

## APPLYING POSSIBILITIES OF SOLAR CADASTRE IN ARAB WORLD FOR ELECTRICITY SUPPLY

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**Abstract:** Human development has been possible by designing technological applications using diverse energy resources. Anyway, recorded progress has been feasible because of using fossil fuels for energy production, fact that has had as a result also undesired environmental pollution, especially by CO<sub>2</sub> emissions bringing much debated global warming. Connected to fossil fuels, they have limited availability, renewable energy resources being understood as solution for assuring energy supply. In this context, Arab countries could play an important role regarding the usage of solar energy for assuring electric energy supply. Related to this fact, solar cadastre is currently much debated, implying main data collection by considering different natural conditions such as diverse levels of solar radiation. Available odds of power supply by photovoltaic panels by using solar cadastre will be pointed out in Arab countries, a case study for Jordan being presented. Applying potential of photovoltaic panels will be emphasized where the role of solar cadastre will be emphasized. Finally, some conclusions will be drawn about applying potential of solar cadastre for power supply.

**Keywords:** solar cadastre, photovoltaic panels, solar radiation, land footprint, Arab World, environmental impact

### 1. Introduction

Starting with the '70s the world began to notice also the dangers and undesired impacts of human activities, especially industrial ones. After releasing the first report to the Club of Rome „Limits to Growth“ in 1972, and carrying out the Conference for Environment in Stockholm in the same year it was finally understood that besides desired impact of technology advance, undesired negative impact can be noticed [1]. Following same evolution trends, the environmental awareness in the Western World has begun to change. In that time, it started to become clear that arisen regional and global environmental challenges are stringent and cannot be anymore neglected, needing to be debated for finding potential solutions [2]. Humanity confronts nowadays several global challenges, as presented in Figure 1, which can be mainly divided into three groups: world population growth, growth of energy and natural resources consumption and environmental pollution [2].

Debates on scientific, social and political levels began to try finding appropriate solutions for the challenges presented above, which could be applicable with respect to regional differences to the developed as well as to the developing countries [3]. After several debates the Brundtland Report of the World Council on Environment and Development was published, representing a result of worldwide scientific, social and political debates [4].

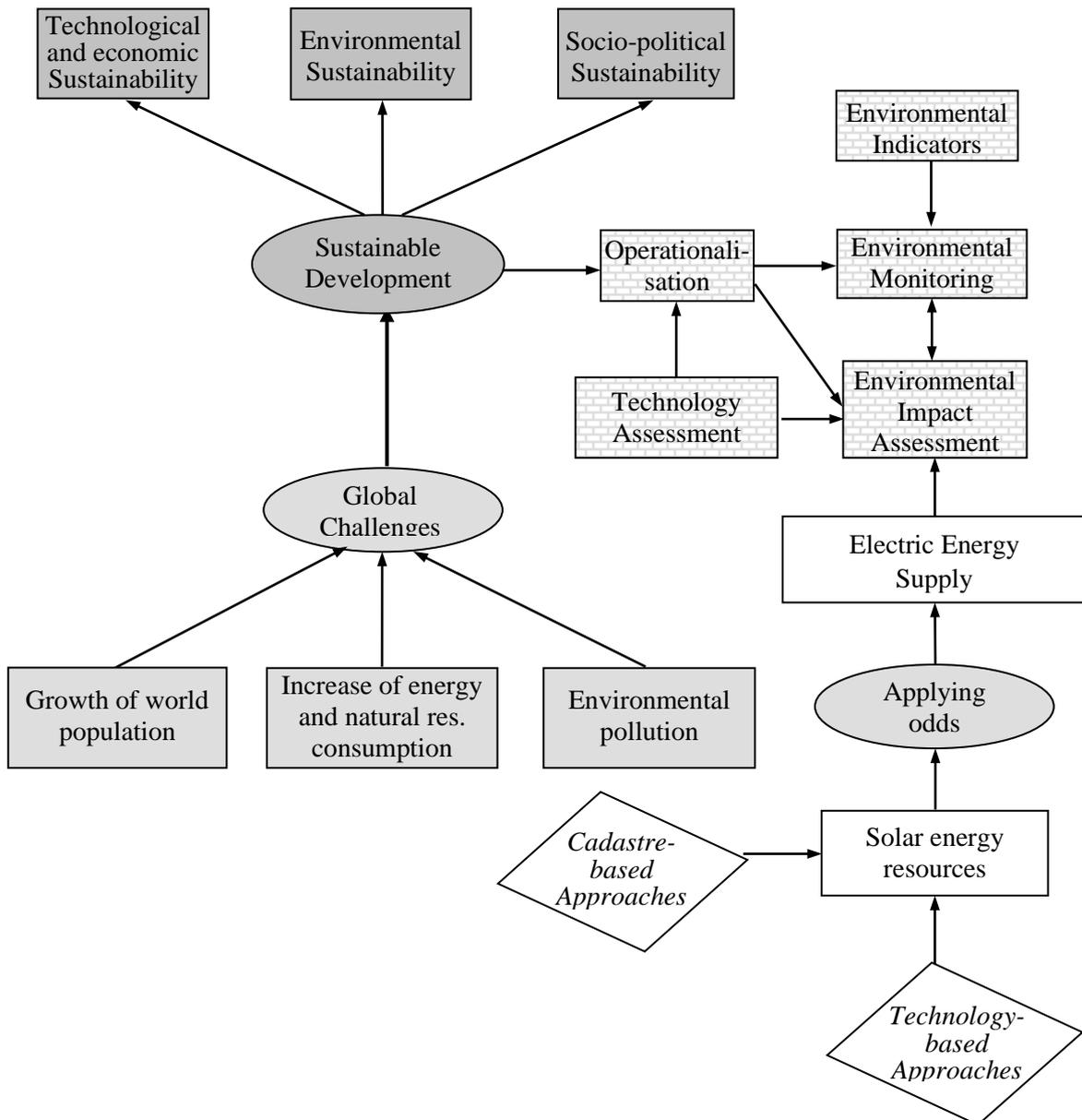


Figure 1. Role of Cadastre and Technology based Approaches for Operationalization of Sustainable Development

The release 1987 of mentioned Brundtland Report had a decisive importance because the concept of sustainable development was first defined in the Brundtland Report 1987 and accepted as a potential answer to the global complex environmental, economic and social challenges [4]. The concept of sustainable development was much debated after its definition during several conferences and events, as for instance on the Conference for Environment and Development in Rio de Janeiro 1992, known as “Rio” – Conference as well as in the closing document „Agenda 21“ [5]. Ten years later 2002 took place in Johannesburg, South Africa, the World Summit on Sustainable Development, known as “Rio+10” – Conference [6].

Many actions after this time have been carried out, emphasizing that the evolution of technical, environmental and social systems must be analysed in synergetic relation. In this context “Rio+20” – Conference is to be mentioned, held 2012 again in Rio de Janeiro in Brazil, where the concept of sustainable development has been again debated from the point

of view of concrete applying possibilities [7]. Next conference, organized in 2025, took place in Belém, Brazil, the United Nations Climate Change Conference, also known as the Conference of the Parties to the UNFCCC (COP30), marking other ten years, more precisely 13 years, being the 30th session of the United Nations Climate Change Conference [8]. Looking on the special activities during COP30 it can be concluded that global cooperation for keeping climate change under control is alive and tries to keep humanity on track in the fight for mitigating environmental impacts of economic activities [8].

In this context a particular relevance has become assuring possibilities for energy supply of the world population with minimum environmental impacts, where applying renewable energy resources plays a main role especially solar energy resources for power supply in Arab World because of pretty high levels of solar radiation in this part of the world, solar cadastre starting to become a pretty important role in this context [9, 10, 11].

## 2. Materials and Methods

Sustainable development has become a widely used term today. The last time it has been clear that increasing humanity's quality of life has been possible by modern sophisticated technology applications [2]. Anyway, the positive direct impact of designing and operating such applications by registered technological advance has always been attended by indirect unwanted effects in different fields as in energy supply one [12, 13]. Energy supply represents in the meantime a main task, supporting humanity life, and supporting developing way in each country in the world [13]. By considering the concept of sustainable development of humanity the most suitable way in this context currently seems to be analyzing usage odds of renewable energy resources for energy supply, such as solar, wind, water as well as bioresources [2].

Considering regional aspects, it is obvious that to assure sustainable energy supply in Arab countries main role is played by existing solar energy in each region of the world [14]. Natural conditions in each region of the world are influencing different levels of solar radiation and by this are shaping the real potential to gain different energy types in considered regions [15].

Available possibilities to generate electric energy by applying solar energy resources in Arab World is emphasized especially by considering specific natural conditions in the case of Jordan emphasizing by this the existing possibilities to shape in this region of the world sustainable energy supply systems. Finally, corresponding conclusions will be drawn about assuring sustainability of human society by applying renewable energy resources [3].

Regarding getting a high efficiency in applying solar energy for power supply it is needed to first shape so-called *solar cadastre* in considered region [16]. The procedure of solar cadastre is represented by mapping a certain territory, highlighting the solar radiation, i.e. the amount of solar energy reaching Earth surface [11]. Marking the solar radiation with diverse colors in order to represent several levels of it, a solar cadastre can have several levels of precision and thus provide more precise values depending on the intended utilization [11, 17].

Solar cadastre represents an important aspect to be considered when choosing the optimal areas for placing photovoltaic panels and it is mainly based on digital terrain model and climate information for approached regions. Approaching solar energy in detailed manner assured by the full potential of solar cadastre can be used in various fields of environmental and civil engineering as well as in urban planning, and future needed infrastructure development.

Solar energy can be applied to produce either thermal energy or electric energy depending on available infrastructure in this regard [13, 14]. By considering natural conditions in Arab countries, especially in Jordan, the solar radiation can be estimated, following by this that by solar cadastre, as presented in Figure 2, the amount of electric energy supply by photovoltaic panels is to be deduced by applying presented model.

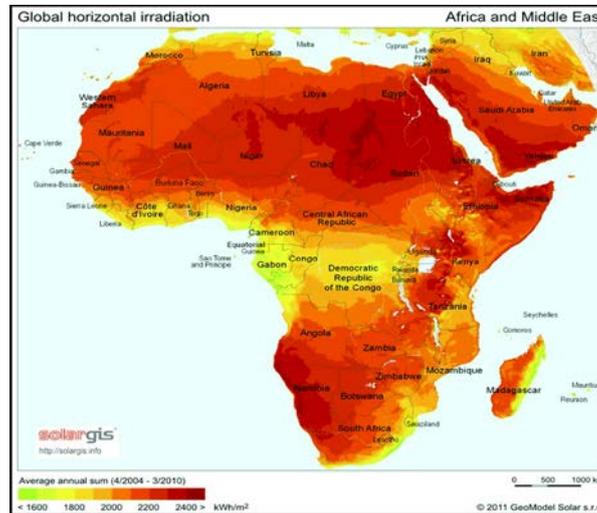


Figure 2. Land solar cadastre as solar radiation map for Africa and Arab World ([https://www.researchgate.net/figure/Global-Solar-Radiation-Map-for-Africa-and-Middle-East-5\\_fig3\\_311940146](https://www.researchgate.net/figure/Global-Solar-Radiation-Map-for-Africa-and-Middle-East-5_fig3_311940146))

Nevertheless, a main aspect when designing solar power plants by applying photovoltaic panels is represented by the need of extended lands to be covered by photovoltaic panels [18]. Anyway, one option to produce electric energy in urban areas is by applying solar energy, where the solar radiation potential is emphasized by solar cadastre, which provides data about yearly solar radiation on the base of GIS [16]. The current solar maps have different levels of advancement.

For succeeding in finally getting a land solar cadastre, several technical parameters must be considered such as values for solar radiation, meteorological parameters, shadowing aspects in considered area. Without considering several mentioned parameters, data for solar cadastre would not be useful as they would not be very reliable and could not support improving the efficiency of solar power plants [16]. On the other side, made experiences have emphasised that solar power plants need significant land, depending on their capacity, varying greatly by panel efficiency, solar radiation, mounting conditions as well as by site design [19].

For approaching the possibility of electric energy production by photovoltaic panels the model for establishing potential yearly electric energy to be produced knowing land solar cadastre can be applied using following relation [10, 18]:

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

where:

- $E$  = Supplied electric energy [kWh]
- $A$  = Total surface of photovoltaic panels system [m<sup>2</sup>]
- $R$  = Photovoltaic panel efficiency [%]
- $H$  = Annual average solar radiation [kWh/m<sup>2</sup>]
- $PR$  = Performance ratio

By considering a photovoltaic panel with the power  $P = 440 \text{ W}_p$ , as presented in Fig. 1 and by knowing specific details, as the total surface of  $A = 2,22 \text{ m}^2$ , the panel efficiency,  $R = 22,5 \%$  and the performance ratio,  $PR = 75\%$ , it is possible to calculate electric energy produced by a photovoltaic panel, then by a photovoltaic panels set in dependance of the annual average solar radiation in considered region or country [20]. From Fig. 2, the average yearly solar radiation in Jordan is  $H = 2400 \text{ kWh/m}^2$ , and the total yearly electric energy possible to be supplied by a photovoltaic panel has after relation (1) the value:

$$E_{\text{panel}} = 899,1 \text{ kWh}$$

The potential environmental impact of solar power plants is actually materialized in the land,  $S \text{ [m}^2\text{]}$ , needed to be covered by the multitude of photovoltaic panels for producing corresponding electric energy,  $W \text{ [MWh]}$ . Consequently, the environmental impact of solar power plants can be expressed by the so-called *land footprint of photovoltaic panels* [21].

$$F_p = \frac{S}{W} \quad [\text{m}^2/\text{MWh}] \quad (2)$$

### 3. Results and Discussion

Among different countries with high solar radiation, in current paper the situation in Jordan will be approached in a detailed way, as in last years a real progress in the field of electricity production by photovoltaic power plants has been noticed [22].

In this study three photovoltaic solar power plants from Jordan have been considered with the goal of approaching their potential environmental impact by land needed to be covered by them for producing corresponding electric energy. Concretely, following solar power plants have been approached:

- a. Shams Ma'an Power Plant – located in Ma'an, Jordan
- b. Al Badiya Solar PV Park – located in Al Mafraq, Jordan
- c. Risha PV IPP project – located in Risha area in Jordan.

#### a. Shams Ma'an Power Plant

*Shams Ma'an Power Plant*, as presented in Figure 3, located in Ma'an, Jordan, is a significant photovoltaic solar farm, representing a main part of Jordan's energy diversification, utilizing over 600,000 panels covering a land surface of  $S = 1,9 \text{ km}^2$  and supplying about 160 GWh, reducing by this carbon emissions, while also supporting local community projects. Designed in 2016, this power supply project of 160 MW proves the new strategic direction of Jordan to apply renewable energy resources for power supply [23]. The land footprint of Shams Ma'an Power Plant by using relation (1) and mentioned data is  $11,87 \text{ m}^2/\text{MWh}$ .



Figure 3. Shams Ma'an Power Plant [23]

b. Al Badiya Solar PV Park

The Al Badiya Solar PV Park in Al Mafraq, Jordan, as presented in Figure 4, is an important renewable energy project, featuring a combined 23 MW capacity with an integrated 12.6 MWh Tesla energy storage system, making it the first and largest solar-plus-storage plant in the Middle East when expanded, boosting grid stability by providing power during peak hours and enhancing renewable energy integration. The project is spread over an area of 220,000 square meters, generating 42,000 MWh electricity in a year [24]. Applying mentioned values in relation (1), it results in a land footprint of Al Badiya Solar PV Park of 5,24 m<sup>2</sup>/MWh.



Figure 4. Al Badiya Solar PV Park [24]

c. Risha PV IPP project

The Risha PV IPP project, shown in Figure 5, is a 50 MW solar photovoltaic plant located within the Risha area, 300 km east of Amman in Jordan. The Project covering an area of 200 ha supports the country in increasing its renewable energy capacity, generating annual 115 GWh electricity and reducing its reliance on costly hydrocarbon imports [25]. The land footprint of Risha PV IPPt by using relation (1) and mentioned data results in 17,39 m<sup>2</sup>/MWh.



Figure 5. Risha PV IPP project [25]

### Discussion:

Got results about needed land to be covered by the huge number of photovoltaic panels in all three cases of solar power plants in Jordan for producing mentioned electricity emphasize that it is about a huge value of land surface to be covered by panels sets, namely the land footprint has values in the range of 5,24 till 17,39 m<sup>2</sup>/MWh. The established land footprints of considered solar power plants in Jordan opens another question related to incredible big, needed land surfaces to place all photovoltaic panels in best conditions of solar radiation to succeed in properly operating for electric energy supply. Got results demonstrate the need of a lot of technical analyses and assessments regarding producing and placing such a huge number of photovoltaic panels being components of solar power plants. On the other hand, provoking societal debates will follow about challenges connected to big land surfaces to be covered by such photovoltaic plants emphasizing various impacts of potential future usage of renewable energy resources, in this case solar energy. Of course, the land footprint of solar power plants is much influenced by solar cadastre and by photovoltaic panels efficiency. In this context, key factors influencing the land footprint are the panel efficiency, as higher efficiency panels require less area for the same kWh output, as well as the solar cadastre, by the solar radiation, as locations with more "Peak Sun Hours" produce more energy per square meter annually, and the system losses, as well as the technology applied.

### 4. Conclusions

As it is to be noticed on a worldwide level, renewable energy resources are starting to be efficiently applied for electric energy supply, especially solar energy by photovoltaic panels for assuring future energy supply. From the presentation made it became obvious that solar radiation is influencing in a decisive manner the electricity production in solar power plants. Arab countries, having high levels of solar radiation, demonstrate excellent natural conditions for producing electric energy by photovoltaic panels. In presented case study for several solar power plants in Jordan, namely Shams Ma'an Power Plant, Al Badiya Solar PV Park and Al Badiya Solar PV Park, knowing needed number of photovoltaic panels for succeeding in generating prescribed electric energy, as well as covered land surface by them, the land footprint has been established for each single analyzed case. As a conclusion, it came out the need for considering solar cadastre and land footprint of photovoltaic panels, which besides the huge number of photovoltaic panels sets to succeed in producing needed electric energy in Jordan, represents potential environmental impact connected to using solar energy for electricity generation. It is to be considered that in Arab World, where the solar radiation is high, being a need to improve solar cadastre for assessing needed land surfaces to be covered by these panels, which could be anyway pretty high, then it follows that for European countries the land footprint of solar power plants could be much higher because of smaller solar radiation compared to the Arab World.

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