PAPER • **OPEN ACCESS**

The Utilization of Solar Energy in the Building Sector in Mediterranean Countries

To cite this article: Nikos Papamanolis 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **410** 012045

The Utilization of Solar Energy in the Building Sector in Mediterranean Countries

Nikos Papamanolis

School of Architecture, Technical University of Crete, Building K4, University Campus, 73100 Chania, Greece

npapama@arch.tuc.gr

Abstract. In the Mediterranean region, relatively high solar radiation rates are recorded throughout the year. A part of this radiation is harnessed in energy production. At the same time, the similar climatic conditions in the area, justify comparable energy needs in key sectors of energy consumption (e.g. building, rural). Therefore, the Mediterranean area is an appropriate field for comparison and evaluation of data concerning production and consumption of renewable energy and in particular, of solar energy. Based on the available statistics, this work studies the production and consumption of solar energy in the building sector in the Mediterranean countries. It studies the evolution of energy production from the Sun in relation to energy production from other renewable and non-renewable sources. It also identifies and examines the factors that impact, positively or negatively, on the exploitation of solar energy in the building sector in the region. Insofar as the data permit, the study specializes in different areas of exploitation of solar energy (e.g. electricity generation, photovoltaic, solar thermal). The findings help to optimize the utilization of solar energy in the Mediterranean region and areas with similar climatic conditions.

1. Introduction

The Mediterranean basin and the surrounding countries are an important geopolitical area of the planet with many common characteristics. The climate is one of them.

The Mediterranean climate is characterized by a distinct alternation of seasons. Winters are mild and relatively rainy. Summers are warm and dry. During summers, there are no excessively high temperatures, as the temperature is tempered by the effect of the sea. Also, the feeling of heat is not stifling, because most days the relative humidity of the atmosphere is low. The spring season is a very unstable and transitional period, while autumn is mostly short term as winter starts abruptly. The Mediterranean region is characterized by increased sunshine and high values of solar radiation (Figure 1).

Mediterranean countries include southern European countries (Portugal, Spain, France, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece), the Near East (Turkey, Cyprus, Syria, Lebanon, Israel) and northern Africa (Morocco, Algeria, Tunisia, Malta, Libya, Egypt). The population of the Mediterranean basin is nearing 500 million and is expected to increase to 600 million by 2030, of which 60% will be on its south bank. Energy consumption in the Mediterranean region corresponds to 9% of the global demand and is expected to continue to grow by 1.5% per annum [2].

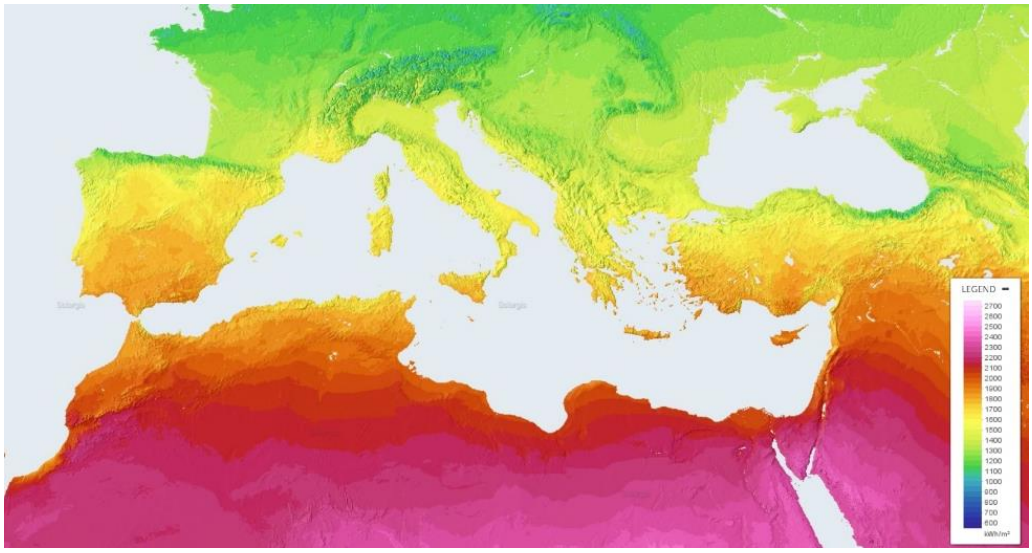

Figure 1: Average annual solar radiation on a horizontal level in the Mediterranean region [1]

This work studies comparatively the production and consumption of energy from RES in Mediterranean countries, with emphasis on the production and consumption of solar energy. It studies the evolution of energy production from the Sun in relation to energy production from other renewable and non-renewable sources. Based on the available statistics, it studies the production and consumption of solar energy in the building sector in the Mediterranean countries. It also identifies and examines the factors that impact, positively or negatively, on the exploitation of solar energy in the building sector in the region. Insofar as the data permit, the study specializes in different areas of exploitation of solar energy (e.g. electricity generation, photovoltaic, solar thermal). The findings help to optimize the utilization of solar energy in the Mediterranean region and areas with similar climatic conditions.

2. The Energy Profile of the Mediterranean

Energy production in the Mediterranean region is based on fossil sources (coal, oil, natural gas). It is estimated that by 2030 the energy consumptions from fossil sources in the region would exceed 80% of total consumption. A part of fossil fuel needs is covered by domestic stocks. North Africa gathers less than 5% of the world's proven oil and gas reserves. From all the countries producing fossil fuel in the Mediterranean region, only Libya, mainly due to its small population, has a potential stock of around 50 years. On the contrary, Algeria and Egypt, on the basis of existing data on their inventories, are being led to convert to energy importers. According to studies, oil production in the Mediterranean region is expected to increase only 20% in twenty years, and gas production is expected to double. On the other hand, the countries of the southern and eastern shores of the Mediterranean are at a crucial stage in their political, economic, social and energy development. It is therefore natural for them to face growth rates in energy demand of 6% to 7% and in some cases 8%. With this data, it is estimated that by 2030, the Mediterranean countries, in total, will import 40% and 30% of their oil and gas needs, respectively [2].

The Mediterranean region has significant resources in RES, mainly in solar and wind energy. It also has significant biomass reserves and potential geothermal energy reserves in Greece, Algeria and Morocco. Despite the high potential of resources and the will of most states to exploit them, the share of RES remains low, or even marginal in the energy balance of the southern and eastern Mediterranean States. However, it is noteworthy that this share has increased in recent years.

3. RES in the Mediterranean countries

Table 1 records the statistics describing the evolution of energy production from RES in the Mediterranean countries over the last decade. We observe that the trends, both overall (Figure 2), and for each country separately (excluding exceptions) are incremental, reflecting significant progress in the potential of installed renewable energy production in the region. The increase is basically due to solar

and wind power. We note that the countries located north of the Mediterranean (southern Europe) are the largest producers of renewable energy. In particular, Table 1 shows that, on the basis of the most recent statistics available (2016), countries such as France, Italy, Spain are placed at the forefront of the production of RES. Conversely, countries located on the southern shore of the Mediterranean display low performance. Moreover, in some of these countries there is stagnation or even negative trend (e.g. Lebanon, Libya, Algeria) in the development of RES applications.

Table1: Energy production from Renewables in Mediterranean (in Mtoe)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Portugal	4.5	4.3	4.8	5.6	5.4	4.6	5.6	5.8	5.2	5.8
Spain	10.0	10.3	12.4	14.6	14.0	14.7	17.6	18	16.9	17.7
France	16.5	18.7	19.0	21.1	18.2	20.8	23.2	21.5	22.0	23.9
Italy	16.0	18.8	19.3	19.4	18.2	21.1	23.5	23.6	23.6	23.8
Slovenia	0.7	0.8	1.1	1.1	1.0	1.0	1.1	1.2	1.0	1.1
Croatia	1.6	1.7	1.9	2.2	1.9	1.9	2.3	2.3	2.2	2.3
Bosnia and Herzegovina	0.5	0.6	0.7	0.9	0.6	0.5	0.8	1.2	1.2	1.2
Montenegro	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4
Albania	0.5	0.6	0.7	0.9	0.6	0.6	0.8	0.6	0.7	0.9
Greece	1.7	1.7	1.8	2.0	2.0	2.3	2.5	2.3	2.6	2.5
Turkey	9.6	9.3	9.9	11.6	11.2	12.1	12.7	12.0	15.7	17.1
Cyprus	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Syria	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.0	0.1
Lebanon	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Israel	0.8	1.1	1.1	1.2	1.1	0.4	0.4	0.5	0.5	0.5
Egypt	2.9	2.9	2.8	2.9	2.9	3.0	3.0	3.1	3.2	3.2
Libya	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Malta	-	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Tunisia	1.2	1.3	1.3	1.1	1.1	1.1	1.2	1.2	1.2	1.2
Algeria	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Morocco	1.9	1.8	1.8	1.8	1.6	1.5	1.7	1.6	1.7	1.7
Mediterranean Total	69.6	75.1	79.7	87.6	81.0	86.8	97.8	95.9	98.5	103.9
World Total	1220.4	1249.6	1274.3	1330.1	1360.3	1405.8	1449.9	1480.3	1516.3	1570.5

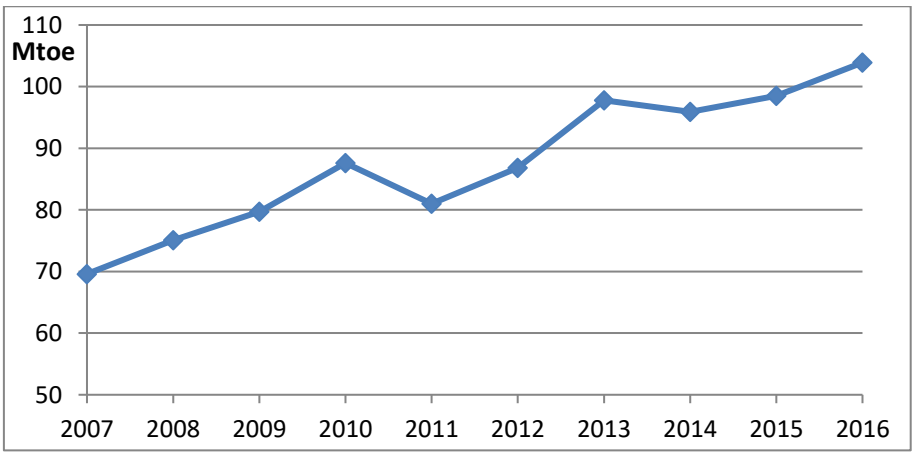

Figure 2: Evolution of the overall Energy production from renewables in the Mediterranean countries.

4. Solar energy in the countries of the Mediterranean

Mediterranean countries produce the 13.7% of world energy production from the Sun (Table 2). Largest producer country is Spain (36,962.2 GWh) followed by Italy (24,432.3 GWh) and Turkey (10,661.1 GWh). This production followed a steadily upward trend over the last decade in which it rose almost fivefold (from 19,343.8 GWh to 98,484.9 GWh). The rise was steepest for the Solar PV component. At the beginning of the decade it had an insignificant contribution to total energy production. However, by end of the decade it had achieved similar levels of production to the Solar thermals (Figure 3).

Table 2: Energy from the Sun in the Mediterranean countries in the year 2016.

Country	Solar thermal [GWh]	Solar PV [GWh]	Total [GWh]
Portugal	976.4	822.0	1,798.4
Spain	28,892.2	8,070.0	36,962.2
France	1,171.9	8,160.0	9,331.9
Italy	2,328.3	22,104.0	24,432.3
Slovenia	126.9	267.0	393.9
Croatia	134.4	66.0	200.4
Bosnia and Herzegovina	0.0	24.0	24.0
Montenegro	2.2	0.0	2.2
Albania	148.3	0.0	148.3
Greece	2,328.9	3,930.0	6,258.9
Turkey	9,618.1	1,043.0	10,661.1
Cyprus	801.9	146.0	947.9
Syria	0.0	0.0	0.0
Lebanon	282.5	0.0	282.5
Israel	4,413.1	1,544.0	5,957.1
Egypt	0.0	168.0	168.0
Libya	0.0	8.0	8.0
Malta	50.8	125.0	175.8
Tunisia	580.8	63.0	643.8
Algeria	0.0	87.0	87.0
Morocco	0.0	1.0	1.0
Mediterranean Total	51,856.9	46,628.0	98,484.9
World Total	393,050.8	328,038.0	721,088.8

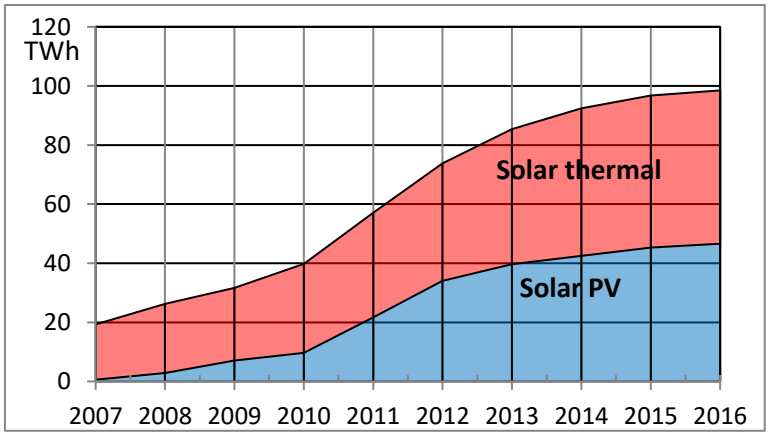

Figure 3: Evolution of total energy production from solar systems in the Mediterranean region.

From the available data for the utilization of solar energy in the Mediterranean countries, it is apparent that the total amounts of energy harvested through photovoltaic systems are comparable to those that are harvested through solar thermal systems. However, the variations from country to country are distinct. In some countries (e.g. Spain, Turkey, Cyprus, Israel) the solar thermal prevail and in other countries (e.g. Italy, France, Greece) the photovoltaic.

Table 3 registers the evolution of the per capita solar energy consumption in Mediterranean countries. The data refer to the decade from 2007 to 2016 and include energy that has been harvested cumulatively from photovoltaic and solar thermal systems. The trend, for the countries listed in the table, is clearly positive. From this table, for the last year official data is available (2016), it follows that the first country in per capita consumption of solar energy annually in the Mediterranean is Cyprus (with 1115.2 kWH per capita), followed by Spain (803.5 kWH per capita) and Israel (661.9 kWh per capita).

Table 3: Annual per capita consumption of solar energy in Mediterranean countries (in kWh/per capita) [4,5].

Country	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Portugal	29.2	35.7	51.4	70.0	88.4	106.9	132.5	152.1	172.9	179.8
Spain	35.5	88.2	179.6	256.1	334.8	595.7	699.8	785.7	805.0	803.5
France	7.5	9.7	13.0	21.1	44.7	75.2	87.5	106.4	125.6	139.3
Italy	10.9	16.5	27.7	57.8	207.1	344.5	386.0	399.9	412.3	400.5
Slovenia	0.0	0.5	46.3	53.9	84.4	138.3	168.2	191.3	200.3	197.0
Croatia	9.4	11.5	13.3	15.1	17.6	21.3	26.7	35.9	44.5	50.1
Bosnia and Herzegovina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Montenegro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.6	3.6
Albania	24.4	25.2	25.7	26.0	45.4	45.7	46.1	48.1	48.0	49.4
Greece	169.0	183.5	197.3	208.2	248.8	348.9	529.4	547.5	562.1	569.0
Turkey	69.8	68.8	69.3	68.8	99.0	119.1	121.7	121.5	127.5	136.7
Cyprus	821.3	839.7	847.0	870.7	882.3	897.7	932.4	1000.8	1076.7	1115.2
Syria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lebanon	29.0	33.5	38.5	43.8	39.1	46.6	49.7	44.5	46.0	47.1
Israel	1241.6	1765.7	1730.6	1640.0	1623.7	491.4	561.8	652.4	691.0	661.9
Egypt	0.0	0.0	0.0	2.5	2.6	2.7	1.3	2.7	1.8	1.8
Libya	0.5	0.7	0.8	1.0	1.0	1.2	1.3	1.3	1.3	1.3
Malta	22.4	25.7	26.4	106.2	120.4	152.2	183.5	273.1	332.6	399.6
Tunisia	0.0	0.0	0.0	28.8	33.0	37.8	42.7	48.2	53.1	58.5
Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.1
Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A significant part of the progress in the utilization of solar energy in the Mediterranean countries is directed to the building sector. Figure 4 presents the evolution of the energy consumption by solar thermal systems in the building sector (Residential + Commercial and public services) in the Mediterranean countries with the highest consumptions. It is also noteworthy that seven Mediterranean countries (Spain, France, Italy, Greece, Turkey, Israel and Tunisia) are among the top 20 countries with Solar Water Heating collectors and Total Capacity at the end of 2016 and Newly Installed Capacity at the 2017 [6].

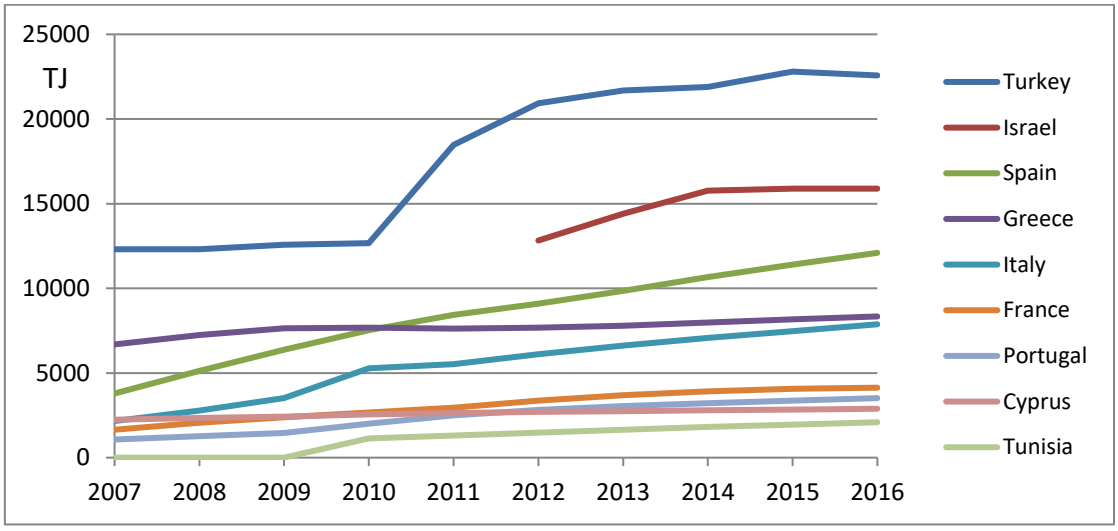

Figure 4: Evolution of the energy consumption by solar thermal systems in the building sector (Residential + Commercial and public services) in the Mediterranean countries with the highest consumptions.

For the countries of North Africa, the performance in the area of solar energy utilization is, in general, modest - however, incompatible with their high potential - it has been estimated that, technically, this potential is sufficient to cover all the Energy needs of the planet. However, it is noteworthy that in recent years significant efforts have been recorded by these countries to catch up with the more advanced in the field of exploitation of solar energy countries of northern shores of the Mediterranean. As an example, Morocco within the framework of a programme for the construction of power plants 10 GW for the production of electricity from RES until 2020, has begun the construction of the largest solar park in the world, power 580 MW [7]. Similarly, Egypt, aiming to cover 20% of energy-generating power from RES up until 2022, of which 2.2% will come from solar energy, plans to build 3.5 GW solar power plants with a completion horizon of 2027 [8]. Similar grandiose programmes are in the planning or implementation phase in Algeria (Power 4.6 GW), Tunisia, Libya and also on the northern shore of the Mediterranean (Spain, Italy, etc.), which is estimated that, if completed, up to 35% of the energy needs of the region could be covered. These programmes are likely to have already influenced the correlations in the performance of solar energy utilization among Mediterranean countries, which, due to the delay in the publication of statistical data, will become evident in a few years. However, the growing growth of the RES sector in Mediterranean areas often comes up against problems and challenges, such as shortcomings in regulatory standards, infrastructure etc [9].

5. Conclusions

The Mediterranean basin and the surrounding countries are part of the planet with very rich potential in RES, mainly solar energy. This potential, based on the available data, it is not used equally in all countries and regions of the Mediterranean. Thus, the countries on its north bank are the ones that seem to have developed more appropriate infrastructure and facilities for more intensive exploitation. However, there are clear differences between the elements illustrating the performance of these countries in the exploitation of solar radiation - a typical example of these are the different technologies (photovoltaics, solar thermal) prevailing in different countries. On the contrary, the countries in the eastern and, above all, the southern shores of the Mediterranean lag considerably behind in this area. This finding is in stark contrast to the fact that the rates of solar radiation are clearly higher on the southern shore of the Mediterranean. In addition to the availability of resources and other factors such as institutional, economic, social, technological, infrastructure, they have a strong impact on their utilisation.

It is encouraging that the use of solar energy in the Mediterranean region has been increasing in recent years. This trend will certainly be supported by the major projects which are currently under way in many countries in the region, particularly in countries that have hitherto been lagging behind in the area of RES utilization. In this way, the achievement of the objectives set by international organisations (and the EU) for tackling climate change and sustainable development is reinforced through the coverage of a significant part of the energy needs from RES.

References

[1] Global Solar Atlas, http://globalsolaratlas.info/?c=39.225447,13.992186,5&s=54.815879,63.449113&m=sg:ghi&l=0

[2] Euro-Mediterranean Regional and Local Assembly (ARLEM), 2012, "The promotion of renewable energy sources as a factor of the common economic and social development of the Mediterranean region", http://cor.europa.eu/en/activities/arlem/Documents/report-on-renewable-energies-2011/EL.pdf

[3] Knoema, World Development Indicators (WDI), https://knoema.com/WBWDIGDF2017Sep/world-development-indicators-wdi?gclid=EAIaIQobChMInITq4Pu21wIVIgvTCh36aAD7EAAYASAAEgIgB_D_BwE&accesskey=olmgapg

[4] Eurostat, Primary production of renewable energy by type, http://ec.europa.eu/eurostat/tgm/table.do?tab=table&tableSelection=4&labeling=labels&footnotes=yes&layout=time,geo,cat&language=en&pcode=ten00081&plugin=1

[5] IEA, Atlas of Energy, Renewables, http://energyatlas.iea.org/#!/tellmap/-1076250891

[6] REN21, Renewable Energy Policy Network for the 21st Century, Renewables 2018, Global Status Report, p. 325, file:///E:/17-8652_GSR2018_FullReport_web_-1.pdf

[7] https://www.theguardian.com/global-development/2016/nov/17/cop22-host-morocco-lights-way-africa-renewable-energy-2020

[8] https://www.export.gov/article?id=Egypt-Renewable-Energy

[9] http://www.medaeconomicweek.org/the-mediterranean-solar-energy-as-a-source-of-sustainable-growth/