comparison, the European Commission has adopted a mandatory goal of achieving 32% of renewable energy by 2030, with the possibility of revising this target upwards by 2023 [22].

However, as electrical systems incorporate higher levels of RE, the quality and reliability of the power supply becomes more challenging to manage [23]. Although there are many alternative options to facilitate the integration of RE systems, they are costly and complex [24]. In addition, to ensure these options, significant changes in the organization and functioning of electrical systems are required.

Many papers [10,13,17] have explored Morocco's renewable energy potential under various perspectives with a focus towards its national energy strategy development. However, in this present paper, the current situation of the Moroccan energy strategy is assessed with an in-depth analysis of the main renewable energy projects completed or under development in Morocco. As well as it focuses on a general scope of the main actual trails and challenges facing the national energy strategy, with a clear and detailed roadmap of the key elements and guidelines to be followed by Morocco in order to achieve its objectives in terms of renewable energy and energy efficiency by 2030.

2. Current status of major RE projects in Morocco

In addition to its commitments in favour of the climate (GHGE reduction of 32% by 2030), the Kingdom of Morocco faces many challenges in its energy transition. Efforts are aimed at matching the supply and demand of primary energy, which is increasing by 5% per year, driven by the electricity demand, which is growing at a fairly steady annual rate of more than 6%, through the development of new electricity production capacities, which should bring the installed capacity to 25,000 MW in 2030. Security of supply also remains one of the major challenges of the Moroccan energy model, which it is attempting to address through the diversification of its energy resources.

Morocco's primary energy demand and electricity demand will both be expected to double by 2030. Figs. 2 and 3 show the evolution of the primary energy demand and electricity consumption in Morocco respectively [25]. Through 2020, in accordance with the SDGs (Sustainable Development Goals), the Kingdom of Morocco is making good strides towards sustainable, secure and modern electricity. However, the ultimate target is to build a more diversified power system with a significant contribution from renewable sources.

In 2018, Morocco installed 34% of renewable energy (i.e. 3,700 MW), divided as follows: 1,770 MW, 1,220 MW and 711 MW respectively originate from hydroelectricity, wind power and solar energy [26].

Currently, Morocco's renewable electricity system is widely diversified and has a mix of solar, wind and hydroelectric power plants. Table 1 presents the total installed and planned capacity in 2018 and in 2020, respectively [27].

The Kingdom of Morocco is currently considered as one of the leading countries in the world's energy transition, especially in Africa, with several programmes to generate electricity from renewable sources.

2.1. Solar program

Morocco has taken advantage of its geographical position and environment to gain an edge in the field of renewables, especially solar energy [28]. The average incident solar radiation varies between 4.7 and 5.6 kWh/m2/day with a number of hours of sunshine that varies from 2700 hours/year in the North of Morocco to more than 3500 hours/year in the South.

Initiated in 2009, the Moroccan Solar Plan is a very ambitious project. A number of solar power plants have been planned and scheduled to be installed as part of this project. The Moroccan Agency for Solar Energy (MASEN) was set up specifically to execute these projects. Its mission is to implement all projects related to the National Energy Strategy and to co-ordinate and supervise all other activities connected with this initiative. Table 2 lists the major projects completed, in the process or planned in sites, with total investment estimated at approximately USD 9 billion through to 2020.

We note that PV technology is featured in all projects due to a decrease in the price of photovoltaic modules of more than 80% over the last ten years [29]. As part of the Mediterranean Solar Plan, Ouarzazate plant has benefited from European co-financing. The overall Ouarzazate project includes four power plants: Noor 1, Noor 2, Noor 3 and Noor 4 with different technologies. Noor 2 has a capacity of 200 MW based on parabolic mirror technology and Noor 3 is equipped with a solar tower of 100 MW capacity. Noor 4 based on photovoltaic technology has an output of 72 MW. With a capacity of 160 MW, Noor 1 is currently one of the largest concentrated solar thermal (CSP) parabolic cylinder power plants in the world.

The solar power plant Noor 1 is mainly equipped with the advanced Concentrating Solar Power (CSP) generation, with Parabolic Trough Collector (PTC) [30]. By comparing this technology to solar energy tower, linear Fresnel Reflector and parabolic dish collector, the PTC with thermal oil and molten salt storage is considered to be the simplest and most mature system [31,32] Prospective sites for CSP plants are generally selected based on the global distribution of Direct Normal Irradiance (DNI) [33]. Commercially viable CSP plants should maintain a DNI of at least 2000–2800 kWh/m^2/yr [33,34]. The Rankine cycle

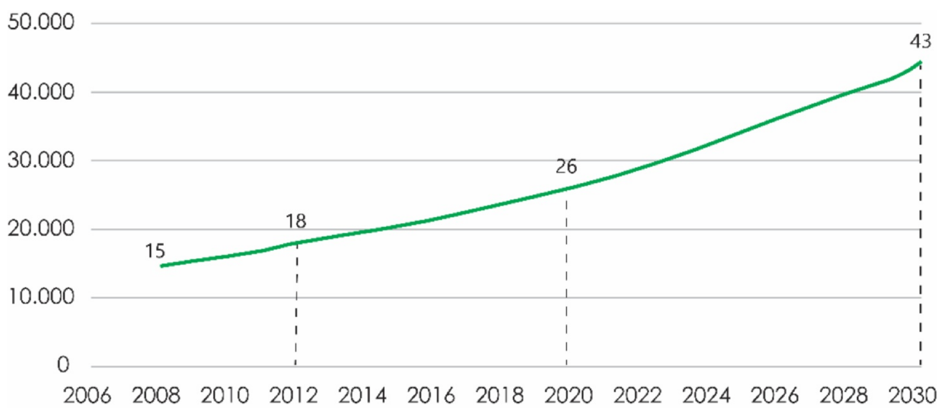

Fig. 2. Morocco's primary energy demand in Millions TEP [25].

with molten salt storage is the operating principle of the Noor 1 plant (see Fig. 4) [35,36].

As shown in Fig. 4, the Noor 1 plant consists of three parts, which are the solar field, the power block and the thermal storage system. These parts are properly outlined by Kuravi et al.[37]. The Noor 1 power plant's solar field consists of 400 parabolic trough loops arranged in parallel and connected to each other. Each loop consists of 4 arrays of solar collectors in series and each array is composed of 12 solar collector elements. The solar collectors composed of very reflective parabolic mirrors and heat collection elements (HCE) installed in the center of the dish. A monitoring system allows the collectors to follow the sun from sunrise to sunset [37]. Once the direct solar irradiation is received on the solar field and reflected by the parabolic collectors to the absorber, where the heat is transferred to the heat transfer fluid (HTF). A synthetic oil which is used as HTF circulates through the collectors. At the output of the solar field, the HTF is collected and then pumped to an expansion tank, which is connected to the power block unit to transfer its energy to water. The power block includes a steam generator, preheater, steam turbine, power generator, condenser, cooling systems (air condenser and cooling tower) and auxiliary equipment. The steam generator has two heat exchanger trains including economizers, evaporators, superheaters and preheaters. The HTF flows through the two heat exchanger trains in order to produce steam at high temperature and pressure.

The Noor 1 plant has been designed with two tanks of an eutectic molten salt composed of a mixture of sodium nitrate and potassium nitrate (60% $NaNO_3$ + 40% KNO_3). This mixture has a high heat transfer coefficient and high thermal storage capacity. The function of the thermal storage system is to store excess sensible heat from the solar field (charge mode) during daily sunshine hours, in order to extend plant operation during night or when solar irradiation is insufficient (discharge mode). The HTF flows in heat exchanger to charge/discharge the thermal storage system. The molten salt circulates from the cold storage tank through the heat exchanger and enters the hot salt storage tank, with temperature of approximately 368°C. The temperature of the cold molten salt is about 292°C. When the storage system is discharged, the molten salt from the hot storage tank is sent back to cold storage tank through the heat exchanger that is used to heat up the cold HTF. The heated HTF is then sent to the power block.

Table 1
Total installed and planned capacity in 2018 and in 2020.

Plant type	2018 Capacity installed (MW)	2020 Capacity to be installed (MW)
Solar	710.8	2000
Wind	1220	2000
Hydro	1770	2000

Table 2
Major solar projects.

Plant/Site	Production capacity	Technology	Commissioning year
Ain Beni Mather	472 MW	CSP/PV	2011
Ourazazatte	580 MW	CSP/PV	2018
Foum Al Oued	500 MW	CSP/PV	2020
Boujdour	100 MW	PV	2018
Sbkhat –Tah	500 MW	CSP/PV	2020
NOOR Tafilalt	120 MW	PV	2019
NOOR Atlas	200 MW	PV	2020
NOOR Argane	200 MW	PV	After 2020

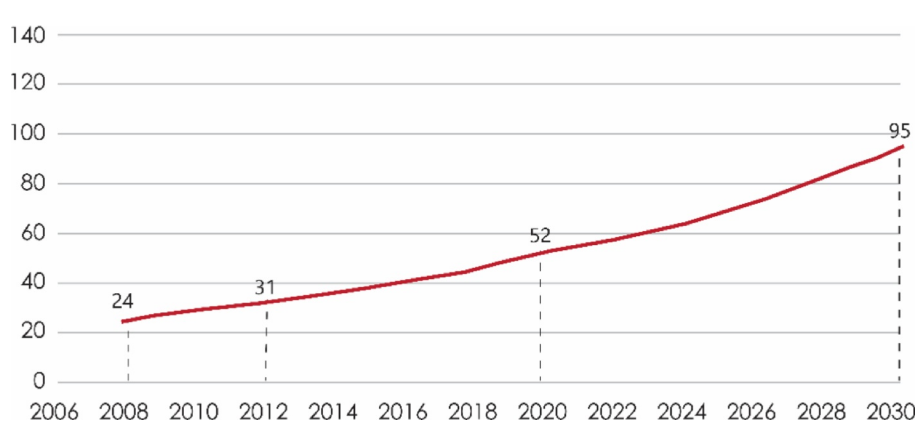

Fig. 3. Morocco's electricity consumption in TWh [25].

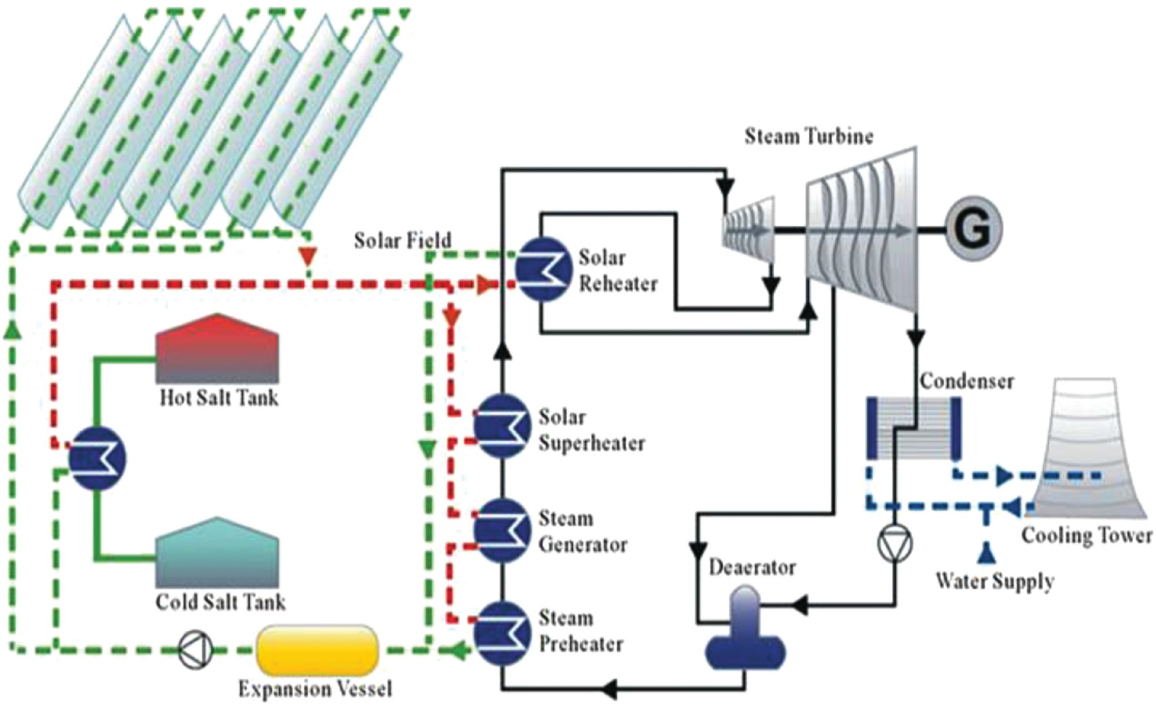

Fig. 4. Schematic of PTC power plant with thermal storage [36] .

2.2. Wind program

The favourable geographical location of Morocco provides it an important wind energy potential, estimated at about 6000 MW [13,38]. Most of Morocco's windiest regions are located in the extreme north on the Strait of Gibraltar side in the Tangier-Tetouan region, the Essaouira region, the South Atlantic area from Tarfaya to Lagouira and the Taza corridor between the Atlas and Rif mountain ranges. The wind field is characterized by average wind speeds above 8 m/s for the windiest regions [17].

Under its energy strategy, Morocco has implemented an ambitious wind energy program to promote the deployment of renewable energies. This program intends to expand installed wind power capacity to 2,000 MW by the end of 2020 and to boost this capacity to 2,600 MW by 2030. Table 3 shows the commissioned wind power plants and Table 4 lists the projects in development [39].

Table 3
Commissioned wind power plants.

Project	Capacity	Year of commissioning
Amgdoul	60 MW	2007
Tanger I	140 MW	2009
Koudia Al Baida/Toress	50 MW	2000
Cimar	5 MW	2011
Lafarge	32 MW	2009
Trfaya	300 MW	2014
Akhfenir	100 MW	2014
Akhfenir 2	100 MW	2016
Foum Al Oued	50 MW	2014
Haouma	50 MW	2014
Jbel Khalladi	120 MW	2018
Aftissat	200 MW	2018
PEI 85 — MIDELT	180 MW	2019
PEI 850 — BOUJDOUR	100 MW	2019
Law 13-09 – OUALIDIA	36 MW	2019
PEI 850 — TISKRAD	300 MW	2020
PEI 850 — TANGER II	70 MW	2020
PEI 850 — JBEL LAHDID	200 MW	2020
Total	2,093 MW	

Table 4
Wind Power Projects in development.

Project	Capacity	Year of commissioning
TAZA	150 MW	2021
Law 13-09 SAFI	200 MW	2021
Repowering Koudia	100 MW	2021

One of the most important projects in wind energy program is the giant Tarfaya wind farm (see Fig. 5), which is operational. It is the largest wind energy project on the African continent. The year 2015 has witnessed the injection of the total capacity of this park of 300 MW. In addition to electricity production, the wind program also includes industrial integration of the wind energy sector, as well as the promotion of research and development and technical training in this field. In this sense, the program includes the manufacture of equipment for wind farms in the national industrial fabric to amplify and sustain its impact on the national economy in general and the development of wind energy in particular.

2.3. Hydropower program

In Morocco's new energy strategy, 14% of the country's energy production will come from hydropower by 2020. Installed hydropower capacity will be increased from 1,730 MW in 2008 to **2,000** MW in 2020 through the construction of new hydropower dams and Pumped Energy Transfer Station (PETS).

Morocco currently has 1,770 MW of hydropower generation capacity, of which **464 MW** is in PETS mode [41]. This production capacity is really achievable only when water reservoirs are at their maximum. This is not always the case, rather the opposite; Morocco is a semi-arid country. In hydraulics, the other element that must be taken into account in Morocco is irrigation. Thus, turbining to produce electricity is, therefore, dependent to a certain extent on irrigation needs. However, throughout the world, the production of hydroelectric power is always lower than the level of existing installed capacity dictates. In 2011, for example, hydropower production is in sharp decline, with only 2.2 TWh

Fig. 5. Tarfaya Wind farm [40] .

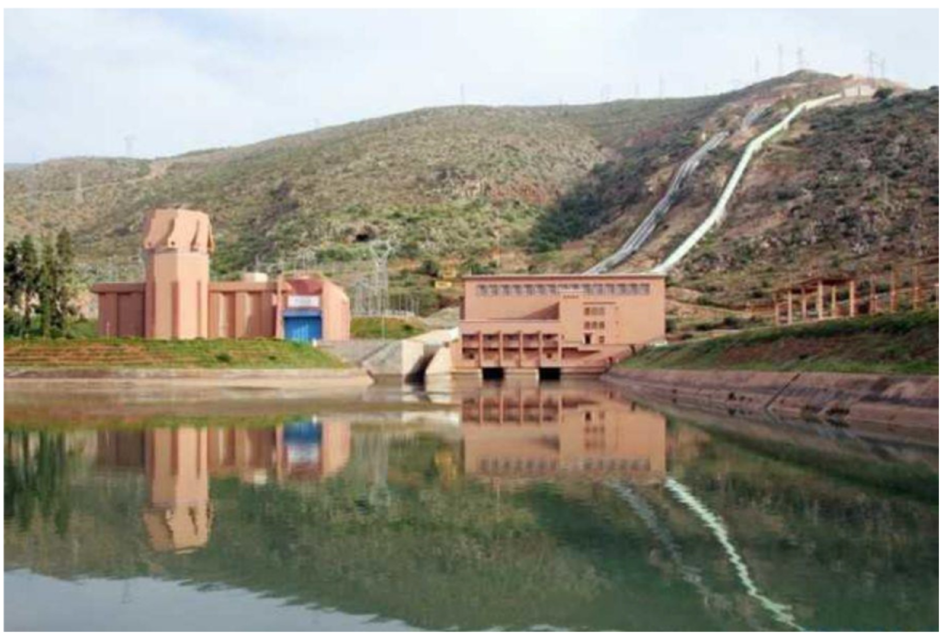

Fig. 6. Hydroelectric Plant near Agadir – Morocco [42] .

Table 5
Current situation of the hydro projects by Mars 2020.

Project	Capacity
PETS Afourer	464 MW
Diverses usines	337 MW
Al Wahda	240 MW
Allal El Fassi	240 MW
Bin El Ouidane	135 MW
Al Massira	128 MW
Afourer	94 MW
Ahmed El Hansali	92 MW
Tanafnit	40 MW
Total	1,770 MW

Table 6
Future hydropower projects in Morocco.

Project	Location	Capacity	Situation
Afrer	Agadir	465 MW	Under construction
Step Abdelmoumen	Agadir	350 MW	Under construction
Ifhsa	Oued Laou	300 MW	Under construction
M'dez El Mnzel	Sefrou	300 MW	Under construction
Khenifra	Khenifra	125 MW	Under construction
BarOuender	Taounate	30 MW	Under construction
Tamejout	Beni Mellal	30 MW	Under construction
Tillougit I	Beni Mellal	26 MW	Under construction
Boutferda	Azilal	18 MW	Under construction
Tillouguit II	Beni Mellal	8 MW	Under construction

compared to 3.7 TWh in 2010, a year with abundant rainfall in Morocco. PETSs that are constructed or under development are expected to serve as a storage mechanism for solar and wind energy Fig. 6 shows The PETS of 350 MW at the Abdelmoumen site in the Agadir region which will increase the hydraulic capacity of Morocco to 2120 MW by the end of 2020. Meanwhile, Morocco plans to build about sixty large dams over the next twenty years; however, most of them should be dedicated to water resource management, and therefore not necessarily to power generation. Table 5 shows the current situation of the hydro projects [39], and Table 6 shows the future hydropower projects in

Morocco [10].

2.4. Biomass program

In addition to solar, wind and hydraulic power, the process of diversification of energy resources in Morocco also concerns biomass. Currently, Morocco has considerable biomass potential thanks to a forest area of more than 5,350,000 ha, Halfa areas of nearly 3,300,000 ha, an agricultural area of nearly 9,000,000 ha and a highly diversified livestock (cattle, sheep, goats, etc.) of around 7,000,000 livestock units [43]. Despite its enormous resources in biomass, Morocco currently has only less than 1% of its potential capacity because of its high initial expenditure and the lack of knowledge about energy production techniques and processes [13]. Nevertheless, its main potential has yet to be covered by national policies, although some small companies already are involved in this sector.

In order to organise the use of biomass efficiently, the Department of Energy and Mines in Morocco has initiated a national strategy for the energy recovery of biomass. This initiative has been financed by the European Union, as part of the support for the reform of the energy sector. This initiative was initially based on an evaluation of the business potential of biomass, with an analysis of the main material flows, coming from the sectors of agriculture, forestry, waste management and wastewater treatment, according to the indications of the Department of Energy. Until now, two agricultural regions (Northen and Souss-Massa) have been studied to evaluate their biomass energy potential. These two regions generate agricultural waste of the order of 1.3 million tonnes per year and 8,198 tonnes per year respectively. The recovery of this waste shows a potential of 417,806 MWh in the northern region, i.e. a saving of 0.33 million tons of oil. Moreover, even if the potential exists, this does not mean that it is exploitable. The costs as well as the profitability have yet to be determined. In the Souss-Massa area, a few pilot projects, financed by donors, have already been tested.

Other projects are under development to promote the exploitation of biomass as an energy source, and the most important of them are:

- Program for disseminating biogas digesters in the Souss-Massa region;
- Development of new biofuels technologies.

MASEN (Moroccan Agency for Solar Energy) has also started to explore options for initiating waste-to-energy projects. While, **IRESEN** (Institute of Research in Solar Energy and New Energies) has commissioned in 2018 a prototype combining solar thermal collectors and biomass for electricity production [44].

It is interesting to outline that large-scale biogas production is still at the stage of feasibility studies, particularly by private investors. The legislative framework remains insufficient since there is no obligation for biogas recovery. The major obstacles to the dissemination of biogas technologies in Morocco are probably the non-availability of water and the insufficient technical monitoring of the installations and the inadequacy of incentives.

Based on the analysis of the results obtained in the first half of 2020, we can recognize and appreciate the considerable progress accomplished in recent years by Morocco, leading it to achieve the 2020 targets. However, to achieve the ambitious targets set for 2030, the Moroccan government needs to diversify financing models for renewable energy projects and stimulate private sector investment in RE. In addition, it needs to capitalize on the high potential of biomass through concrete projects and immediate investments.

3. Key elements for successful transformation of the power system

In Morocco, renewable energy policy has gained attention as an effective solution to recognize ecological problems and achieve sustainable growth and with high economic impact [45]. Fulfilling the targets for renewable electrical energy development in Morocco by 2030 presents a new challenge regarding the integration of renewable energy sources. This must not involve any systems integration problems but opportunities abound the further increase power system flexibility, efficiency and remove constraints in the current power system operation. For a productive electricity transition focused on a broad renewable portion, a systemic approach is required, given the evolution trajectories of supply and demand, electricity infrastructure and the competition of various flexibility options to ensure the stability of the system (interconnections, active demand management, energy storage). A forward-looking study in electricity allows this increasing need for flexibility to be measured while recognizing other pathways for maximizing renewable energy adoption in Morocco.

3.1. Improving and reinforcing the national power grid

Energy transition in Morocco is expected to have a significant impact on the national power grid stability, generating both a significant need for a network (to integrate a growing fraction of renewable production and benefit from the proliferation of intermittent production) and a decrease in its utilization rate (linked to self-consumption and decentralization of production). The transition to a high proportion of RE in Morocco will represent a complete redesign of the power grid, requiring a comprehensive reflection to optimize investments in transmission (or perhaps distribution) networks and production plants. Congestion problems observed in systems where generation assets are located far from consumption areas (e.g. offshore wind farms in northern Germany, solar and wind generation in northern and western China for industrial consumption centers in the east and south) demonstrate the importance of these challenges.

The Moroccan power system has an extensive and complicated network, comprising a dense transmission grid with 3,000 km of 400 kV lines, about 9,000 km of 225 kV lines, 147 km of 150 kV lines and about 11,780 km of 60 kV lines [44]. The network was created fifty years ago and is a combination of old and new technological elements. The majority of the network's system is outdated and subject to aging due to the effects of stress, such as extreme temperatures, vibrations, water infiltration and damage due to civil engineering works [44,46]. Several initiatives have been implemented by the National Agency for Electricity and Water (**ONEE)** to reinforce the electricity grid. **Table 7** summarizes the grid expansion planned between 2019 and 2020 [25]. However, these initiatives are unfortunately insufficient to meet Morocco's 2030 objectives.

There is an urgent need to modernize and improve the Moroccan grid infrastructure to ensure a wide penetration of wind in the energy mix [47]. Most wind farms are either remote from the power grid or

Table 7
Planned grid reinforcement added between 2019 and 2020.

Reinforcement	**2019**	**Horizon end of 2020**
	• Installation of a third transformer of 400/225 kV • Installation of a third autotransformer of 400/225 kV • Setup of a 3-phase line of 400 kV (55 km) • Setup of a 3-phase line of 400 kV (400 km)	• Setup of a 3-phase line of 400 kV (300 km) • Setup of a 3-phase line of 400 kV (300 km) • Setup of a 3-phase line of 400 kV • Addition of a new post of 400/225 kV • Replacement of a 225/60 kV transformer by a 400/225 kV transformer.

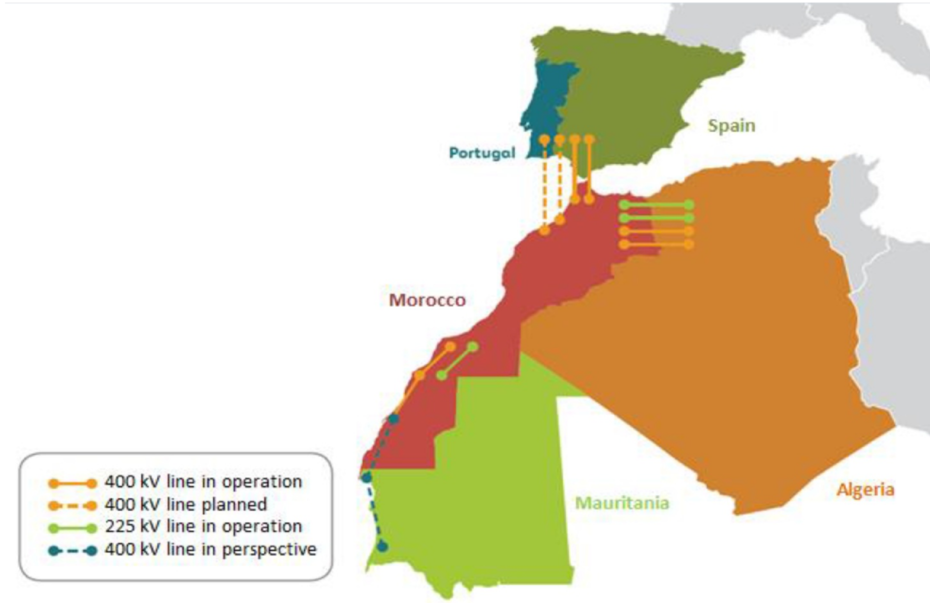

Fig. 7. Regional and international interconnections.

have poor electrical infrastructure that limits their level of penetration into the power grid. Today, the large amounts of electricity from renewable sources and solidarity between territories are the main vectors for the evolution of the power grid and new challenges for transmission system operators. Some regions will essentially be importing and others will be strongly exporting. The mesh and density of the electricity network will be a key point in guaranteeing access to electricity and security of supply from renewable energy sources.

The integration of renewable energies in the Moroccan electricity system also requires the mobilization of flexible modes of production to address their intermittency and improve the stability of the power grid. Today, the introduction of combined cycle power plants operating on natural gas is positioned in Morocco as one of the most appropriate means to meet the challenges of intermittent power generated by renewable energies. Gas is expected to play a major role in the electricity mix and according to [48] in 2011 the gas demand in the MENA countries grew faster than in other regions., since Morocco plans to import 5 billion cubic meters (bcm) of LNG via a new LNG import terminal, which will provide 2,400 MW of new combined cycle gas turbines (CCGTs).Morocco's needs for flexibility will increase and will mainly be provided via decentralized tools (energy storage, erasure, consumption modulation, electric vehicles batteries, decentralized production) requiring the aggregation of a large number of diffuse points; distribution network operators will become real operators, responsible for active network management and the organization of local flexibility markets. The exploitation and optimization of the sources of flexibility (question of global optimization / local optimization) will become an essential issue in Morocco.

3.2. Smart grid in Morocco

The principal challenge for electricity distribution in Morocco is associated to environmental and climatic conditions caused by long land distances, vast forests, severe winter seasons and high number of overhead lines [49]. These problems require advanced automatic solutions for fast defect management and long term grid forecasting. Accordingly, in 2008 the ONEE installed a new more modern and efficient national distribution control centre called "Dispatching". The new system, which has been installed in Casablanca city, manages in real time and under different conditions, between the change in electricity production facilities and a steadily rising of the national demand. Despite the dispatching system, there are still production losses based on future energy forecasts and emergency needs. Another important problem is that most of the electrical energy produced in the grid cannot be stored. Therefore, the smart grid is essential to correlate electricity generation with demand [50]. The development of smart grids is an essential prerequisite for moving from a unidirectional to a bidirectional system, making it possible to act on demand and to adapt consumption in part to instantaneous production capacities. Smart grids are designed to improve control of the electrical system throughout the entire chain of value from the producer to the end consumer. By making a portion of consumption (industrial and domestic) dependent on available production, they make it possible to reduce demand peaks and thus reduce maximum production capacities in a given geographical area. Similarly, it is perfectly possible to program certain equipment (e.g. electric vehicles) to receive energy when there is a given overproduction. The smart grid can reduce transmission and distribution losses by monitoring the capacity to distribute electrical energy efficiently through communication technologies. Digitalisation of network will in some ways be a condition for the success of the energy transition [51]. The deployment of renewable energies is challenging the way in which the supply-demand balance has been achieved in the electricity sector until now.

Flexibility and security of the energy system must rely on the operating capability to allow both generation and usage dispersal and distortion between service quality and continuity [46]. That's why the smart grid remains an essential element to develop in order to meet the ambitious target of 2030.

3.3. Developing interconnections at regional level and with Europe

One of the most practical ways to reduce the intermittency of renewable energy is to interconnect them in order to mitigate the variations in electricity generated from such intermittent sources. For that purpose, Morocco needs to reinforce electricity interconnection infrastructures at the regional level and with the European continent (see Fig. 7). Electricity importations represent the main source of flexibility in Morocco since they play an important role in balancing supply and demand [44].

By exporting green electricity to Europe, considering its proximity to Spain, Morocco has the potential to become an important actor in the export of renewable electricity to a large regional market. In this regard, several EU countries have interestingly implemented a "Roadmap for Sustainable Electricity Trade" (SET Roadmap) and signed an official declaration during the COP22 with Morocco. In this perspective, Morocco has already achieved significant electricity interconnection capacities with Spain (1,400 MW). Currently, the interconnection with Spain is the unique link between Europe and North Africa. Morocco is also interconnected with Algeria, with an exchange capacity of 1,200 MW. The African market is very promising since it is relatively poorly electrified and represents real investment opportunities for future years. Currently, Morocco continues the process of regional integration of energy markets. Firstly, the country has a project to establish an electrical interconnection line to Portugal with a capacity of 1,000 MW. Morocco is also planning to expand the interconnection with Spain by a third line with a capacity of 700 MW. Discussions are under way to establish new interconnection lines with Mauritania.

Thanks to the electricity interconnections with Algeria and Spain, Morocco is positioned as a leading electricity market player in the Western Mediterranean region and fully plays an important role both as a regional energy hub and as a transit country for cross-border electricity exchanges. An ambitious project (Xlinks) is under consideration to develop a new 3 GW submarine cable linking Morocco to the UK, which will allow green electricity to be sent directly to the UK without using existing infrastructure in Spain and France [52]. The project will generate 6% of the UK's electricity demand. Given the important role of interconnections in improving reserves capacity, the development of electricity generation from renewable sources and the increase of RE integration capacity from new interconnection projects are under consideration.

In line with the 2030 objective, Morocco is expected to significantly boost investment in electricity trading and interconnections and to play an important role in the development of the regional electricity market in West Africa and its integration into the European market.

3.4. Reorganisation of the electricity sector

ONEE is currently the major player in Morocco's electricity market; it is the sole purchaser and responsible for power imports and exports and the purchase of electricity generated by independent power producers (IPPs), surplus electricity from self-generators and all renewable electricity production from MASEN projects. [44]. ONEE holds long-term power purchase agreements (PPAs) with these entities. ONEE also owns generation plants, including coal, gas and wind (which will be transferred to MASEN by 2021). ONEE's own generation market share has decreased, with the growth of renewable energy projects developed by MASEN [44].

Otherwise, under Law 38-16, ONEE has to transfer all renewable energy generation assets within five years to MASEN (with the exception of pump storage hydro plants, plants that are critical for the national electricity supply security and plants under Law 13-09). In terms of market shares in 2016, ONEE supplied power to the national market from its own plants (29.2%), and through IPPs (52.9%) and imports (14.6%), with power from private industrial producers accounting for the remainder (3.3%) [44]. The structure of the electricity industry is detailed in the **Fig. 8**.

Two observations can be drawn from the analysis of Fig. 8:

- The National Agency for Electricity Regulation, which was created in 2016, has not yet initiated its principal missions to ensure effective operation of the electricity market and to control the transmission and distribution operators. There is an urgent need to allocate financial and human resources to this agency to ensure its function in the Moroccan electricity market.
- The reorganisation of the ONEE and its business model by separating the activities of the electricity value chain (i.e. generation, transmission, distribution and marketing) is required to ensure a more effective operation of the Moroccan electricity market.

3.5. Energy storage

One of the main drawbacks of using renewable energy sources is the management of their intermittent production. Thus, even if Morocco holds the world record, especially in wind energy, the load factor, i.e. what the installation actually produces in relation to its capacity, is 40% for wind energy projects and falls at best to 20% for photovoltaic projects. For the latter, it is therefore necessary to use electricity storage [12].

Energy storage can render several services to power grids [53]:

- It can be used to address erratic and rapid variations in energy demand and prevent the possible requirement for frequency adjustment from the main power system. It can also resolve temporary power interruptions, minimize harmonic distortions, and prevent voltage drops and bursts.
- It avoids a partially loaded main power system, which is held operational to meet unplanned, unexpected demands and electrical urgencies resulting from the breakdown of generation plants and/or transmission lines.
- It helps to handle the peaks of the daily demand curve.
- It allows excess electricity generated during off-peak hours to be stored to meet increased demand during peak hours.
- It ensures the storage of electricity produced by renewable energies in order to adapt fluctuating supply to shifting demand.

The first large-scale electricity storage project in Morocco is the 460 MW Afourer Pumped Storage Power Station (**PETS**), commissioned in 2004. It consists of a hydraulic system composed of two 1.3 million-m^3 water reservoirs connected by a pipeline with two hydroelectric production units between the basins. The Abdelmoumen WWTP located in Taroudant province will enhance hydraulic storage capacity in Morocco. This station, piloted by the ONEE, has been under construction since July 2019 after the project was awarded to the consortium led by the French company Vinci Construction and including the company Andritz Hydro. The €284 million contract consists of the construction of a WWTP (Waste Water Treatment Plan) with two basins connected by a 3 km transfer line with a 350 MW reversible hydropower plant located in the middle.

It is interesting to mention that the Noor 1 power plant is equipped with a 3 hours thermal storage system. For Noor 2 and 3 plants, the thermal storage time is up to 8 hours. This will guarantee continuity of energy distribution, even in the evening, at times of peak consumption [54]. CSP thermal storage was also chosen to ensure 5 hours of autonomy for the first phase of the 800 MW Noor Midelt station in hybrid technology: CSP and PV. A 2nd phase, currently being prequalified by MASEN, is competing between different solar technologies with storage, in particular PV and CSP associated with different thermal storage or battery technologies, with the aim of ensuring a stable power injected into the grid up to 230 MW.

Energy Storage Technologies (EST) can be classified in to [55]:

- Mechanical storage systems [56] like Pumped Hydro-Storage (PHS), Compressed Air Energy Storage (CAES) and Flywheel Energy Storage (FES) technologies.
- Electrochemical storage systems [57] like batteries (Lead acid, NiCd/NiMH, Li-ion, metal air, sodium sulphur and sodium nickel chloride) and flow batteries (Redox flow battery (RFB) and Hybrid flow battery (HFB)).
- Electrical storage systems [53] like Supercapacitors (SC) and Superconducting Magnet energy storage (SMES) systems.
- Chemical energy storage [58], which emphasizes hydrogen (H_2) and synthetic natural gas (SNG) as secondary energy, vectors, as they could have a considerable impact on the storage of large quantities

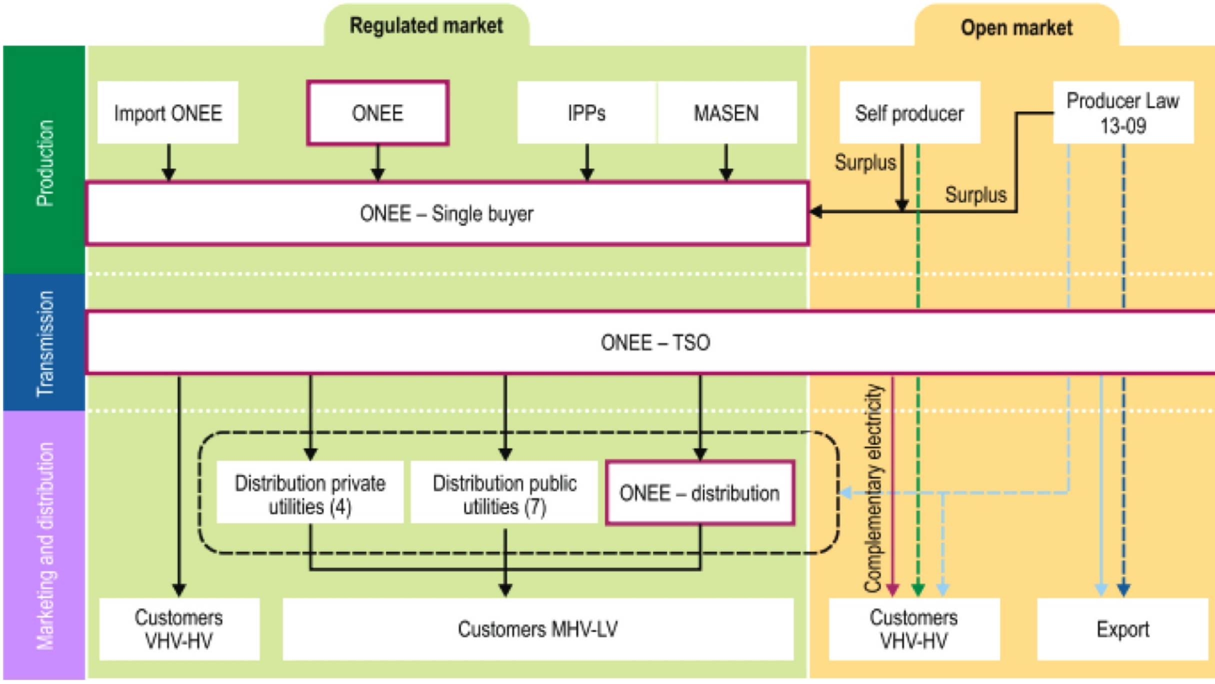

Fig. 8. Structure of the electricity industry [39].

of electrical energy.
- Thermal Storage Systems (TSS) [59], which includes sensible, latent and thermochemical storage technologies. Thermal sensible storage is the most mature technology but has the lowest energy density, which is followed by the latent storage and then by thermochemical storage. Thermal storage can provide important services to Moroccan power system and increase the flexibility of the network. Many thermal storage options can be developed in Morocco such as the storage of excess renewable electrical energy in buildings (e.g. domestic hot water tank). The development of district heating networks in Morocco can also give a growing role to the massive thermal storage in Morocco [60].

The principle of the above technologies has been presented in detail in various articles [56,61]. Power density and energy density are two main characteristics of energy storages technologies [62]. The higher the power and energy density, the lower the required volume for the storage system. So, EST can be classified according to discharge time [56,57,62]:

- Short discharge time (seconds to minutes): SMES and FES. The energy-to-power ratio is less than one.
- Medium discharge time (minutes to hours): FES and for large capacities, electrochemical storage systems, which is the dominant technology: lead acid, Li-ion and sodium sulphur batteries.
- Long discharge time (days to months): H_2 and SNG. For these EST, the energy-to-power ratio is greater than 10. The main advantage of H_2 and SNG is the high energy density, superior to all other storage systems.

PHS, CAES flow batteries systems are situated between storage systems for medium and long discharge times [53,58]. Like H_2 and SNG systems, these EST have external storage tanks. However, the energy densities are rather low, which limits the energy-to-power ratio to values between approximately 5 and 30.

Among all existing technologies, whether commercially available or under development, there is no technology that can achieve both power and energy density at the same time. In this context, the hybridization of high-energy systems in combination with high power systems appears to be more efficient EST [63]. High power storage systems produce energy at very high rates, but typically for short time periods. Conversely, high-energy storage systems can generate energy for longer periods [63,64]. To ensure its place in an electrical system, the hybrid energy storage system must not only demonstrate its technical relevance but also prove its economic viability. The most appropriate energy storage technology for a given storage situation should be chosen according to needs, available space and financial resource.

Actually, no legislative or regulatory framework exclusively dedicated to the regulation of energy storage exists in Morocco. However, the electricity storage legislation is expected to change in order to address the evolutions and challenges presented by the recent dynamic of energy transition in Morocco. To ensure a sustainable energy strategy in Morocco, the implementation of energy storage solutions adapted to the Moroccan context is essential. As well as developing mature solutions such as **PETSs** and CSP storage [65]**,** it is time to achieve benchmarks with new technologies such as lithium batteries and storage via hydrogen [66] as part of the ambitious Power-To-X techniques in the R&D phase.

The promulgation of a legislation to regulate energy storage is necessary to initiate the development of new large-scale storage projects. In addition, it is recommended to integrate tax incentives to encourage entrepreneurship in the field of energy storage with a view to opening, through Smart Grids, the national electricity grid to the surplus injections of industrial and private owners.

3.6. *Power to X in Morocco*

"Power-to-X" is a way of storing electrical energy for greater flexibility. The excess of the available energy can be stored in other forms: chemical or industrial products, etc. The first step of the PtX pathway consists in using low-carbon electricity and water to produce hydrogen by means of water electrolysis: the power-to-hydrogen (PtH) segment. Hydrogen can be used immediately (e.g. as a fuel for mobility or as feedstock in industry), or used in further synthesis steps with carbon, nitrogen or oxygen to produce chemical compounds such as methane, ammonia or gasoline that replace fossil fuels [50]. Fig. 9 shows the

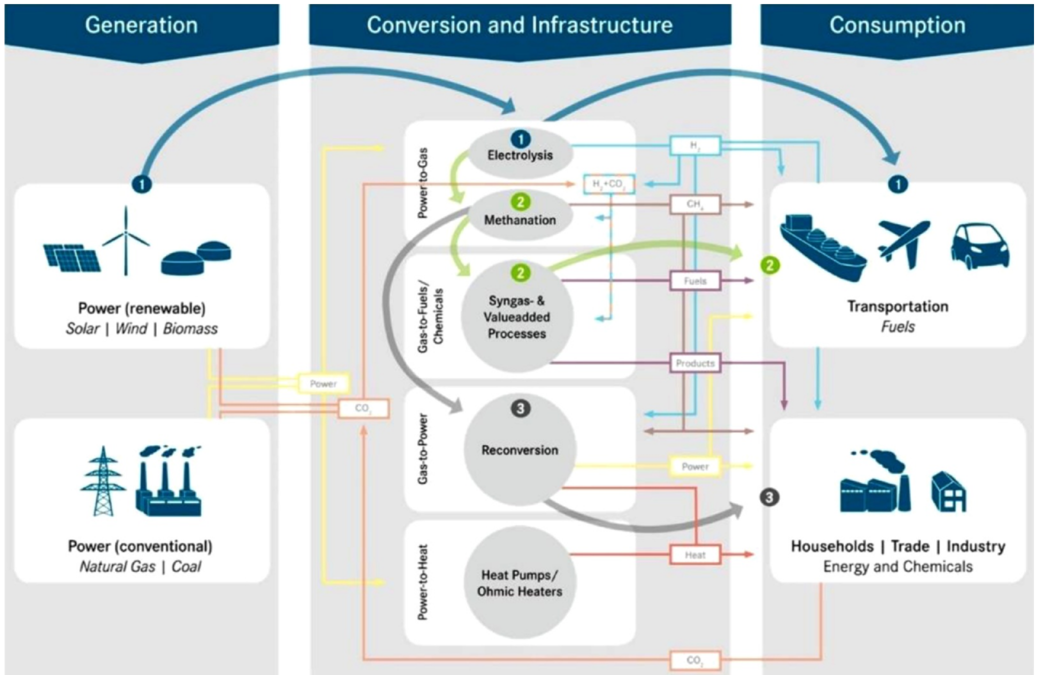

Fig. 9. Power-to-X applications [67].

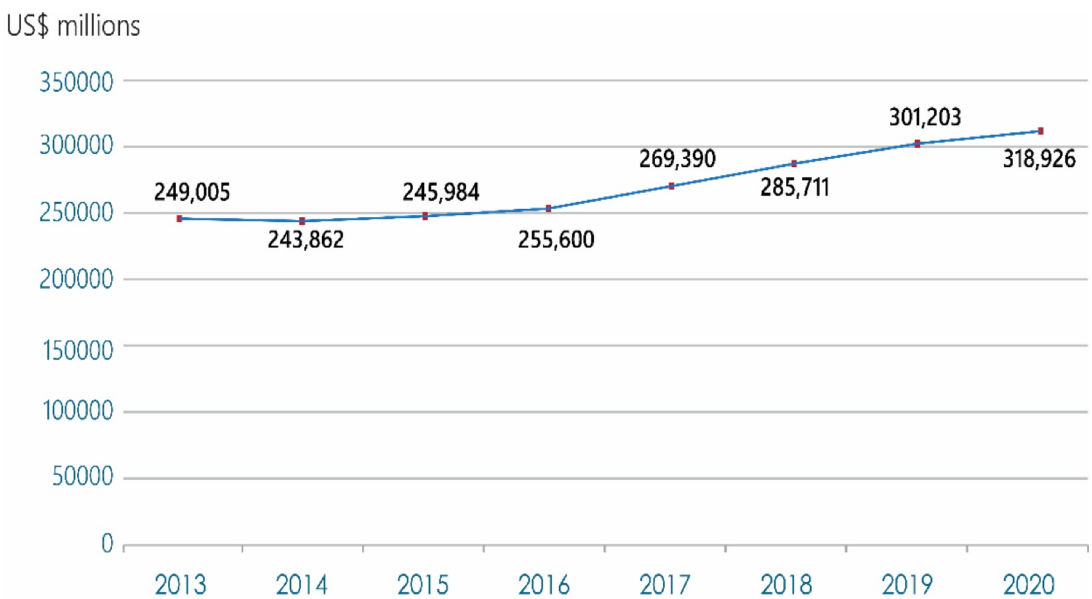

Fig. 10. Evolution of water desalination Market between 2013 and 2020.

power to X applications [67].

With its geographical position and outstanding wind and solar capacity, Moroccan government is able to achieve a valuable share of the 'Power-to-X' market expected to be between 2% and 4% of global production in 2030[68]. Otherwise, economic assessment of hydrogen production potential from solar energy in Morocco is detailed in [69].

According to a study carried out by the World Energy Council Germany, Morocco is among the countries with a high potential in terms of Power to X. Power to X requires an energy mix that allows plants to run for as long as possible during the 24 hours. Solar energy can cover about 30% of the need. If we add the contribution of wind power, we can reach 50%. This means that up to 70–80% can even be achieved if storage is used. The other goal is to reach a balance between the cost of hydrogen or fossil-fuel ammonia production and the cost of the photovoltaic and wind energy output of these technologies. In this sense, "green ammonia" will provide Morocco with opportunities to fulfil the long-term demands of its local fertilizer industry and foreign market [68].

Morocco will therefore draw up a roadmap for hydrogen and PtX products, a roadmap for hydrogen technology and related PtX products for Morocco, and establish sustainability requirements as part of the hydrogen / PtX roadmap. Otherwise, several exporting industries are facing a critical situation due to the implication of the carbon tax on the products exported by most European countries. For this reason, the Moroccan industry must promptly respond to the new requirements and constraints of the European market in which the power to X represents one of the best potential solutions to promote the national economy.

3.7. Water desalination

Freshwater is a crucial factor in regional economic development. Domestic users, agriculture and industry require large quantities of freshwater. Meeting current and future demands for freshwater has become a serious challenge in many countries of the world [70,71]. However, seawater and sometimes brackish water desalination constitute an important option as a very safe water source comparatively to conventional water supply. Nevertheless, the world desalination market has experienced rapid expansion since the beginning of the 2000s, with growth in contracted capacity increasing by an average of 8.1% per year [72]. **Fig. 10** shows the evolution of water desalination market between 2013 and 2020 [73]. The current technologies of water desalination are classified into two categories, according to the principle applied [74,75]:

- Thermal processes involving a change of phases: freezing and distillation.
- Processes using membranes: reverse osmosis and electro dialysis.

Among the above methods, distillation and reverse osmosis are technologies with proven efficiency in desalining seawater. Indeed, these two processes are the most commercialized in the world desalination market. The other techniques have not experienced a significant development in the field due to problems generally related to energy consumption and/or the size of the investments they require. **Fig. 11** shows awarded membrane and thermal desalination capacity between 1990 and 2014 [73].

Regardless of the salt-water separation process envisaged, all desalination plants consist of four stages:

- Seawater intake with a pump and coarse filtration,
- Pretreatment with finer filtration, addition of biocidal compounds and anti-pattern products,
- The desalination process itself,
- Post-treatment with possible remineralization of produced water.

At the end of these four stages, the sea water is made potable or industrially usable; it must then contain less than 0.5 g of salts per liter [76]. However, energy consumption accounts for about 41% of the total costs of a reverse osmosis desalination plant [77]. **Table 8** represents a comparative study of the energy consumption of the different desalination technologies [78]. Otherwise, to minimize energy consumption, more studies have been conducted [79,80].

Several studies indicate that the combination of desalination technologies and renewable sources is among the most promising approaches for the development of the sector [70]. During the drought periods in the last three decades, Morocco is facing a real issue in water supply, due to the water demand increasing and because of the climate changes [72,73]. The first desalination plants in Morocco were installed in 1975 to address the shortage of potable water in the southern regions, and all subsequent schemes contribute to water supplies in southern Moroccan areas that shortage fresh water and have insufficient brackish water availability [81]. Agadir's seawater desalination plant is the Africa's largest desalination station with a capacity of 275,000 m^3 per day, expandable to 450,000 m^3 a day. In addition, to reduce production costs, the station will be coupled to a wind power plant. **Table 9** shows more details about water desalination plants in Morocco [81].

Since desalination is such an energy-intensive operation, its economic feasibility is directly affected by the resources needed to generate fresh water [82]. That's why the interest in renewable energy – driven desalination systems have been growing very rapidly, the number of developed plants is still limited, and the applications are primarily in early stages of development [83].

With a huge capacity of renewable energy sources and with the 2020 and 2030 goals, the use of the energy surplus coming from renewable sources or the alimentation of the desalination plants by renewable energy sources represent one of the most pioneer's solution to reduce the production cost in the desalination plants. Moreover, more studies had been contacted by many research shows how Morocco could use its high potential of renewable energy sources coupled with the desalination plants [77,84].

In Morocco, the seawater desalination market seems promised to continue to grow in the coming years. However, the current technologies can only meet certain targeted needs concentrated in a few regions. The high costs of these plants limit their dissemination throughout the country, which suffers from fresh water shortages for economic reasons and whose hydraulic infrastructures are generally deficient.

The energy consumption of desalination plants coupled with environmental uncertainties implies imperative technological evolutions in order to support the development of this sector. Cooperation between project developers and energy specialists makes it possible to envisage the large-scale development of photovoltaic and wind-powered structures.

In the absence of an efficient distribution network and sufficient financing capacities, decentralized desalination systems are more relevant than large-capacity plants to fulfil Morocco's demands. Moreover, small-scale infrastructure would make it possible to reduce the amount of investment required and reach isolated populations

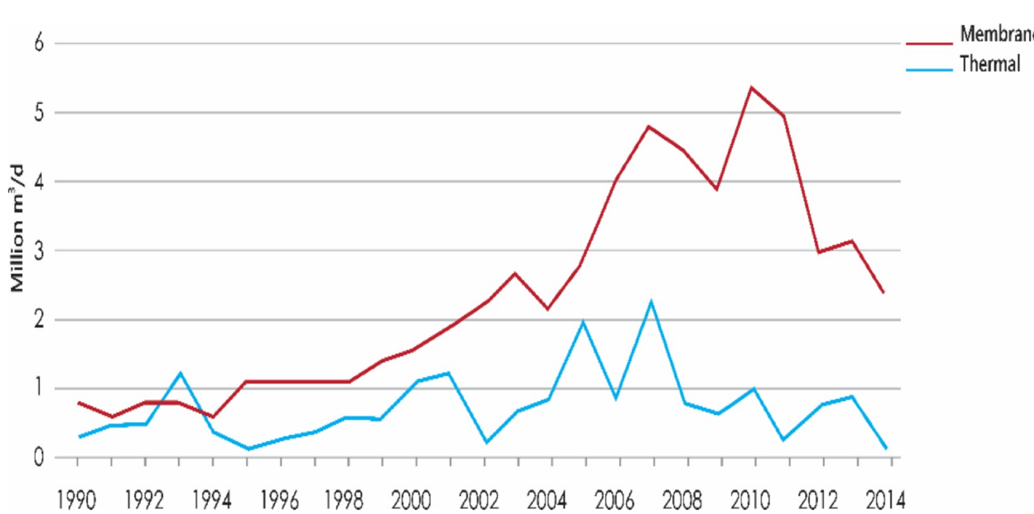

Fig. 11. Awarded membrane and thermal desalination capacity, 1990–2014 [73].

Table 8
Comparative analysis of the energy consumption of the different desalination technologies.

Desalination type	Desalination technology	Average Energy Consumption (kWh/m^3)
Desalting by thermal installation	Multi-stage flash (MSF)	23.45
	Multi-effect distillation (MED)	17.95
	Mechanical vapor compression (MVC)	9.5
	Thermo-vapor compression (TVC)	16.3
Membrane desalting	Reverse Osmose (RO)	3
	Electro dialyses (ED)	4.15

Table 9
Water desalination projects in Morocco.

Location	Technology	Capacity m^3/d	Year
Trafaya	ED	75	1975
Boujdour	MED-VC	250	1977
Trafaya	BWRO	120	1983
Laayoun	SWRO	7 000	1995
Boujdour	SWRO	800	1995
Agadir	RO	275 000	2021

while reducing the energy consumption of the devices by exploiting the great potential of renewable energy in Morocco.

3.8. Encouraging the adoption of electric vehicles

3.8.1. Electric mobility in Morocco

With over 5 million vehicles, transport sector is the pillar of Moroccan economy accounts for 6% of GDP and employs 10% of the urban active population. Morocco has a road network of about 60,000 km of roads, 1,000 km of expressways and 1,800 km of motorways [85]. However, transport is the second polluting sector in Morocco and a major source of gas emissions; it is responsible for 15% of total emissions of the kingdom. The major problem is that the transport sector absorbs 35% of national energy consumption including 50% of petroleum products [86]. For these reasons and because of the transport remains an essential link in the development of the country's economy, the interest in electric vehicles has increased in recent years in Morocco. Many automobile manufacturers have installed in the kingdom at this point developed and commercialized their first modern electric models, proving that the electric drive is technically viable, environmentally friendly and affordable and it's a better solution in order to improve Moroccan economy. As well as the renewal of the state's vehicle fleet with electric and hybrid vehicles are one of the first measures that the government intends to put in place as part of the kingdom's 2030 sustainable development strategy. Clean cars should make up 30% of the fleet by 2021 [87]. Meanwhile, the deployment of a strong charging infrastructure is the backbone of the electric vehicle adoption. Through IRESEN, Morocco has started some initiatives to encourage the development of electric mobility. The example is the Green miles project that focuses on the installation of 74 charging points to cover more than 600 km highway. Furthermore, the implementation of 2 charging units coupled to photovoltaic panels in Rabat City [88]. Fig. 12 and Fig. 13 represent respectively the evolution of charging pools number in Morocco between the last trimester of 2018 and the second trimester of 2020 and the distribution of plugs by charging speed [89].

3.8.2. Electric mobility and renewable energies

Transport always goes with energy, and the major question is where the energy needed comes from? Otherwise, given the impact of transport on the consumption of fossil fuels and greenhouse gas emissions, the implementation of a policy allowing the development of electro mobility in Morocco represented an important fraction of the renewable energy objectives. In this context a socio-economic study of electric vehicles in Morocco was conducted by [90], it shows the reasons influencing the Moroccan choices of transportation modes, in particular, those taken according to electric vehicles technologies. It also explores potential options for incorporating this green transport style into the Moroccan context, while respecting their preferences and limitations. In several studies, rechargeable electric vehicles are used in combination with renewable energies at different levels of the electrical system [91–93].

The integration rate of electric vehicles in 2018 was estimated at 0.02% [94]. A literature review and prospects for sustainability about adoption of electric vehicles are detailed in [95]. Otherwise, [96] describes the challenges and assessment of electric vehicles integration, with a comprehensive analysis of political, economic, social, technical, legislative and environmental aspects and rigorously assesses achievability of the EV integration. Thus, electric mobility contributes to the independence of imported fossil energies, constitutes a lever for the integration of RE in the energy mix because partial electrification of transport encourages the installation of (decentralized) renewable energy production units, storage (V2G: vehicle to grid) and the valorization of surpluses for the production of hydrogen [97,98].

3.8.3. Barriers Matrix of Electric Vehicles Adoption in Morocco

Based on an in-deep analysis of the current electric mobility situation and on data collected from electric mobility actors in Morocco, barriers of electric vehicles adoption are categorized on three major elements. **Table 10** presents the matrix of these barriers.

3.8.4. Recommandations

Morocco expects a real growth in electric-vehicle sales in coming years. However, the market is currently in a period of transition, as companies and cities scale up to meet the demands. The demand for electric vehicles comes with a few factors that require collaboration between cities and car owners. Research agencies, vehicles manufacturers and operating entities are encouraged to maximize electric vehicles adoption based on local conditions, and to develop responsibilities for implementation. **Fig. 14** shows the four key elements for a successful transformation for EV adoption acceleration in Morocco.

A voluntarist policy of the government, through concrete actions and subsidies aimed to encourage consumers to buy green vehicles at competitive prices, are the main acts allowing the development of electric mobility in Morocco. Finally, it is necessary to ensure the compatibility of charging, communication, and billing and payment systems and to adapt them to the Moroccan context.

3.9. Energy efficiency

According to the national energy strategy adopted at the end of 2008, energy efficiency is considered a key element of economic and social progress [99]. In this context, a number of measures to save energy and control energy consumption in various sectors (industry, buildings, agriculture, public lighting and transport) have been adopted in Morocco.

To support energy efficiency programmes, Law 47-09 on energy efficiency was published in 2011 [100]. It focuses on energy audits, energy impact studies, energy performance in several sectors,

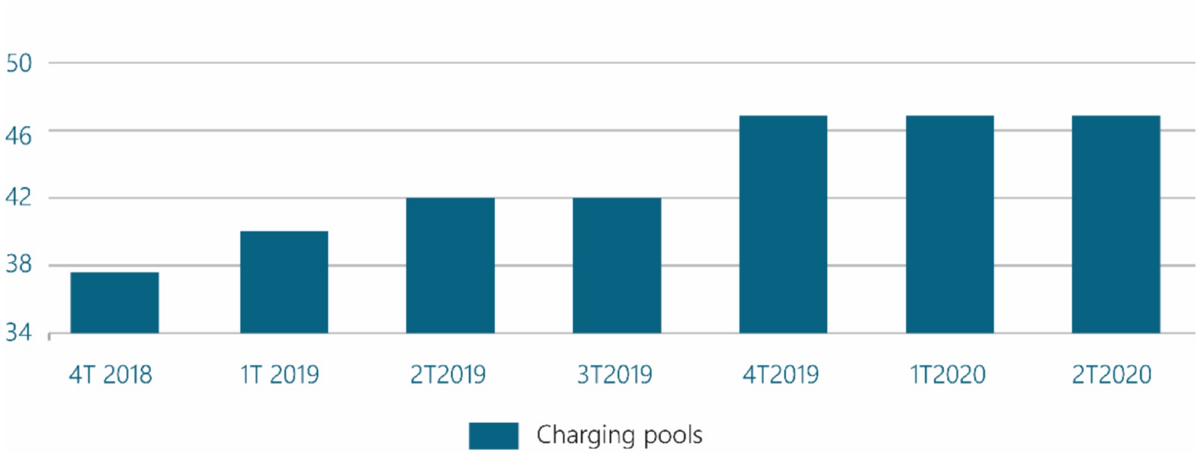

Fig. 12. The charging pools evolution in Morocco.

rationalisation of the energy used by public establishments and local authorities, the creation of the status of energy service companies and the introduction of technical controls for audits by accredited companies. The new thermal building regulation, which defines energy performance rules in Buildings, was drafted in 2014. In 2019, the energy audit of industries is mandated.

The goals for energy efficiency, which have been adjusted from 2009′s initial ambition, are now 5% by 2020 (compared to 12% initially) and 20% by 2030 [99,101]. This delay in implementing the energy efficiency objectives is due to the positioning of the AMEE (Moroccan Agency for Energy Efficiency), its organisation and the lack of human and financial resources needed to carry out this important project. Current analysis of Morocco's energy sector reveals that there is significant potential for additional energy savings in the country [99].

We consider that the success of the energy transition policy in Morocco can only be achieved through local authorities (Region, Municipalities and Communes), which are in the first line to apply and adapt the national objectives in terms of energy efficiency to the local context. Local and regional authorities should be committed to a process of achieving a balance between energy consumption and production at local level by reducing energy needs as far as possible and respecting the national energy system's equilibrium. In their policies, they must promote energy efficiency, the reduction of greenhouse gas emissions, the reduction of fossil fuel consumption and the deployment of renewable energies.

Different instruments can be implemented locally in each region to achieve the 2030 energy efficiency targets and accelerate the transition to a more energy-efficient society:

- Assess the potential of energy savings, renewable energy and heat recovery in each region [102]. Waste heat recovery can lead to two complementary heat valorisation processes [103]:
  - Internal valorization, to meet the heat needs in the company;
  - External valorization, to meet the heat needs of other companies or, more generally, of a region, via a district heating network. In addition to thermal recovery, the heat can also be transformed into electricity, for internal or external use.
- Reducing energy consumption: in particular, by improving the thermal isolation of public buildings, switching off public lighting after a certain period, promoting car sharing as well as clean and collective transport, mutualising facilities, encouraging local product, etc.
- Development of renewable energies: for example, through a regional programme for the installation of photovoltaic panels on public

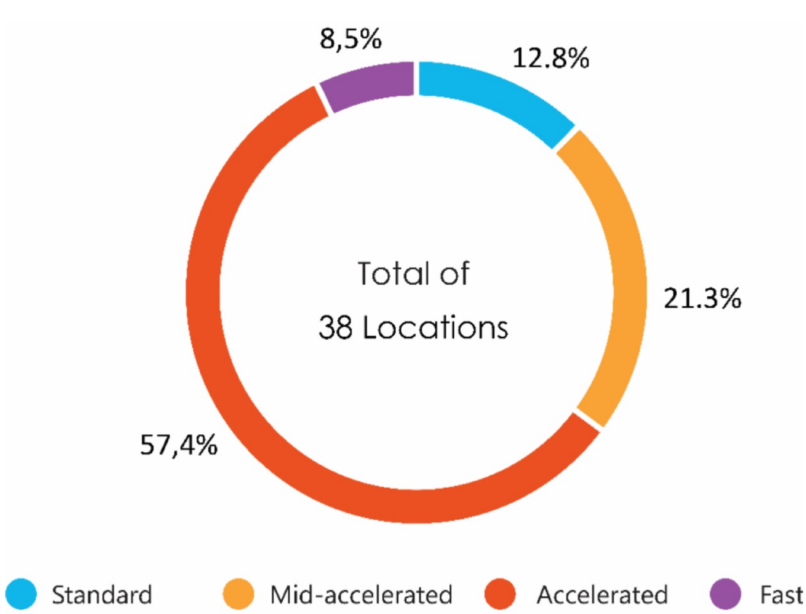

Fig. 13. Ddistribution of plugs by charging speed.

Table 10
Barriers matrix.

	Vehicles	Agencies and operators	Grid and charging infrastructures
Institutional	• Difficulties for manufacturers in engaging with cities and e-mobility actors • Targeted policies toward sustainable urban transport are still quite limited	• Negative public perception • Weak governmental coordination • Not enough policies supporting the adoption of electric vehicles	• Limited planning for long-term implications • Lack of law of energy integration in Law voltage
Financial	• Lack of financing options • High upfront capital costs of electric vehicles	• Scaling investment past initial pilot programs • Strong financial management and business models	• Large capital expenses for grid infrastructure
Technological	• Range and power limitation of electric vehicles • Disjointed or limited electric vehicles marketplace • Lack of information on advantages and disadvantages of electric vehicles.	• Lack of information on how to start • Lack of operational data	• Limitations of the charging stations • Grid instability • Lack of standards and regulations on charging infrastructures • Lack of understanding of the requirements to upgrade infrastructure

buildings, the implementation of district heating networks integrating renewable energies in new urban areas, etc....

- Implement a thermal renovation program for existing residential buildings, and integrate the issue of environmental quality into this program.
- Development of Eco-neighbourhoods.
- Environmental education: by promoting awareness in schools, encouraging information for residents...

Other measures are needed at the national level to ensure that energy efficiency can fully contribute to the energy transition in Morocco:

- ■ Establishment of a national energy efficiency fund.
- ■ Implement norms and financial mechanisms to support energy efficiency policies.
- ■ Reinforcing the expertise, the human and the financial resources of the AMEE.
- ■ Creation of an AMEE office at the level of each region. The covid 19 sanitary crisis that recently affected the entire world has clearly revealed the necessity to develop locally an economic, energy and social policy in relation to the specificities of each region.
- ■ A legislative framework to regulate and control the conformity in terms of quality and safety must govern renewable energy equipments introduced in the national market.
- ■ National competence and expertise must also be created to develop testing laboratories to facilitate the study and certification of energy equipments and regional construction materials.

3.10. Innovation and Energy R&D

Morocco has outstanding RE prospects, including solar, wind and biomass technologies. Such technologies have different needs in terms of support for research and development, demonstration and market development [104]. Moreover, innovation remains an important link for a wide integration of these technologies [105]. The energy research, development and innovation policies remain mandatory to enhance the Morocco's ambitious energy policy priorities, boosting the use of renewable energy technology, and helping to develop a local manufacturing industry.

MASEN and IRESEN are responsible for implementing R&D projects and identify strategic topics to guide the R&D and create a real and concrete research map. IRESEN is a network of applied research platforms at the service of researchers and innovation actors. Based on the implementation of current projects, IRESEN will have to assess the progress, priorities and organization of R&D governance in order to ensure the success of Morocco's energy transition for 2030.

Continued support is needed for universities and educational centres to ensure that students, scientists and operators are informed and trained in RE technologies. To this end, it is recommended that research, education and training in RE be included in the legislative framework and educational policies. In addition, it becomes necessary to strengthen the coordination of energy technologies and R&D between different agencies, universities and government in order to avoid duplication of activities and to develop stronger synergies between industry and universities.

4. Conclusion

Morocco has made the transition to renewable energy a high priority since the 2009 national energy strategy. After 2020, the Moroccan government has set an ambitious long-term target for renewable energy by reaching 52% of total installed capacity by 2030, by taking advantage of the country's high potential conditions for wind and solar power in addition to the contributions of hydropower, thus demonstrating a clear long-term commitment. However, Morocco must implement several measures and strategies in order to achieve the ambitious target of 2030. Among these measures: the modernization of the electricity network with the introduction of intelligent metering and analysis systems, the development of regional and international interconnections and the promotion of energy storage.

Otherwise, the kingdom must complete the regulatory framework for open and transparent access to low-voltage grid, including through harmonized permitting, and tariff structures. It is urgent for policymakers to explore possibilities for developing the "power to x" concept

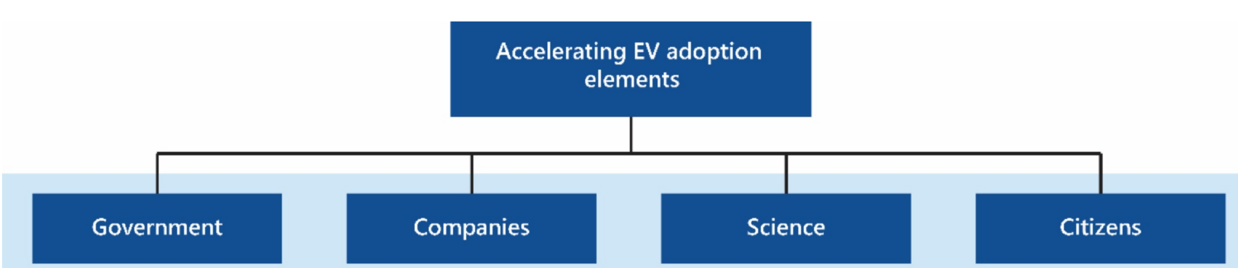

Fig. 14. Key elements for a successful transformation for EV adoption acceleration in Morocco.

in industry and the feasibility of exporting it into Europe. Moreover, it is necessary to promote electric mobility start-ups including operators from all fields: very light, light and heavy rolling stock, infrastructures, business models for sharing and recharging, batteries and their recycling. It is also essential to promote local research to adapt international experience to local needs in terms of recharging systems and use; stimulate local production of electrical vehicles components.

Meanwhile, research and innovation, in relation to all REs applications must be encouraged, strengthen the coordination of energy R&D programs across government, universities and agencies, and boost the Kingdom energy innovation ecosystem by developing synergies between business and universities.

CRediT authorship contribution statement

M. Boulakhbar: Investigation, Writing - original draft. **B. Lebrouhi:** Formal analysis, Investigation, Writing - original draft, Methodology. **T. Kousksou:** Supervision, Project administration, Methodology. **S. Smouh:** Writing - review & editing, Formal analysis. **A. Jamil:** Writing - review & editing, Formal analysis. **M. Maaroufi:** Writing - review & editing, Formal analysis. **M. Zazi:** Writing - review & editing, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors acknowledge funding provided by the research institute for solar energy and new energies (IRESEN).

References

[1] J. Sarkis, M. Tamarkin, Real options analysis for renewable energy technologies in a GHG emissions trading environment, Emiss. Trading Institutional Des. Decis. Mak. Corp. Strateg., Springer, New York, 2008, pp. 103–119, https://doi.org/10.1007/978-0-387-73653-2_7.
[2] R. Habachi, A. Touil, A. Charkaoui, E. Abdelwahed, Management and Control of Smart Grid Systems: Opportunities and Challenges in Morocco, 3 (2017) 6–14.
[3] O. Ellabban, H. Abu-Rub, F. Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, Renew. Sustain. Energy Rev. 39 (2014) 748–764, https://doi.org/10.1016/j.rser.2014.07.113.
[4] A. Gasparatos, C.N.H. Doll, M. Esteban, A. Ahmed, T.A. Olang, Renewable energy and biodiversity: Implications for transitioning to a Green Economy, Renew. Sustain. Energy Rev. 70 (2017) 161–184, https://doi.org/10.1016/j.rser.2016.08.030.
[5] G. Papaefthymiou, K. Dragoon, Towards 100% renewable energy systems: Uncapping power system flexibility, Energy Policy 92 (2016) 69–82, https://doi.org/10.1016/j.enpol.2016.01.025.
[6] M. Child, C. Kemfert, D. Bogdanov, C. Breyer, Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe, Renew. Energy. 139 (2019) 80–101, https://doi.org/10.1016/j.renene.2019.02.077.
[7] A.J. Chapman, K. Itaoka, Energy transition to a future low-carbon energy society in Japan's liberalizing electricity market: Precedents, policies and factors of successful transition, Renew. Sustain. Energy Rev. 81 (2018) 2019–2027, https://doi.org/10.1016/j.rser.2017.06.011.
[8] N. Vidadili, E. Suleymanov, C. Bulut, C. Mahmudlu, Transition to renewable energy and sustainable energy development in Azerbaijan, Renew. Sustain. Energy Rev. 80 (2017) 1153–1161, https://doi.org/10.1016/j.rser.2017.05.168.
[9] A. Ghezloun, A. Saidane, N. Oucher, Energy policy in the context of sustainable development: Case of Morocco and Algeria, in: Energy Procedia, Elsevier Ltd (2014) 536–543, https://doi.org/10.1016/j.egypro.2014.06.065.
[10] A. Šimelytė, Promotion of renewable energy in morocco, 2019. 10.1016/B978-0-12-817688-7.00013-6.
[11] S. Moore, Evaluating the energy security of electricity interdependence: Perspectives from Morocco, Energy Res. Soc. Sci. 24 (2017) 21–29, https://doi.org/10.1016/j.erss.2016.12.008.
[12] S. Griffiths, A review and assessment of energy policy in the Middle East and North Africa region, Energy Policy 102 (2017) 249–269, https://doi.org/10.1016/j.enpol.2016.12.023.
[13] 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, Renew. Sustain. Energy Rev. 47 (2015) 46–57, https://doi.org/10.1016/j.rser.2015.02.056.
[14] 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, https://doi.org/10.1016/j.energy.2015.02.048.
[15] N. Belakhdar, M. Kharbach, M.E. Afilal, The renewable energy plan in Morocco, a Divisia index approach, Energy Strateg. Rev. 4 (2014) 11–15, https://doi.org/10.1016/j.esr.2014.06.001.
[16] S. Moore, Evaluating the energy security of electricity interdependence: Perspectives from Morocco, Energy Res. Soc. Sci. 24 (2017) 21–29, https://doi.org/10.1016/j.erss.2016.12.008.
[17] 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, https://doi.org/10.1016/j.energy.2015.02.048.
[18] A. Bennouna, C. El Hebil, Energy needs for Morocco 2030, as obtained from GDP-energy and GDP-energy intensity correlations, Energy Policy 88 (2016) 45–55, https://doi.org/10.1016/j.enpol.2015.10.003.
[19] A. Allouhi, M. Benzakour Amine, T. Kousksou, A. Jamil, K. Lahrech, Yearly performance of low-enthalpy parabolic trough collectors in MENA region according to different sun-tracking strategies, Appl. Therm. Eng. 128 (2018) 1404–1419, https://doi.org/10.1016/j.applthermaleng.2017.09.099.
[20] T. Bouhal, Y. Agrouaz, T. Kousksou, A. Allouhi, T. El Rhafiki, A. Jamil, M. Bakkas, Technical feasibility of a sustainable Concentrated Solar Power in Morocco through an energy analysis, Renew. Sustain. Energy Rev. 81 (2018) 1087–1095, https://doi.org/10.1016/j.rser.2017.08.056.
[21] R. Cantoni, K. Rignall, Kingdom of the Sun: a critical, multiscalar analysis of Morocco's solar energy strategy, Energy Res. Soc. Sci. 51 (2019) 20–31, https://doi.org/10.1016/j.erss.2018.12.012.
[22] L. Bartolucci, S. Cordiner, V. Mulone, V. Rocco, J.L. Rossi, Hybrid renewable energy systems for renewable integration in microgrids: Influence of sizing on performance, Energy 152 (2018) 744–758, https://doi.org/10.1016/j.energy.2018.03.165.
[23] M. McPherson, S. Tahseen, Deploying storage assets to facilitate variable renewable energy integration: The impacts of grid flexibility, renewable penetration, and market structure, Energy 145 (2018) 856–870, https://doi.org/10.1016/j.energy.2018.01.002.
[24] K. Choukri, A. Naddami, S. Hayani, Renewable energy in emergent countries: lessons from energy transition in Morocco, Energy. Sustain. Soc. 7 (2017) 1–11, https://doi.org/10.1186/s13705-017-0131-2.
[25] A.E. Forum, Moroccan Energy Outlook : Achievements and opportunities, (2018).
[26] A. Ameur, A. Berrada, K. Loudiyi, M. Aggour, Analysis of renewable energy integration into the transmission network, Electr. J. 32 (2019) 106676, , https://doi.org/10.1016/j.tej.2019.106676.
[27] I. García, A. Leidreiter, Feuille de route pour un Maroc 100 % énergie renouvelable, (2016).
[28] O.N. Mensour, B. El Ghazzani, B. Hlimi, A. Ihlal, A geographical information system-based multi-criteria method for the evaluation of solar farms locations: A case study in Souss-Massa area, southern Morocco, Energy 182 (2019) 900–919, https://doi.org/10.1016/j.energy.2019.06.063.
[29] E. Meza, IRENA: PV prices have declined 80% since 2008 – pv magazine International, PV Mag (2014), https://www.pv-magazine.com/2014/09/11/irena-pv-prices-have-declined-80-since-2008_100016383/ (accessed July 28, 2020).
[30] M.T. Islam, N. Huda, A.B. Abdullah, R. Saidur, A comprehensive review of state-of-the-art concentrating solar power (CSP) technologies: Current status and research trends, Renew. Sustain. Energy Rev. 91 (2018) 987–1018, https://doi.org/10.1016/j.rser.2018.04.097.
[31] J. Lilliestam, T. Barradi, N. Caldés, M. Gomez, S. Hanger, J. Kern, N. Komendantova, M. Mehos, W.M. Hong, Z. Wang, A. Patt, Policies to keep and expand the option of concentrating solar power for dispatchable renewable electricity, Energy Policy 116 (2018) 193–197, https://doi.org/10.1016/j.enpol.2018.02.014.
[32] E. Du, N. Zhang, B.M. Hodge, C. Kang, B. Kroposki, Q. Xia, Economic justification of concentrating solar power in high renewable energy penetrated power systems, Appl. Energy. 222 (2018) 649–661, https://doi.org/10.1016/j.apenergy.2018.03.161.
[33] F. Trieb, C. Schillings, M. O'Sullivan, T. Pregger, C. Hoyer-Klick, Global Potential of Concentrating Solar Power, SolarPaces Conf. Berlin, 2009, pp. 1–11 http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/reaccess/DNI-Atlas-SP-Berlin_20090915-04-Final-Colour.pdf%5Cnpapers2://publication/uuid/C95C09CC-EE2A-4FB4-A390-D9BA6002CEB9.
[34] B. Belgasim, Y. Aldali, M.J.R. Abdunnabi, G. Hashem, K. Hossin, The potential of concentrating solar power (CSP) for electricity generation in Libya, Renew. Sustain. Energy Rev. 90 (2018) 1–15, https://doi.org/10.1016/j.rser.2018.03.045.
[35] M.S. Ben Fares, S. Abderafi, Water consumption analysis of Moroccan concentrating solar power station, Sol. Energy. 172 (2018) 146–151, https://doi.org/10.1016/j.solener.2018.06.003.
[36] Z. Aqachmar, A. Allouhi, A. Jamil, B. Gagouch, T. Kousksou, Parabolic trough solar thermal power plant Noor I in Morocco, Energy 178 (2019) 572–584, https://doi.org/10.1016/j.energy.2019.04.160.
[37] S. Kuravi, J. Trahan, D.Y. Goswami, M.M. Rahman, E.K. Stefanakos, Thermal energy storage technologies and systems for concentrating solar power plants, Prog. Energy Combust. Sci. 39 (2013) 285–319, https://doi.org/10.1016/j.pecs.2013.02.001.

[38] A. Allouhi, O. Zamzoum, M.R. Islam, R. Saidur, T. Kousksou, A. Jamil, A. Derouich, Evaluation of wind energy potential in Morocco's coastal regions, Renew. Sustain. Energy Rev. 72 (2017) 311–324, https://doi.org/10.1016/j.rser.2017.01.047.
[39] International Energy Agency, ENERGY POLICIES BEYOND IEA COUNTRIES - Morocco 2019, 2019.
[40] Tarfaya: Nareva Holding réalise le plus grand parc éolien en Afrique | www.le360.ma, (n.d.). https://fr.le360.ma/economie/tarfaya-nareva-holding-realise-le-plus-grand-parc-eolien-en-afrique-69219(accessed May 14, 2020).
[41] MAROC : le parc éolien de Khalladi exploité par Besta entre en service près de Tanger | Afrik 21, (n.d.). https://www.afrik21.africa/maroc-le-parc-eolien-de-khalladi-exploite-par-besta-entre-en-service-pres-de-tanger/(accessed April 30, 2020).
[42] Morocco to Build €284 Mln hydroelectric Plant near Agadir | The North Africa Post, (n.d.). https://northafricapost.com/21656-morocco-build-e284-mln-hydroelectric-plant-near-agadir.html(accessed May 1, 2020).
[43] Y. Naimi, M. Saghir, A. Cherqaoui, B. Chatre, Energetic recovery of biomass in the region of Rabat, Int. J. Hydrogen Energy. 42 (2017) 1396–1402, https://doi.org/10.1016/j.ijhydene.2016.07.055.
[44] Office National de l'Electricité, électrification rurale (ONEE), (n.d.). http://www.onee.org.ma.
[45] R. de Arce, R. Mahía, E. Medina, G. Escribano, A simulation of the economic impact of renewable energy development in Morocco, Energy Policy 46 (2012) 335–345, https://doi.org/10.1016/j.enpol.2012.03.068.
[46] T. Ahmad, H. Zhang, B. Yan, A review on renewable energy and electricity requirement forecasting models for smart grid and buildings, Sustain. Cities Soc. 55 (2020) 102052, , https://doi.org/10.1016/j.scs.2020.102052.
[47] T. Schinko, S. Bohm, N. Komendantova, E.M. Jamea, M. Blohm, Morocco's sustainable energy transition and the role of financing costs: A participatory electricity system modeling approach, Energy. Sustain. Soc. 9 (2019) 1–17, https://doi.org/10.1186/s13705-018-0186-8.
[48] S. Hamdaoui, M. Mahdaoui, A. Allouhi, R. El Alaiji, T. Kousksou, A. El Bouardi, Energy demand and environmental impact of various construction scenarios of an office building in Morocco, J. Clean. Prod. 188 (2018) 113–124, https://doi.org/10.1016/j.jclepro.2018.03.298.
[49] S. Sahbani, H. Mahmoudi, A. Hasnaoui, M. Kchikach, Development Prospect of Smart Grid in Morocco, Procedia Comput. Sci. Elsevier, 2016, pp. 1313–1320, https://doi.org/10.1016/j.procs.2016.04.274.
[50] B. Decourt, Weaknesses and drivers for power-to-X diffusion in Europe. Insights from technological innovation system analysis, Int. J. Hydrogen Energy. 44 (2019) 17411–17430, https://doi.org/10.1016/j.ijhydene.2019.05.149.
[51] Copenhagen Center for Health Technology - CACHET, (n.d.). https://www.cachet.dk/(accessed April 13, 2020).
[52] Xlinks – 24/7 Solar Energy from the Sahara to the UK, (n.d.).https://xlinks.co/(accessed May 24, 2020).
[53] M. Aneke, M. Wang, Energy storage technologies and real life applications – A state of the art review, Appl. Energy. 179 (2016) 350–377, https://doi.org/10.1016/j.apenergy.2016.06.097.
[54] Stockage D'énergie à Grande échelle Au Maroc : État Des Lieux Et Perspectives, (n.d.). https://www.ecoactu.ma/stockage-denergie-a-grande-echelle-au-maroc-etat-des-lieux-et-perspectives/(accessed April 13, 2020).
[55] M. Baumann, M. Weil, J.F. Peters, N. Chibeles-Martins, A.B. Moniz, A review of multi-criteria decision making approaches for evaluating energy storage systems for grid applications, Renew. Sustain. Energy Rev. 107 (2019) 516–534, https://doi.org/10.1016/j.rser.2019.02.016.
[56] S. Koohi-Fayegh, M.A. Rosen, A review of energy storage types, applications and recent developments, J. Energy Storage 27 (2020) 101047, , https://doi.org/10.1016/j.est.2019.101047.
[57] S. Hajiaghasi, A. Salemnia, M. Hamzeh, Hybrid energy storage system for microgrids applications: A review, J. Energy Storage 21 (2019) 543–570, https://doi.org/10.1016/j.est.2018.12.017.
[58] J.O. Abe, A.P.I. Popoola, E. Ajenifuja, O.M. Popoola, Hydrogen energy, economy and storage: Review and recommendation, Int. J. Hydrogen Energy 44 (2019) 15072–15086, https://doi.org/10.1016/j.ijhydene.2019.04.068.
[59] W. Villasmil, L.J. Fischer, J. Worlitschek, A review and evaluation of thermal insulation materials and methods for thermal energy storage systems, Renew. Sustain. Energy Rev. 103 (2019) 71–84, https://doi.org/10.1016/j.rser.2018.12.040.
[60] Z. Ma, A. Knotzer, J.D. Billanes, B.N. Jørgensen, A literature review of energy flexibility in district heating with a survey of the stakeholders' participation, Renew. Sustain. Energy Rev. 123 (2020) 109750, , https://doi.org/10.1016/j.rser.2020.109750.
[61] T. Kousksou, P. Bruel, A. Jamil, T. El Rhafiki, Y. Zeraouli, Energy storage: Applications and challenges, Sol. Energy Mater. Sol. Cells. 120 (2014) 59–80, https://doi.org/10.1016/j.solmat.2013.08.015.
[62] H. Zhao, Q. Wu, S. Hu, H. Xu, C.N. Rasmussen, Review of energy storage system for wind power integration support, Appl. Energy. 137 (2015) 545–553, https://doi.org/10.1016/j.apenergy.2014.04.103.
[63] R. Hemmati, H. Saboori, Emergence of hybrid energy storage systems in renewable energy and transport applications – A review, Renew. Sustain. Energy Rev. 65 (2016) 11–23, https://doi.org/10.1016/j.rser.2016.06.029.
[64] T. Zimmermann, P. Keil, M. Hofmann, M.F. Horsche, S. Pichlmaier, A. Jossen, Review of system topologies for hybrid electrical energy storage systems, J. Energy Storage 8 (2016) 78–90, https://doi.org/10.1016/j.est.2016.09.006.
[65] J.M. Rodríguez, D. Sánchez, G.S. Martínez, E.G. Bennouna, B. Ikken, Techno-economic assessment of thermal energy storage solutions for a 1 MWe CSP-ORC power plant, Sol. Energy. 140 (2016) 206–218, https://doi.org/10.1016/j.solener.2016.11.007.
[66] M. McPherson, N. Johnson, M. Strubegger, The role of electricity storage and hydrogen technologies in enabling global low-carbon energy transitions, Appl. Energy. 216 (2018) 649–661, https://doi.org/10.1016/j.apenergy.2018.02.110.
[67] M. Robinius, A. Otto, P. Heuser, L. Welder, K. Syranidis, D.S. Ryberg, T. Grube, P. Markewitz, R. Peters, D. Stolten, Linking the power and transport sectors - Part 1: The principle of sector coupling, Energies 10 (2017), https://doi.org/10.3390/en10070956.
[68] Le Maroc se met à la technologie «Power-to-X», (n.d.). https://www.laquotidienne.ma/article/developpement_durable/le-maroc-se-met-a-la-technologie-power-to-x(accessed April 13, 2020).
[69] S. Touili, A. Alami Merrouni, A. Azouzoute, Y. El Hassouani, A. illah Amrani, A technical and economical assessment of hydrogen production potential from solar energy in Morocco, Int. J. Hydrogen Energy. 43 (2018) 22777–22796, https://doi.org/10.1016/j.ijhydene.2018.10.136.
[70] N. Ghaffour, J. Bundschuh, H. Mahmoudi, M.F.A. Goosen, Renewable energy-driven desalination technologies: A comprehensive review on challenges and potential applications of integrated systems, Desalination 356 (2015) 94–114, https://doi.org/10.1016/j.desal.2014.10.024.
[71] M.A. Mandil, A.A. Bushnak, Future needs for desalination in South Mediterranean countries, Desalination 152 (2003) 15–18, https://doi.org/10.1016/S0011-9164(02)01043-3.
[72] Global desalination capacity growing substantially, finds study | Water Tech Online, (n.d.). https://www.watertechonline.com/wastewater/article/16207865/global-desalination-capacity-growing-substantially-finds-study(accessed April 13, 2020).
[73] Home - Global Water Intelligence, (n.d.). https://www.globalwaterintel.com/(accessed April 13, 2020).
[74] A. Subramani, J.G. Jacangelo, Emerging desalination technologies for water treatment: A critical review, Water Res 75 (2015) 164–187, https://doi.org/10.1016/j.watres.2015.02.032.
[75] W.J. Lee, Z.C. Ng, S.K. Hubadillah, P.S. Goh, W.J. Lau, M.H.D. Othman, A.F. Ismail, N. Hilal, Fouling mitigation in forward osmosis and membrane distillation for desalination, Desalination 480 (2020), https://doi.org/10.1016/j.desal.2020.114338.
[76] Le dessalement de l'eau de mer et des eaux saumâtres. | CultureSciences-Chimie, (n.d.). http://culturesciences.chimie.ens.fr/content/le-dessalement-de-leau-de-mer-et-des-eaux-saumatres-840(accessed April 13, 2020).
[77] D. Zejli, R. Benchrifa, A. Bennouna, K. Zazi, Economic analysis of wind-powered desalination in the south of Morocco, Desalination 165 (2004) 219–230, https://doi.org/10.1016/j.desal.2004.06.025.
[78] An Analysis of the Overall Adoption of RPA | Sia Partners, (n.d.). https://sia-partners.com/insights/analysis-overall-adoption-rpa(accessed April 13, 2020).
[79] A.A. Alsarayreh, M.A. Al-Obaidi, A.M. Al-Hroub, R. Patel, I.M. Mujtaba, Evaluation and minimisation of energy consumption in a medium-scale reverse osmosis brackish water desalination plant, J. Clean. Prod. 248 (2020) 119220, , https://doi.org/10.1016/j.jclepro.2019.119220.
[80] W. Kaminski, J. Marszalek, E. Tomczak, Water desalination by pervaporation – Comparison of energy consumption, Desalination 433 (2018) 89–93, https://doi.org/10.1016/j.desal.2018.01.014.
[81] K. Tahri, Desalination experience in Morocco, Desalination 136 (2001) 43–48, https://doi.org/10.1016/S0011-9164(01)00163-1.
[82] G. Gopi, G. Arthanareeswaran, I. AF, Perspective of renewable desalination by using membrane distillation, Chem. Eng. Res. Des. 144 (2019) 520–537, https://doi.org/10.1016/j.cherd.2019.02.036.
[83] K.M. Powell, K. Rashid, K. Ellingwood, J. Tuttle, B.D. Iverson, Hybrid Concentrated Solar Thermal Power Systems: A Review Hybrid concentrated solar thermal power systems: a review, Renew. Sustain. Energy Rev. 80 (2017) 215–237 BYU Scholars Archive Citation https://scholarsarchive.byu.edu/facpub://scholarsarchive.byu.edu/facpub/1872. (accessed April 13, 2020).
[84] M. Ibrahimi, A. Arbaoui, Y. Aoura, Design analysis of MVC desalination unit powered by a grid connected photovoltaic system, Energy Procedia 139 (2017) 524–529, https://doi.org/10.1016/j.egypro.2017.11.248.
[85] Ministry of Equipment, Transport, Logistics, (n.d.). http://www.equipement.gov.ma/Pages/accueil.aspx(accessed July 26, 2020).
[86] Kingdom of Morocco, Moroccan Climate Change Policy, (n.d.). http://www.4c.ma/medias/MCCP - Moroccan Climate Change Policy.pdf.
[87] L'état électrifie son parc automobile dès 2019 - www.voitureelectrique.ma, (n.d.).http://www.voitureelectrique.ma/letat-electrifie-son-parc-automobile-des-2019/(accessed April 13, 2020).
[88] IRESEN – Institut de Recherche en Energie Solaire et Energies Nouvelles,(n.d.). http://www.iresen.org/(accessed July 4, 2019).
[89] Charging stations' statistics in ., (n.d.). https://chargemap.com/about/stats/morocco(accessed April 13, 2020).
[90] A. Chachdi, B. Rahmouni, G. Aniba, Socio-economic Analysis of Electric Vehicles in Morocco, Energy Procedia, Elsevier Ltd, 2017, pp. 644–653, https://doi.org/10.1016/j.egypro.2017.11.087.
[91] A. Majzoobi, A. Khodaei, Application of microgrids in addressing distribution network net-load ramping, 2016 IEEE Power Energy Soc. Innov. Smart Grid Technol. Conf. ISGT 2016, Institute of Electrical and Electronics Engineers Inc., 2016, , https://doi.org/10.1109/ISGT.2016.7781276.
[92] P. Denholm, M. Kuss, R.M. Margolis, Co-benefits of large scale plug-in hybrid electric vehicle and solar PV deployment, J. Power Sources 236 (2013) 350–356, https://doi.org/10.1016/j.jpowsour.2012.10.007.
[93] Z. Yang, K. Li, Q. Niu, Y. Xue, A comprehensive study of economic unit

commitment of power systems integrating various renewable generations and plug-in electric vehicles, Energy Convers. Manage. 132 (2017) 460–481, https://doi.org/10.1016/j.enconman.2016.11.050.
[94] Fédération de l'Energie, (n.d.). https://www.fedenerg.ma/(accessed April 13, 2020).
[95] R.R. Kumar, K. Alok, Adoption of electric vehicle: A literature review and prospects for sustainability, J. Clean. Prod. 253 (2020) 119911, , https://doi.org/10.1016/j.jclepro.2019.119911.
[96] T. Capuder, D. Miloš Sprčić, D. Zoričić, H. Pandžić, Review of challenges and assessment of electric vehicles integration policy goals: Integrated risk analysis approach, Int. J. Electr. Power Energy Syst. 119 (2020) 105894, , https://doi.org/10.1016/j.ijepes.2020.105894.
[97] K. Pietrzak, O. Pietrzak, Environmental effects of electromobility in a sustainable urban public transport, Sustain 12 (2020), https://doi.org/10.3390/su12031052.
[98] T. Manders, R. Cox, A. Wieczorek, G. Verbong, The ultimate smart mobility combination for sustainable transport? A case study on shared electric automated mobility initiatives in the Netherlands, Transp. Res. Interdiscip. Perspect. 5 (2020) 100129, , https://doi.org/10.1016/j.trip.2020.100129.
[99] RENEWABLE ENERGY | Ministère de l'Industrie, du Commerce et de l'Économie Verte et Numérique, (n.d.). http://www.mcinet.gov.ma/en/content/renewable-energy(accessed August 1, 2020).
[100] Loi n° 47-09 relative à l'efficacité énergétique promulguée par le Dahir n° 1-11-161 du 1er kaada1432, 2011. 10.16194/j.cnki.31-1059/g4.2011.07.016.
[101] Efficacité énergétique, (n.d.). https://www.mem.gov.ma/Pages/secteur.aspx?e=3(accessed August 2, 2020).
[102] S. Brueckner, L. Miró, L.F. Cabeza, M. Pehnt, E. Laevemann, Methods to estimate the industrial waste heat potential of regions - A categorization and literature review, Renew. Sustain. Energy Rev. 38 (2014) 164–171, https://doi.org/10.1016/j.rser.2014.04.078.
[103] S. Moser, S. Lassacher, External use of industrial waste heat - An analysis of existing implementations in Austria, J. Clean. Prod. 264 (2020) 121531, , https://doi.org/10.1016/j.jclepro.2020.121531.
[104] B.S. Silvestre, D.M. Ţîrcă, Innovations for sustainable development: Moving toward a sustainable future, J. Clean. Prod. 208 (2019) 325–332, https://doi.org/10.1016/j.jclepro.2018.09.244.
[105] A. Calabrese, C. Castaldi, G. Forte, N.G. Levialdi, Sustainability-oriented service innovation: An emerging research field, J. Clean. Prod. 193 (2018) 533–548, https://doi.org/10.1016/j.jclepro.2018.05.073.