International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.12, April 2014

REFERENCE OF THE PAPER: 268.14-Flazi

Sahara deserts ensure sustainable energy security of MENA countries and Europe

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Abstract. In this article, a particular attention is being given to first the Middle East & north Africa Deserts (MENA) in terms of solar potential capability in that it could capture enough solar energy to meet the entire world's energy needs using Very Large Scale- Photovoltaic (VLS-PV) system, second to its possibility of attracting inhabitant for accessing to a good quality life, agriculture and energy infrastructure, third to its Sand or Silicon (Si) reserves which is more than the needs to manufacture Photovoltaic (PV) cells for all the suitable area of MENA deserts.

Keywords

Photovoltaic, Solar energy, Sustainable development, Sahara, Sand.

1. Introduction

Of all the RE sources now being fiercely debated, solar generation seems to be custom-tailored for Middle East & north Africa (MENA) countries being endowed with large reserves of solar energy source . It is clean, efficient, freely available and now becoming more affordable. With almost 365 days of radiant sunshine a year, MENA Deserts has the potential to be one of the major contributors in solar energy and become a role model to other region in the world.
With a total area of 11.65 million km², the (MENA) deserts extends over 27 countries being Bahrain, Qatar, Oman, Kuwait, Lebanon, Palestine [Israel, West Bank (Cisjordanie) and Gaza], Jordan, United Arab Emirates, Syria, Yemen, Saudi Arabia, Iraq, Iran, Egypt, Libya, Tunisia, Algeria, Morocco, Western sahara, Mauritania, Mali, Niger, Chad, Sudan and South Sudan. It is hoped that energy potential using VLS-PV system would be sufficient to meet MENA countries and Europe countries energy needs in the future at the end of oil. Sharing this energy should become the engine for sustainable energy which guarantees a global future for all populations, the unbreakable link between the countries for a lasting peaceful world.

2. MENA deserts irradiation compared to world energies

Total annual irradiation for all world deserts (31 deserts of 19 million km^2), was calculated [1-3]. A summary of calculated results is depicted in Tables 1 and 2. The first one concerns the annual irradiation at different world deserts grouped by region and the second one is about the annual irradiation at the MENA deserts. It can be seen easily that the MENA deserts has a 65 % share of the total irradiation of world deserts which is higher the primary energy consumption of the world in 2011 (12275 Mtoe [4]) the MENA deserts annual irradiation (2262132 Mtoe/y) is more than 184 times higher.

3. MENA deserts solar net energy potential using VLS-PV

3.1. Suitable area for VLS-PV system

The deserts offer contrasting landscapes (Figure 1): sand dunes, oasis, wades (dry beds of rivers and streams), mountains, reg (composed of pebbles and gravel) and steppe. It is impossible to use the total area of the deserts for VLS-PV (Very Large Scale- Photovoltaic) system; the suitable area for this kind of systems is the regs and the steppes only.
Table 3 shows a rough calculation of the different areas of MENA deserts; it can be seen that the suitable area for VLS-PV is about 6956500 km^2.

3.2. The range of VLS-PV system

The size of a VLS- PV system may range from 10 MW to 1 or several GW, consisting of one plant, or an aggregation of plural units [5]. Figure 2 shows a conceptual image of a one GW system [5,6], occupying 30 km^2 (15 km x 2 km) of land, and taking into account, PV collectors, buffer plant, roods and transmission lines.

Table 1: Annual irradiation in world deserts grouped by region

WORLD REGION DESERTS		Area (km^2)	Annual irradiation (kWh/m2)	Total annual irradiation (PWh)	Total annual irradiation (Mtoe)	share of total annual irradiation (%)
Africa	North Africa (Sahara)	8 600 000	2 300	19 780	1 701 080	48,79
	South Africa (2)*	1 040 000	2 313	2 406	206 916	5,94
	TOTAL AFRICA (3)*	9 640 000	2 301	22 186	1 907 996	54,73
Asia	Middle East (6)*	3 052 400	2 137	6 524	561 052	16,09
	Central Asia (5)*	2 420 000	1 661	4 019	345 634	9,91
	TOTAL ASIA (11)*	5 472 400	1 927	10 543	906 686	26,01
Australia						
	TOTAL AUSTRALIA (10)*	1 388 743	2 246	3 119	268 256	7,69
America	North America (5)*	1 664 000	2 188	3 641	313 126	8,98
	South America (2)*	813 000	1 289	1 048	90 154	2,59
	TOTAL AMERICA (7)*	2 477 000	1 893	4 689	403 280	11,57
TOTAL WORLD DESERTS (31)* * Deserts number		**18 978 143**	**2 136**	**40 537**	**3 486 218**	**100**

Table 2: Annual irradiation in MENA deserts

North Africa (NA)	8 600 000	2300	19780	1701080	49
Middle East (ME)	3 052 400	2137	6524	561052	16
Middle East+North Africa= (MENA)	11 652 400	2257	26304	2262132	65

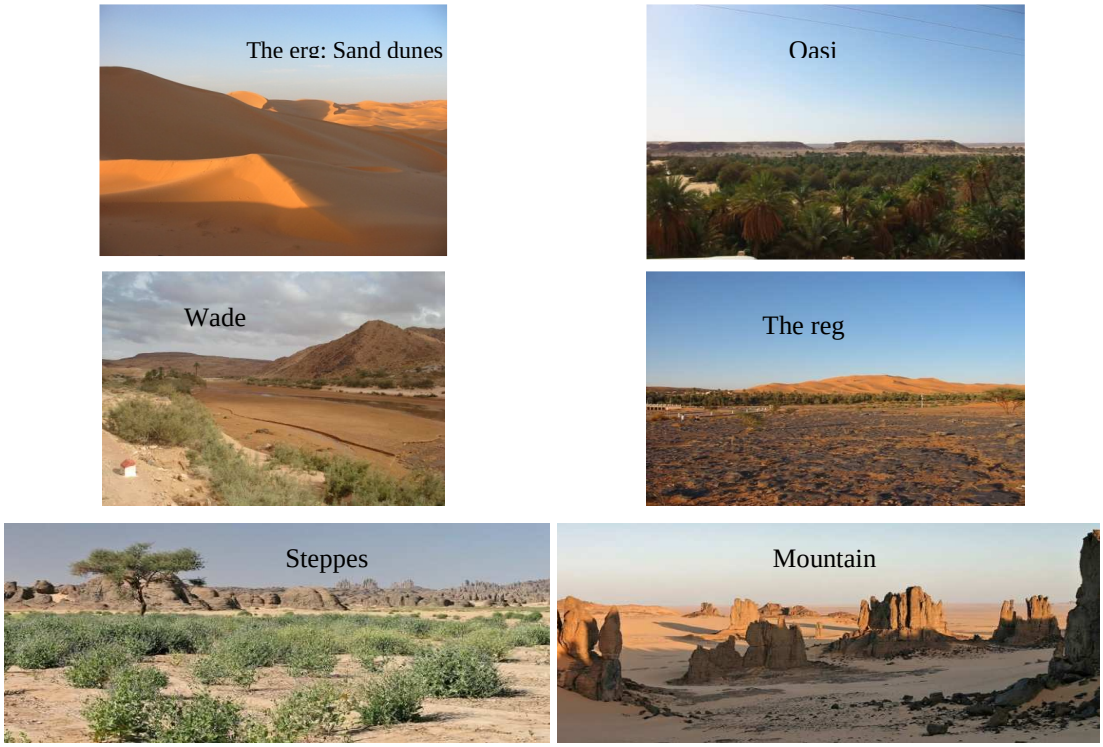

Figure 1: deserts contrasting landscapes

Table 3: different areas of MENA deserts

Total area (km²)	Sand dune area (km²) 20%	Oasis area (km²)	Mountain area (km²) 18%	Reg and Steppe area (km²)
11 652 400	2 330 480	268 000	2 097 432	6 956 488

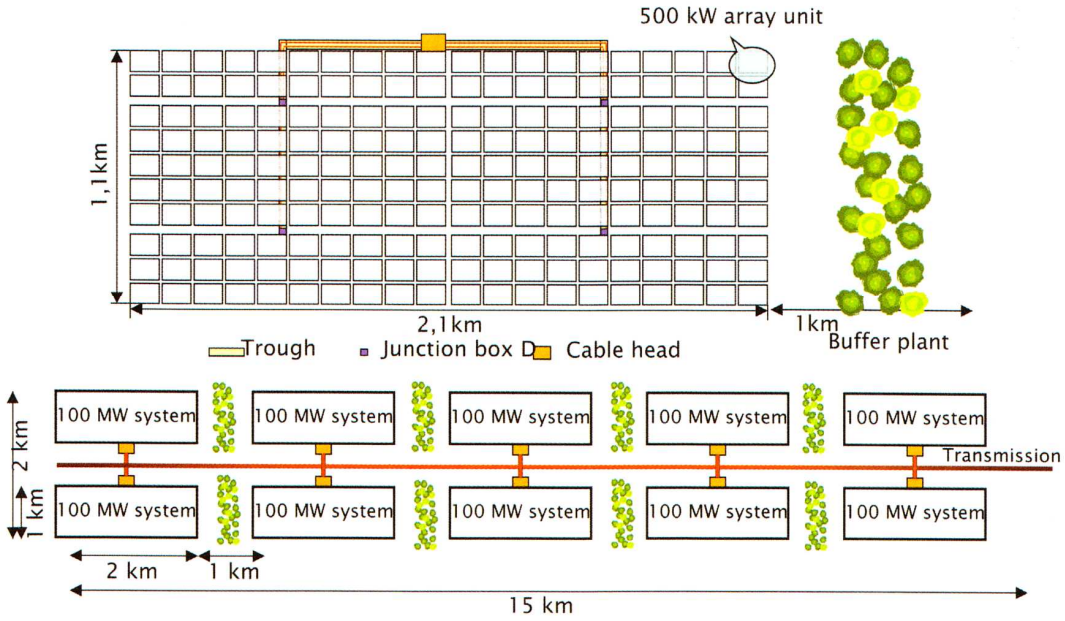

Figure 2: conceptual image of a one GW system [3,4].

3.3. PV capacity and annual power generation

Table 4 shows a rough calculation of PV capacity and annual power generation for all the suitable area of MENA deserts using VLS-PV based on a conceptual image of a one GW system of figure 2.

A comparison with world primary energy consumption [2] allowed us to conclude that MENA solar net annual energy potential using VLS-PV with buffer plants and roads (31 538 Mtoe) is more than 2 times higher of world consumption in 2030 (15000 Mtoe).

Table 4: PV capacity and Annual energy generation
for all the Suitable Deserts area of MENA

PV Capacity and Energy generation using VLS-PV system	PV capacity (TW)	Annual generation (PWh)	Annual generation (Mtoe)	Annual generation to gross annual irradiation %
Without buffer plant and without road	**487**	**769**	**66 163**	**2,93**
Without buffer plant but with road	**348**	**550**	**47 307**	**2,09**
With buffer plant and with road	**232**	**367**	**31 538**	**1,39**

4. What can we do by this area or this energy?

Many purposes can be achieved in that:

- Clean energy production, using Very Large Scale-Photovoltaic system,
- Sustainable development of MENA countries,
- Clean energy production for export to Europe countries,
- Desert greening, cultivation & repopulation:

4.1. Clean energy production for sustainable development of MENA countries

Table 5, 6 and 7 show calculation results of MENA countries population in 2030 and annual energy needs in 2030 (5toe/capita). It can be seen that the needed energy, of MENA countries, in 2030 will be about 4116 which amount the value of 13% of total MENA potential.

Table 5: annual energy needs
for sustainable development of ME countries (2030)

Country (or dependent territory)	Area (km2)	Population 2013	Growth rate	Population 2030	annual energy needs (Mtoe) 2030, (5toe/capita)
Northern Cyprus	9 251	294 906	1,08	353 991	1,8
Cyprus		887 000	1,95	1 231 705	6,2
Bahrain	741	1 546 000	7,36	5 170 494	25,9
Qatar	11 586	1 941 000	4,24	3 931 972	19,7
Oman	3 095	2 950 000	2,43	4 436 944	22,2
Kuwait	17 818	3 852 000	2,94	6 304 012	31,5
Lebanon	104	4 127 000	1,58	5 387 335	26,9
Palestine *	22574	12 419 000	2,16	18 244 944	91,2
Jordan	89 342	6 517 000	2,84	10 490 662	52,5
United Arab Emirates	836	8 659 000	1,56	11 265 579	56,3
Syria	185180	22 269 000	2,45	34 351 036	171,8
Yemen	527 968	25 252 000	2,96	41 463 013	207,3
Saudi Arabia	2 000 000	30 193 000	3,41	53 391 167	267,0
Iraq	438 317	35 404 000	3,06	59 099 619	295,5
Turkey	783 562	76 081 000	1,21	93 341 427	466,7
Iran	1 648 195	76 789 000	1,29	95 484 026	477,4
Total Asia	5 729 318	307 999 000		442 362 230	2211,9

*** (Israel+ West Bank + Gaza)**

Table 6: annual energy needs
for sustainable development of NA countries (2030)

Country	Area (km2)	Population 2010	Growth rate	Population 2030	annual energy needs (Mtoe) 2030, (5toe/capita)
Morocco	458 730	31 951 000	1,42	42 360 061	211,8
Western Sahara	266 000	513 000	2,2	792 748	4,0
Mauritania	1 030 700	3 460 000	2,41	5 570 875	27,9
Algeria	2 381 741	35 468 000	1,19	44 935 401	224,7
Tunisia	163 610	10 549 000	1,14	13 233 365	66,2
Libya	1 775 500	6 355 000	2	9 443 196	47,2
Egypt	1 002 000	81 121 000	1,94	119 131 300	595,7
Mali	1 240 192	14 517 000	3,12	26 837 062	134,2
Niger	1 267 000	15 512 000	3,63	31 650 295	158,3
Chad	1 284 000	11 227 000	2,35	17 865 726	89,3
Sudan	1 886 068	43 552 000	2,33	69 034 723	345,2
South Sudan	619 745		2,33		
Total Africa	13 375 286	254 225 000		380 854 751	1 904

Table 7: annual energy needs
for sustainable development of MENA countries (2030)

	Area (km2)	Population 2010	Population 2030	annual energy needs (Mtoe) 2030
Total Asia	5 572 007	309 130 906	442 989 798	2 212
Total Africa	13 375 286	254 225 000	380 854 751	1 904
Total MENA	18 947 293	563 355 906	823 844 549	4 116

4.2. Clean energy production for export to Europe countries:

Table 8 shows calculation results of Europe countries population in 2030 and annual energy needs in 2030 (5toe/capita). It can be seen that the needed energy, of Europe countries in 2030 will be about 4632 Mtoe which amount the value of 14,7% of total MENA potential.

Table 8: annual energy needs for of Europe countries (2030)

Country	Population 2012	Population 2030	annual energy needs (Mtoe) 2030, (5toe/capita)	Country	Population 2012	Population 2030	annual energy needs (Mtoe) 2030, (5toe/capita)
Russie	142 517 670	170 472 151	852,36	Finlande	5 401 267	6 460 712	32,30
Allemagne	81 843 743	97 897 187	489,49	Norvège	4 985 870	5 963 836	29,82
France	65 327 724	78 141 592	390,71	Irlande	4 582 769	5 481 668	27,41
Royaume-Uni	62 989 551	75 344 792	376,72	Géorgie	4 570 934	5 467 511	27,34
Italie	60 820 696	72 750 522	363,75	Croatie	4 398 150	5 260 836	26,30
Espagne	46 196 276	55 257 559	276,29	Bosnie-Herz.	3 879 296	4 640 210	23,20
Ukraine	44 854 055	53 652 065	268,26	Moldavie	3 656 843	4 374 124	21,87
Pologne	38 538 447	46 097 666	230,49	Lituanie	3 007 758	3 597 722	17,99
Roumanie	21 355 849	25 544 745	127,72	Albanie	3 002 859	3 591 862	17,96
Kazakhstan	17 522 010	20 958 908	104,79	Arménie	2 970 495	3 553 150	17,77
Pays-Bas	16 730 348	20 011 964	100,06	Macédoine	2 059 794	2 463 817	12,32
Grèce	11 290 067	13 504 585	67,52	Slovénie	2 055 496	2 458 676	12,29
Belgique	11 094 850	13 271 077	66,36	Lettonie	2 041 763	2 442 250	12,21
Portugal	10 541 840	12 609 595	63,05	Kosovo	1 836 529	2 196 760	10,98
Rép. tchèque	10 505 445	12 566 062	62,83	Estonie	1 339 662	1 602 433	8,01
Hongrie	9 957 731	11 910 915	59,55	Monténégro	621 240	743 095	3,72
Biélorussie	9 643 566	11 535 127	57,68	Luxembourg	524 853	627 802	3,14
Azerbaïdjan	9 493 600	11 355 746	56,78	Malte	414 520	495 827	2,48
Suède	9 482 855	11 342 893	56,71	Islande	319 575	382 259	1,91
Autriche	8 443 018	10 099 095	50,50	Andorre	72 400	86 601	0,43
Suisse	7 954 662	9 514 949	47,57	Liechtenstein	36 475	43 629	0,22
Bulgarie	7 327 224	8 764 440	43,82	Saint-Marin	32 140	38 444	0,19
Serbie	7 276 604	8 703 892	43,52	Monaco	30 510	36 494	0,18
Danemark	5 580 516	6 675 120	33,38	Vatican	836	836	0,005
Slovaquie	5 404 322	6 464 366	32,32	**TOTAL**	**774 534 703**	**926 457 729**	**4632**

4.3. Clean energy production for desert cultivation & repopulation

Area needed to produce annual energy needs for MENA countries and annual energy needs for Europe (4116 + 4632= 8748 Mtoe) is (892 000 + 1 002 000= 1 894 000 km2). Remaining area for desert cultivation & repopulation is 5 062 500 km2. Figure 3 shows the number of inhabitant according to used area for greening and repopulation. The calculation was based on annual energy need per capita in 2030 which amounts 5toe and the need of land per capita for agriculture, building and green space purposes which amounts 1 hectare. If all remaining area used for deserts greening and repopulation, it can accommodate more than 456 Million people.

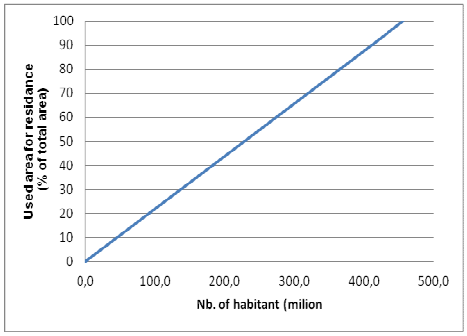

Figure 3: Number of habitant according to used area for greening and repopulation

5. Conclusions

MENA has one natural resource, which so far has received scant attention, despite an abundance that has few parallels around the world: Solar Energy and Silicon, which can participate in solving the energy and climate problems for a world in a sustainable way. Calculation results allowed us to conclude that MENA solar net annual energy potential using VLS-PV with buffer plants and roads (31 538 Mtoe) is more than 2 times higher of world primary energy consumption in 2030 (15000 Mtoe).

Even a small fraction of this solar potential: 15% would already be sufficient to meet Europe countries annual energy needs in 2030, 13% to meet MENA countries energy needs in 2030.

Using solar energy and advance sciences will certainly achieve higher levels of economic development of a community by biological agriculture, integration of unit of desalination of briny water that would permit to irrigate thousands of hectares and solve the serious problem of treatment of waters that pollute the environment and caused the destruction of thousands of palm trees in the deserts. It will also permit to Desert cultivation and repopulation.

It is hoped that this space becomes a haven of peace for future generations. Sharing this energy should become the engine for sustainable energy guarantees a global future for all populations, the unbreakable link between the countries for a lasting world peace. At the end of oil, there will be sun and sand.

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