APPLYING CAPACITY OF RENEWABLE ENERGY RESOURCES FOR ELECTRICITY SUPPLY

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ABSTRACT: *When considering development of human society, it is more than obvious that it registered huge advances, especially in the last century in diverse human-related activity fields, fact that has been possible without any doubt because of applying diverse technologies which need for their operation energy resources among other material resources. Recorded progress in technological field was possible based on using fossil fuels for electric and thermal energy supply, which have had as a result not only positive impacts anyway but also undesired ones in form of environmental pollution. Nowadays, debated climate change and global warming as effect of huge CO2 emissions is bringing new innovative targets on the base of applying renewable energy resources for assuring electricity supply in a sustainable manner. Much discussed renewable energy resources have materialized in solar energy, wind power, hydro power, and bioenergy. By considering single renewable energy resouces as well as natural geographical conditions in Arab World represented by high levels of solar radiation, existing odds for electricity supply based on solar power by photovoltaic panels are pointed out by taking into account regional differences. Following this target, a case study for some Arab countries will be presented about solar energy usage possibilities by photovoltaic panels systems. Finally, some conclusions will be drawn about real applying odds of renewable energy resources in Arab World for warranting sustainable energy supply of human society in this part of the world.*

Keywords: *Energy Resources; Electricity Supply; Regional Conditions; Photovoltaic Panels; Renewable Energy Resources; Sustainability;*

Introduction

Registered huge progress especially in the last century in diverse human-related activity fields was possible without any doubt because of designing and applying diverse technologies and technological applications which need for their operation energy resources among other material resources [15]. Thus, registered advance in technological field was feasible based on applying fossil fuels for electric and thermal energy supply, which have had as a result positive impacts also undesired negative ones materialized in environmental pollution [8]. After the Conference for Environment in Stockholm in 1972 and the first report to the Club of Rome „Limits of the Growth", published also in 1972, was finally understood that besides wanted effects of technological progress, undesired and negative effects can appear [10]. Currently humanity is confronting itself with a series of global problems, which can be grouped in three categories: growth of world population, increase of energy and resources consumption and environmental pollution, as presented in Figure 1 [12]. They can be called "old" problems, because other issues have arisen in the last years and they can be called "new" global problems. As a result, for the first time the concept of sustainable development has been defined in the Brundtland Report and fast accepted as a possible answer to global complex environmental, technological, economic and social challenges [7]. This concept was deeply debated during the Conference for Environment and Development in Rio de Janeiro 1992 as well as approached in the closing document „Agenda 21" [5]. Lot of discussions followed this time anyway till nowadays there is no unique target about applying odds of the concept of sustainable development on diverse levels and in various conditions [14].

Nowadays, debated climate change and global warming as effect of huge CO2 emissions is bringing new innovative targets on the base of applying renewable energy resources for assuring electricity supply in a sustainable manner [2].

Much discussed renewable energy resources have been materialized in solar energy, wind power, hydro power, and bioenergy [12] (Fig. 1).

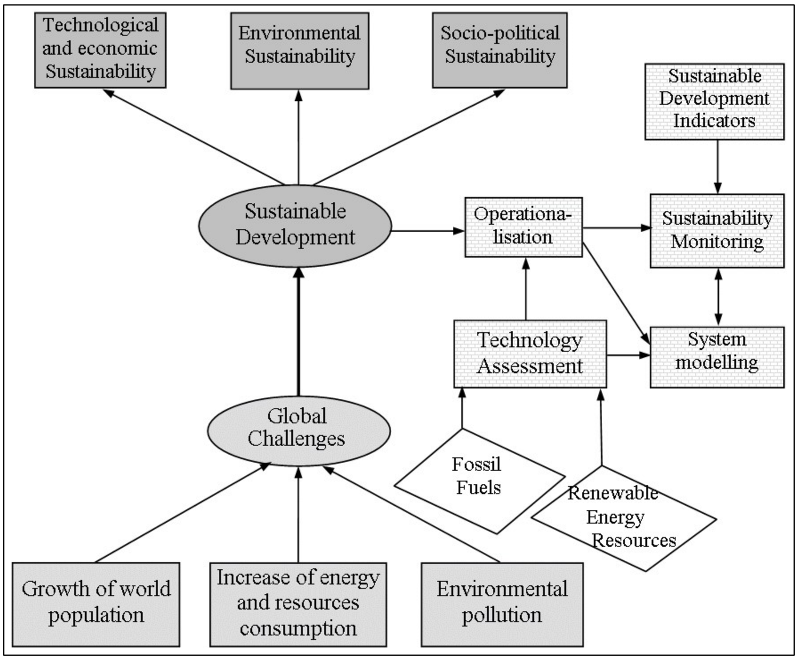

Fig. 1. Global challenges and the concept of sustainable development.

As already emphasized, the rapid advance of human society has been feasible mainly because of technological advance and innovative developments of technological applications what has bought over the years an intensive usage of natural resources especially of energy resources [8]. Though, while fossil fuels have registered the main role in supporting industrialization and the increase in the global electricity and heating need of human society, their extensive application has also had as a result serious environmental impacts [8, 10].

Among these impacts, most pressing issue is nowadays registered because of the uncontrolled increase of carbon dioxide (CO) emissions, which are recognized largely as being the main contributors to anthropogenic climate change and global warming [8, 13). On the other hand, the limited availability of fossil fuels constitutes another challenge because current technological applications and economic activities have over the years remained strongly dependent on non-renewable resources [14]. To try successfully overcoming this provoking situation, renewable energy resources have emerged as feasible option to ensure shaping sustainable energy supply of human society. Among renewable energy resources most debated nowadays are solar and wind resources, as well as hydropower, and bioenergy [2, 9].

By considering solar energy resources and diverse levels of solar radiation depending on various geographical regions, the possibility of solar energy usage by photovoltaic panel systems for electric energy supply in the Arab world will be emphasized. Specifically, the situation of Jordan will be pointed out as being a convincing example in analyzing and assessing the feasibility and advantages of applying solar power [1, 4, 16].

Finally, highlighted case study will for sure demonstrate the applying capacity of renewable energy resources for electricity supply and by this the crucial role of renewable energy in advancing environmental protection and assuring long-term energy supply of human society, anyway the need of carefully analysis and assessment of connected provocations and negative impacts will be simultaneously pointed out [2, 8, 12].

Materials and Methods

When applying the concept of sustainable development, it is to be considered that this actually means transforming or translating its objectives into technical, socio-political and educational measures as well as into monitoring and controlling tools about shaping most representative sustainability targets [7]. In this context sustainability operationalization means to respect a general methodology which can be materialized in the following steps [12]:

- defining sustainability problem in analyzed region;
- establishing space and time scales;
- systemic approach of the region by modeling the interactions;
- establishing concrete aims for studied case;
- designing concepts and measures by establishing priorities;
- developing monitoring, assessing and controlling tools in form of indicators;
- verifying potential results, which could be got after introducing proposed measures by carrying out simulations and comparing different potential developing scenarios;
- applying into the practical situation designed concept for considered case.

In this context, part of engineers'tasks is not only designing and developing technologies or technological applications but also assessing potential technological developments [8, 12]. Made assessments have been focused up to now almost without exception on technical and physical criteria as well as on economic ones following legal and financial boundary conditions [13]. Anyway, with respect to sustainability considerations, more criteria have to be considered like environmental quality, social and human values, quality of life [8]. Assessing technologies in an extensive way by considering technical and physical criteria as well as environmental and social ones, can be carried out by applying the pretty new discipline called Technology Assessment, TA [6, 13].

Presented case study was carried out to assess the possibility of applying solar energy in the Arab world for electric energy supply with main focal point on Jordan [2, 9, 15]. Several specific geographic and technological characteristics in analyzed region must be considered such as solar radiation levels, available photovoltaic technologies as well as their concrete applicability in local Arab conditions [1, 11]. Used methodology based on a literature review, then data analysis as well as comparative calculation and assessing solar energy potential across selected regions [3, 9].

In a first step the step of collecting relevant data followed such as information about solar radiation intensity, average sunshine duration, and climatic conditions from reliable scientific databases such as NASA's Surface Meteorology and Solar Energy dataset, the World Bank, and national energy authorities in the Arab countries [4]. Additional data about energy consumption, existing projects in the field of using solar energy resources, and government policies were got from official reports of the Jordanian Ministry of Energy and Mineral Resources, https://www.memr.gov.jo/Default/En .

In a second step collected data have been analyzed applying a comparative framework for assessing the feasibility of implementing photovoltaic system in various Arab regions [1, 4]. As mentioned in the literature about photovoltaic panels, as the one presented in Figure 2, main characteristics when applying solar energy for electric energy supply are represented by solar potential quantified by solar radiation as well as diverse parameters of specific technical infrastructure [1, 2] as the following:

- Global horizontal irradiance (GHI);
- Average daily solar radiation (kWh/m²/day);
- PV system efficiency and output estimation;
- Cost–benefit analysis of PV installation in urban and rural settings.

The real-world applicability of debated methodology has been demonstrated by the case study developed for concrete situation of Jordan. Going into details, carried out analysis includes assessing average solar potential, estimating the annual energy production by support of a PV installation, and identifying potential challenges such as dust accumulation, temperature effects, and grid integration issues [1, 11].

In a third step a model has been designed for succeeding in calculating electric energy production by photovoltaic panels for some case studies in the example of some Arab countries, such as Algeria, Jordan, and Tunisia [1, 11].

The yearly electric energy produced by a photovoltaic panel can be calculated by the relation [2]:

$$E = A \times R \times H \times PR \text{ [kWh]} \quad (1)$$

where:

E = Supplied electric energy [kWh]

A = Total surface of photovoltaic panels system [m²]

R = Photovoltaic panel efficiency [%]

H = Annual average solar radiation [kWh/m2]

PR = Performance ratio

Such an estimation possibility related to electric energy possible to be produced by using solar energy resources by photovoltaic panels has proven large applicability in diverse parts of the world where the usage possibility of solar energy is considerable because of the fact that the solar radiation has a high value all over the year as the situation in the Arab World [2, 11, 16] (Fig. 2).

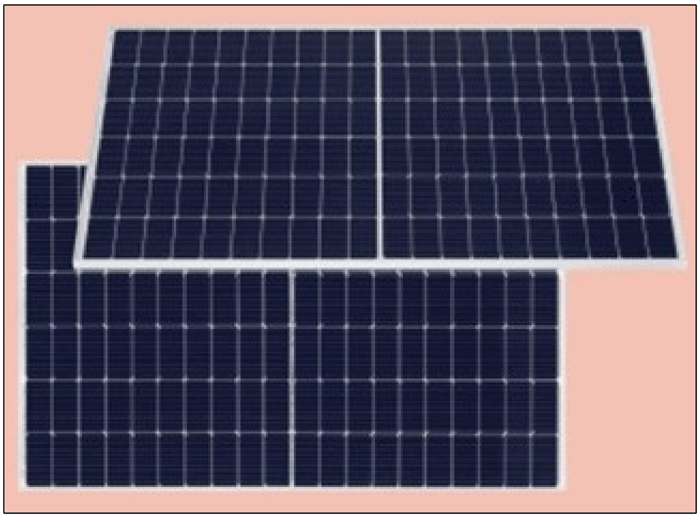

Figure 2. Photovoltaic panels of type LG NeON, (https://www.satmultimedia.ro/panou-fotovoltaic-lg-neon-r-h-bifacial-440w-144-celule-eficienta-22-5-p235876)

By assuming a photovoltaic panel with the power P = 440 Wp, as presented in Fig. 2, https://www.satmultimedia.ro/panou-fotovoltaic-lg-neon-r-h-bifacial-440w-144-celule-eficienta-22-5-p235876/ and by knowing specific details, as the total surface of A = 2,22 m2, the panel efficiency, R = 22,5 % and the performance ratio, PR = 75%, it is possible to calculate the electric energy produced by a photovoltaic panel, then by a photovoltaic panels set in dependance of the annual average solar radiation in considered region.

Knowing the electric energy consumed in a year in different Arab countries, such as in this case study in Algeria, Jordan, and Tunisia, it is possible to estimate the number of photovoltaic panels, which are needed to ensure electric energy supply to cover registered consumption in mentioned countries.

As already emphasized, solar energy can be applied to produce either thermal energy or electric energy depending on available infrastructure in this regard [9, 14]. By considering natural conditions in Arab countries the solar radiation can be estimated, then the amount of electric energy supply by photovoltaic panels can be estimated by applying previously presented model [1, 16].

To calculate the total yearly electric energy possible to be supplied by a photovoltaic panel after relation (1) there is a need to know the average yearly solar radiation in each considered country, which can be got from the solar radiation map from Figure 3.

Results

1. Usage Odds of Solar Energy in Algeria

By knowing the solar radiation for Algeria from the map in Figure 3, which is H = 2300 kWh/m2, the produced electric energy by a photovoltaic panel can be calculated with rel. (1) and results

$$E_{panel} = 861{,}6 \text{ kWh}$$

By operating photovoltaic panels sets in 2P format having coupled 26 single panels, as presented in Figure 4, it is possible to calculate the installed power of a photovoltaic panel set as being:

$$P_{set} = n_p \times P_{panel} = 11440 \text{ Wp[W]}$$

Going further into details, it follows that the electric energy supplied by such a set of photovoltaic panels as the one presented in Figure 4, containing np = 26 panels, can be calculated as:

$$E_{set} = n_p \times E_{panel} = 22401{,}6 \text{ Wp} \qquad [W]$$

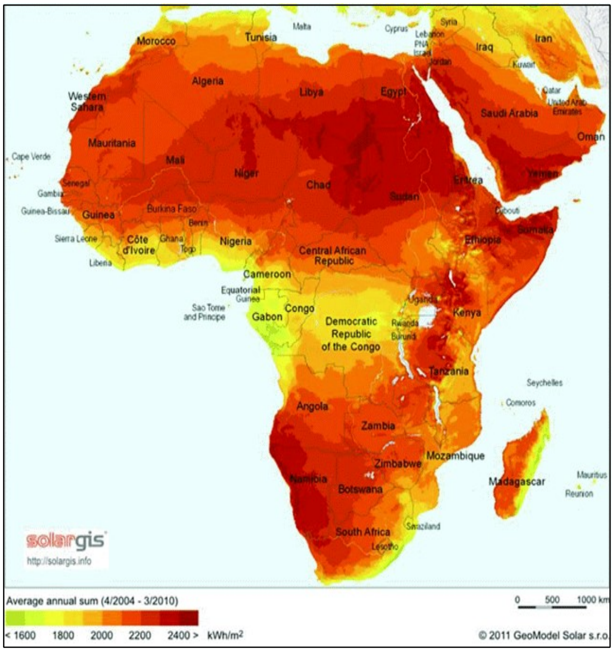

Fig. 3. Solar radiation map for Africa and Arab World (https://www.researchgate.net/figure/Global-Solar-Radiation-Map-for-Africa-and-Middle-East-5_fig3_311940146)

Knowing consumed electric energy in Algeria in 2023 of:

$$E_{cons} = 85687 \text{ Gwh}$$

(https://countryeconomy.com/energy-and-environment/electricity-consumption/algeria), it is possible to determine the needed number, n, of photovoltaic panels to succeed in supplying needed electric energy in Algeria for 2023 as being:

$$n = E_{cons}/E_{set} = 3825039$$

photovoltaic panel sets

2. *Usage Odds of Solar Energy in Jordan*

Following same methodology, by knowing the solar radiation for Jordan from the map in Figure 3, H = 2400 kWh/m2., it is possible to calculate produced electric energy by a photovoltaic panel with rel. (1) and results:

$$E_{panel} = 861{,}6 \text{ kWh}$$

The electric energy supplied by a set of photovoltaic panels as the one presented in Fig. 4, containing np = 26 panels is in conditions of Jordan:

$$E_{set} = n_p \times E_{panel} = 23376{,}6 \text{ kWh}$$

Knowing consumed electric energy in Jordan in 2023 of Econs = 21769 GWh (https://www.memr.gov.jo/ebv4.0/root_storage/en/eb_list_page/energy_balance_2023.pdf), the needed number, n, of photovoltaic panels can be calculated to succeed in supplying needed electric energy in Jordan for 2023 as being:

$$n = E_{cons}/E_{set} = 931457 \text{ photovoltaic panel sets}$$

3. *Usage Odds of Solar Energy in Tunisia*

Following same methodology, by knowing the solar radiation for Tunisia from the map in Figure 3, which is H = 5200 kWh/m2 it is possible to estimate electric energy delivered by a photovoltaic panel with rel. (1) and results:

$$E_{panel} = 1948 \text{ kWh}$$

The electric energy supplied by a set of photovoltaic panels as the one presented in Fig. 4, containing np = 26 panels is in conditions of Tunisia:

$$E_{set} = n_p \times E_{panel} = 50648 \text{ kWh}$$

Knowing the consumed electric energy in Tunisia in 2023 of 19870 GWh, (https://www.iea.org/countries/tunisia/electricity) it is possible to estimate the needed number, n, of photovoltaic panels to succeed in supplying needed electric energy in Tunisia for 2023 as being:

n = Econs/Eset = 849995 photovoltaic panel sets

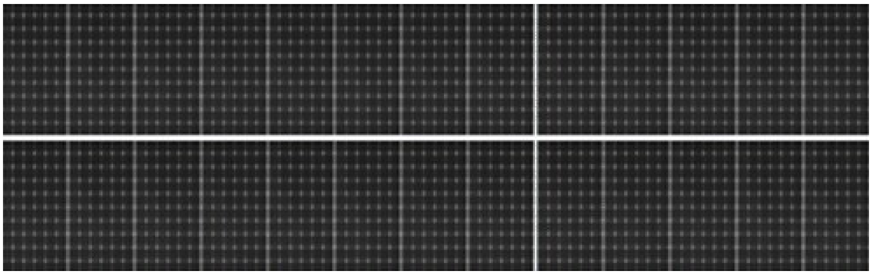

Fig. 4. Photovoltaic panels set in 2P format (with single panels)

Discussion

Obtained results regarding the number of photovoltaic panels sets which are needed in considered Arab countries to cover the electricity consumption in each country for 2023 emphasize that there is a need of a huge number of photovoltaic panels sets. Going into details, for Algeria there is a need of about 3 million sets, for Jordan and Tunisia of about one million sets. Got results start another task related to the huge, needed surfaces to succeed in placing these panels in best conditions of solar radiation to ensure their proper operation for electric energy supply. This result demonstrates the need of detailed technical analyses and assessments about producing and placing such a huge number of photovoltaic panels. Such an endeavor provokes societal debates about provocations related to impacts of future use of renewable energy resources, especially solar ones as in presented case study.

Conclusion

For electric energy supply are starting renewable energy resources to be efficiently applied in the case of solar energy resources by photovoltaic panels. In this context, Arab countries, having high levels of solar radiation, demonstrate several possibilities to use solar energy for producing electric energy by photovoltaic panels. In debated case study several Arab countries have been taken into account, concretely Jordan, Tunisia and Algeria. For each country the number of needed photovoltaic panels have been calculated for covering the energy consumption of 2023. As a conclusion, calculations emphasize that there is a need of a huge number of photovoltaic panels sets to cover the energy consumption registered in these countries and connected to this matter there is a need for huge surfaces to succeed in positioning all needed photovoltaic panels sets.

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