Renewable Energy Technologies Penetration in MENA Region (2010-2030)

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Abstract: This paper focuses on quantifying the renewable energy mix in the MENA (Middle East and North Africa) region and underlines its impact in terms of economic aspects. The installed and targeted capacities of solar, wind and other technologies will be revealed. In addition, distinguished present and on-going projects as well as prominent funding organizations are discussed. The overall strategy as well as the evolution of the renewable energy plan is resumed.

Key words: MENA, renewable energy, solar energy, wind energy, funding organizations.

1. Introduction

Ever since the industrial revolution evoked in the 18th century, immense capacities of fossil fuels have been utilized as a primary source to power the economy and prosper the global economic development. The steady yet expanding reliance on this finite, limited and contaminating source of energy resulted in accession of environmental concerns in the last decade, which prompted a number of energy conservation protocol measures that aim at enhancing the world's nourishment. The transition from finite, temporary and pollutant; to infinite, sustainable and clean energy resources was a fundamental objective worldwide, though it was somehow restricted by economic constraints. For the past fifty years, the MENA (Middle East and North Africa) region attained immense relevance as a global manufacturer and exporter of energy, having most of the world's crude oil and natural gas reserves. Therefore, the national energy market in the MENA region has been classified as negligible in the global frame, provided with sufficiently feasible, regionally created, low cost fossil-fuels [1]. As a result of the world's minimal

domestic costs for both initial energy and electricity, the MENA region confronted an absence of economic inducement essential for applying alternative energy resources like renewable, sustainable energy [2]. According to the OECD (organization for Economic Co-operation and Development) statistics, MENA cumulative energy demand is anticipated to extend superior to the world average, almost 3 percent per year; whereas the electricity demand is enlarging at a pace of 6 percent per year between 2010 and 2030 [1]. Fig. 1 reveals the excessive reliance of the MENA region on fossil fuels, relative to other districts.

As a consequence of the aforementioned dilemma, an imperative transition of fuel reliance should be achieved to perpetuate the economy and human welfare in the distant future.

By May 2013, all 21 MENA countries defined their renewable energy targets that would result in 107 GW installed capacity by year 2030. Saudi Arabia alone aimed for an overwhelming 54 GW by year 2032 [3]. This was agreed in the Copenhagen accord on climate and energy targets in 2009 that have come to endorse the continuation of the Kyoto Protocol.

The abundance of targets and protocols place solar Photovoltaic PV, concentrated Solar Power CSP and Solar Water Heating SWH as a preference indicating the high-quality solar energy resources in the area, and

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decreasing technology prices. As for the succeeding most prominent selection amongst renewable energy resources, comes wind energy [3]. Historically, the reliance was more on traditional renewable systems such as hydropower for used electricity generation and biomass used for cooking. However, currently, a deviation occurred reporting utmost projects are solar and wind.

In 2011, the share of renewable energy attained 3.3% of 1,200 TWh of power generation in the MENA region. More recently, Morocco, Lebanon and Tunisia encountered and increased in their renewable energy contribution by at least 4 percentage points in years 2011 and 2012; reaching 33%, almost 12% and 6% respectively in 2012 [3].

The condition of renewable energy in the MENA region is more compelling than in alternative geographic areas that are much more advanced in that field. This is due to the fact that the region has a fortunate climate and topography which devote immense capacity in the field of solar and wind energy. Thus, the application of renewable technologies will help in the reduction of environmental contamination, exploit oil and gas in further valuable means, improve positions as energy exporters and initiate enrolments [2]. Fig. 2 below shows the energy map of renewable energy in MENA region. These numbers account mainly for both solar and wind energies that are predominant [3, 4].

This paper discusses the state of solar, wind and other renewable technologies in the MENA region. Section 2 introduces the potential of solar technology in the MENA region by revealing current and targeted capacities, leading countries in the field, notable present and ongoing projects. Similarly, Section 3 presents the aforementioned subtitles regarding wind, hydro, biomass and geothermal power. Section 4 reveals the eminent funding organizations and the overall situation and perspectives. Finally, Section 5 presents a summarizing conclusion.

	Renewables (non -Hydro)	Renewables (Hydro)	Nuclear	Coal	Natural Gas	Oil
Latin America	4%	34%	1%	5%	22%	9%
Europe – Central Asia	6%	14%	19%	21%	26%	1%
Sub Saharan Africa	1%	17%	3%	47%	6%	2%
North America	3%	10%	17%	35%	16%	4%
South Asia	2%	12%	2%	50%	14%	5%
East Asia Pacific	1%	12%	6%	54%	10%	2%
MENA Region	1%	2%	0%	3%	56%	25%

Fig. 1 Global fossil fuel shares in utility generation, 2010.

Fig. 2 MENA renewable energy roadmap 2010-2030.

2. Solar Technology in MENA Region

Despite the fact that wind energy grew into the largest renewable energy source following hydro power; solar power generation encountered progressive expansions in recent years. This tendency is anticipated to continue in the forthcoming future [3].

In addition, SWH (Solar Water Heating) systems are also an essential feature in the deployment of renewable technologies in the district. The installed capacities (MW) of PV and CSP by the end of 2012 are estimated to be around 182 and 407.64 respectively. However, according to Ref. [3], targets revealed up to 2030 exceed these numbers by far. The potential estimated for the MENA region for both PV and CSP is approximated to at least 26.4 and 39.7 GW respectively. In this part, targets and capacities of

leading countries in solar PV, CSP and SWH are revealed. Furthermore, the most eminent projects are discussed.

2.1 Current Capacities

Solar PV attained the ultimate average annual growth in power generation in MENA region in years 2008 till 2011 as debriefed in Fig. 3 [3]. We note a remarkable annual growth in solar PV resulting in an increased overall growth in renewable energy systems RES. Table 1 reveals the installed PV capacities in selected MENA countries by 2012 and 2013 [3, 4]. Only leading countries are shown.

As for CSP, it assists considerably to the escalating share of solar energy in the region. In 2011, 40% of the countries running CSP plants were localized in the MENA region, particularly Algeria, Egypt Iran and Morocco having integrated solar combined cycle (ISCC) technologies [4]. In 2013, these countries were united with UAE. Currently, UAE became the dominant participant in the CSP market having Shams 1, the largest CSP plant with a capacity of 100 MW operating since March 2013. Table 2 below reveals the installed CSP capacities in MW in selected MENA countries in 2012 and 2013 [3, 4]. On the other side, solar water heating systems SWH are also a vital element in the distribution of renewable technologies in the region. By 2013, they accounted for approximately 9 million square meters (m^2) of collector area serving 6.3 gigawatts-thermals (GW_{th}) of installed capacity. The PROSOL program in Tunisia was a prosperous regional attainment having more than 500,000 m^2 of installed surface [5].

In addition, the PROMASOL program in Morocco had 240,000 m^2 of surface equipped with SWH panels in 2008 although the target was only 100,000 m^2 [6]. Eminent SWH installed capacity and the corresponding collector area for specific MENA countries in 2012, are shown in Table 3 [3, 4, 7].

2.2 Targets and Potentials

Notable solar PV and CSP capacity targets set by

Fig. 3 Annual growth rate of renewable energy in MENA.

Table 1 Installed PV capacity in MENA countries.

Country	PV (MW)
Egypt, Morocco	15 (2012)
Saudi Arabia	19 (2013)
UAE	33 (2013)
Yemen	3 (2013)
Israel	269 (2012)

Table 2 Installed CSP capacity in MENA countries.

Country	CSP (MW)
Algeria	25 (2012)
Egypt, Morocco	20 (2012)
UAE	100 (2013)

Table 3 Installed capacities of SWH systems.

Country	Capacity (MW_{th})	Collector Area (m^2)
Egypt	525	750,000
Israel	2,917.8	4,168,245
Palstinian Territories	1,120	1,600,000
Tunisia	437.5	625,000

MENA region vary among the different countries. Some have defined their plans up to year 2020, others 2030 or within that range.

In Table 4, only selected MENA countries are listed [3]. Those countries were cited among others as they are considered as leaders in this field. Also, Table 5 reveals targeted SWH capacities by selected MENA countries [3, 4, 7].

2.3 Current and Forthcoming Projects

In the past years, the MENA region attained a compelling advancement in the solar energy sector via

Table 4 Solar capacity targets in MENA.

Country	Year	PV (MW)	CSP (MW)
Algeria	By 2030	2,800	7,200
Kuwait	By 2030	3,500	1,100
Saudi Arabia	By 2032	16,000	25,000

Table 5 SWH targets in MENA countries.

Country	Year	SWH target
Lebanon	By 2020	1,050,000 m ² of collector area
Morocco	By 2020	1,700,000 m ² of collector area

actual project settlements and projected objectives. Vast developments have been achieved in alternative countries engulfing the world's most innovative projects. The following section will highlight the most appealing projects and the forthcoming targets in selected countries.

Let us start first with the eminent present and ongoing projects. According to Refs. [8, 9], the most notable solar projects are concentrated solar power type and take place in UAE, Morocco and Tunisia. Table 6 resumes these projects and lists their capacities.

In terms of prominent forthcoming projects, by April 2013 some MENA countries have defined an estimated solar capacity (MW) relative to their pipelined projects. The number of these projects are disclosed between parentheses and revealed in the bar chart below in Fig. 4 [3]. Israel is leading in terms of number of projects followed by Oman and Jordan. Table 7 below reveals some of the eminent upcoming projects [8, 10].

3. Wind and Other Technologies in MENA Region

Adapting a complex climate model, researchers declare that the MENA region acquires valuable prospects for wind energy. The abundance of wind available is competent to supply half to several times the world's total energy needs within the coming two decades [11].

The development of wind projects across the MENA region is flourishing mainly by including two of the

Table 6 Notable solar projects.

Project	Type	Capacity (MW)	Country
Shams 1	CSP	100	UAE
Quarzazate	CSP	160	Morocco
South-West of Tunisia	CSP	2,000	Tunisia

Fig. 4 Solar capacity targets and pipelined projects.**Table 7** Noted upcoming solar projects.

Project	Type	Capacity (MW)	Country
Shams Ma'an	PV	100	Jordan
K.A.CARE	PV & CSP	4,500	Saudi Arabia
Kisr phase 1	PV & CSP	4,000	Kuwait

world's largest wind farms in Morocco and Egypt. Nevertheless, amongst non-hydro renewable power, wind dominates renewable energy ongoing and forecasted projects [3].

In terms of definite numbers, hydropower preserves the leading renewable energy source in the MENA region presently. As for other technologies, modern biomass and geothermal power are the minimal utilized energy sources in the region in term of deployment [3].

3.1 Current Capacities

The installed power capacities of wind, hydro, biomass and geothermal renewable energy resources by the end of 2012 are 1,094.40, 17,653, 73.5 and 0.023 MW respectively. The capacity and potential of wind and other technologies will be revealed.

After hydro, wind energy is the most prevalent source of electricity production in the region,

particularly in Egypt, Morocco and Tunisia. By the end of year 2012, partly eight MENA countries had a total of approximately 1.1 GW of wind power capacity. Egypt is the head in the sector having 550 MW installed capacity, followed by Morocco with 291 MW and Tunisia with 154 MW [3]. The utmost appealing growth rate of wind power was bounded between years 2005 and 2010 as shown in Fig. 5 [3].

The strongest growth in wind power took place between 2005 and 2010, with a more than fourfold increase in total installed capacity. Recent socio-political events linked to the Arab Spring in some parts of the MENA region seem to have slowed down the promising and rather widespread development of wind [3].

Table 8 shows notable installed wind capacities in selected MENA countries for wind energy in year 2012 [3, 4, 7].

As for hydropower, it is the dominant energy source for electricity generation in the MENA region with the installed capacities in 2012 revealed in Table 9 [3, 4, 7]. The overall capacity in the MENA region by this year was approximated to 17.653 GW.

Regarding biomass and waste power capacities the eminent installed capacities for year 2012 is estimated to be around 73.5 MW in the MENA region. Leading countries are Qatar with 40 MW and Israel with 27 MW. The only country having geothermal capacity installed in the MENA region is the Palestinian territories with only 0.023 MW [3, 4, 7].

3.2 Wind and Other Technologies' Capacity Targets

Notable capacity targets by selected MENA countries are revealed below in Table 10 [3, 4, 7]. Though the targets of each country vary function of the year, the only available numbers estimate an overall capacity of wind energy of around 32.64 GW by year 2030. Regarding other technologies (Biomass, geothermal and hydro) the estimated target by year 2030 for all MENA countries is around 8.32 GW.

Fig. 5 Wind power growth rate between 2005 and 2012.

Table 8 Installed wind power in MENA.

Country	Wind (MW)
Egypt	550
Morocco	291
Tunisia	154
Iran	91

Table 9 Installed hydro power.

Country	Hydro (MW)
Egypt	2,800
Iran	9,500
Iraq	1,864
Morocco	1,745

Table 10 Wind and other technologies' capacity targets in MENA region.

Country	Year	Wind (MW)	Biomass, geothermal and hydro (MW)
Algeria	By 2030	2,000	–
Egypt	By 2020	7,200	–
Kuwait	By 2030	3,100	1,100
Saudi Arabia	By 2032	9,000	4,000
Syria	By 2030	2,000	400 biomass
Morocco	By 2020	2,000	2,000 hydro

3.3 Current and Forthcoming Projects

This section will highlight some of the intriguing projects and reveal the forthcoming targets in selected countries.

Eminent present and ongoing projects are revealed in Table 11 [9, 12-15]. However, the current capacity exceeds these numbers by far. Current hydro capacity in MENA region is estimated to 4.1 GW with Egypt

and Morocco having the lead. Current wind capacity is estimated to 0.9 GW with Egypt and Tunisia on the lead. Biomass and other technologies account for around 1 GW.

Regarding the forthcoming projects related to wind and other technologies, the already pipelined ones are estimated to provide about 5 GW of clean energy. Wind energy projects estimated around 45 provide approximately 4.74 GW. The other 0.26 GW are divided among biomass and waste (12 projects), Geothermal (2 projects) and small hydro (1 project) [3]. As for biomass energy, the residual municipal, agricultural and industrial biomass in Morocco attained 950 MW of electrical production btw 2012, 2014 [16]. Also a 10 MW waste-to-electricity project at the Jebel Chakir landfill in Tunisia has been implemented [15]. In terms of biogas capacities, Jordan was the leading country with capacities up to almost 10 MW through two main projects, the Russaifa (3.5 MW) and the Samra (6 MW) [17].

Pipelined renewable technologies in terms of capacity are revealed in Fig. 6 [3]. In terms of technology and availability, wind and solar energies account for around 42.5% and 41.5% respectively. Some of the most noted forthcoming projects, we note the “Abu Dhabi Waste-to-energy” project that has a capacity of 100 MW and the “K. A. CARE” project in Saudi Arabia that targets 1,700 MW in terms of wind and 700 MW in terms of other technologies [8]. Taxes that may be paid are not taken into consideration, too.

4. Funding Strategies

With ample renewable energy projects in the pipeline in the MENA region, funding constituting of durable, low-interest loans remains an essential source for the abundant renewable projects.

The main contributors in the region are the German Development Bank (KfW), World Bank Group, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) International Bank for Reconstruction and Development (IBRD), the African Development Bank (ADB) which play a significant role in the district.

Table 11 Notable present and ongoing projects.

Project	Type	Capacity (MW)	Country
Zafarana	Wind	550	Egypt
High Dam	Hydro	2,100	Egypt
Bizerte	Wind	186	Tunisia
Jebel Chakir	Biomass	10	Tunisia

Fig. 6 Pipelined renewable energy projects by capacity.

Table 12 Benefactors and beneficiaries of some renewable projects in MENA region.

Benefactor	Beneficiary	Budget	Project
World Bank (EIB, UNDP and UNEP)	MENA countries	MUSD 2,100	17 various projects
Abu Dhabi Fund for Development	Algeria, Yemen	> MUSD 350	Restricted for IRENA members
CTF	Algeria, Egypt, Jordan, Morocco, Tunisia	MUSD 947	1 GW CSP + Quarzazate project
ACWA Power International	Morocco	MUSD 1,160	Quarzazate CSP project
Banque Centrale Populaire			
Attijariwafa Bank	Morocco	MUSD 563	Tarfaya Wind Farm (300 MW)
Nareva Holdings SA			
Consortium of banks	Egypt's NREA	MUSD 455.5	NREA and Gulf of EL Zeit Wind farms (200 MW)

In addition, the EIB (European Investment Bank), the AFD (French Development Agency), Abu Dhabi Fund for Development, and the CTF (Clean Technology Fund) are also dominant participants in the region [3]. The following table underlines the economical strategy adopted by revealing the main grants and funding attributed to the MENA region. The main benefactors of the projects in the MENA region, the beneficiary countries, and the given budget in Millions of Dollars (MUSD) are all presented. Grants are allocated for different type of projects including but not limited to, hydro, geothermal, wind solar (PV, CSP, and SWH)...

In terms of the criteria considered for funding of the renewable energy projects in the MENA region, the GCF (Green Climate Fund) has intended to channel support to the developing world to address climate change, with the goal of mobilizing USD 100 billion annually in climate finance by 2020 from both public and private investors. Progress is being made in the definition of the GCF business model framework. In March 2013, its Board agreed that the "Fund should follow a country-driven and owned approach as a core principle, and should leverage additional resources, including through a private sector facility." The NAMAs (Nationally Appropriate Mitigation Actions) has mitigated greenhouse gas emissions in developing countries that are not subject to mitigation commitments, and these actions can be supported by industrialized countries through financing, technology transfer, or capacity building.

5. Conclusion

Despite the fact that the deployment of renewable energies in the MENA region is considerably hindered by socio-economic factors, the advancement of the renewable energy sector in the past years has been compelling.

Acquiring prime solar energy conveniences in the arena, solar expansion is expected to be substantial both in CSP and PV and may dominate wind energy

by 2020, mainly with Saudi Arabia's vital solar schemes. As for the consecutive renowned renewable energy resource, comes the wind energy. The enrollment of wind energy is outstanding mainly in Egypt, Morocco and Tunisia.

By the end of 2012, the installed renewable capacity in MENA region attained a value of 19 GW; whereas, the objective set by all 21 MENA countries is to attain a target of 107 GW by 2030. This is most likely to be accomplished by climate and private funding organizations that have shown serious involvement following the Copenhagen agreement in 2009. In regards to forthcoming research opportunities, this survey could be extended in order to exploit the advancements in the overall energy plan and the evolution of the preplanned projects, hence evaluating the renewable power blend in the MENA region up to 2050.

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