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Multi-parameter analysis for the technical and economic assessment of photovoltaic systems in the main European Union countries

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ABSTRACT

In the last decades, the attention to solar energy as a renewable and nonpolluting energy source increased a lot through scientists, private and public institutions. Several efforts are made to increase the diffusion of such a source and to create the conditions making it competitive for the energy market. Particularly, for the photovoltaic (PV) sector, the module efficiency increase, manufacturing cost reduction and a strong public support, through favorable incentive schemes, generates a significant rise in the installed power, exceeding 40 GWp in 2010. Although the global trend of the PV sector is positive, differences among countries arise out of local peculiarities and evolutions in the national support policies. This paper investigates such issues focusing on the feasibility analysis of PV solar systems for eight relevant countries in the European Union area, i.e. France, Germany, Greece, Italy, Spain, The Netherlands, Turkey and United Kingdom. A multi-country and multi-parameter comparative analysis, based on the net present value and payback capital budget indices, allows to highlight the conditions most affecting the economic feasibility of PV systems. The national support strategies, along with the most relevant technical, environmental, economic and financial parameters, are the key features included and compared in the analysis.

The major results deal with the conditions which make PV systems potentially profitable for each country and installation feature. The national support strategies to the PV sector still play a key role for the most of the considered countries and configurations. Germany, Italy and Spain present the most favorable conditions for a profitable installation of PV systems. Furthermore, the initial investment heavily affects the plant profitability of all the studied scenarios. For such a parameter, significant returns to scale lead to an increase in the installed plant power, so that high rated power plants generally outperform the smaller ones. Such evidences, together with further relevant outcomes which can potentially drive the future investments in the solar PV systems in the European Union, are discussed in this paper.

1. Introduction

In the last decades, the spread of the renewable energy sources considerably increased due to the permanent rise of the fossil fuel costs and the growing concern for reduction of the environmental emissions from anthropic activities [1]. The guidelines, provided by the most influential international institutions, e.g. the United Nations and the World Bank, emphasize on the need to mark a turning point in the existing trend of the energy source distribution to increase the incidence of the renewable sources actually close to 16% of the global produced energy [2–4] (Fig. 1).

Challenging milestones are set in the recent past. The Advisory Group on Energy and Climate Change pointed out two key and complementary goals to be achieved by 2030: the reduction of the global energy intensity by 40% and the parallel increase in the access to the energy services for three billion people now excluded [5]. In Europe, the European Council set ambitious energy and climate change objectives by 2020, i.e. to reduce the greenhouse gas emissions by 20%, to increase the share of the renewable energy to 20% and to make a 20% improvement in the energy efficiency [6].

In such a context, photovoltaic (PV) systems represent a great opportunity to achieve the aforementioned targets, due to the enormous theoretic potential of the solar source, which is equal to 3.9 trillion PJ per year [7], and the relevant improvements both in the physics of solar cells and in the module conversion performances [8]. Such strengths push several countries, worldwide, to promote massive investments in technologies to convert solar radiation into electric power energy through the introduction of specific strategies and customized national supporting policies. The European Union (EU) plays a pioneering role since 2001, when

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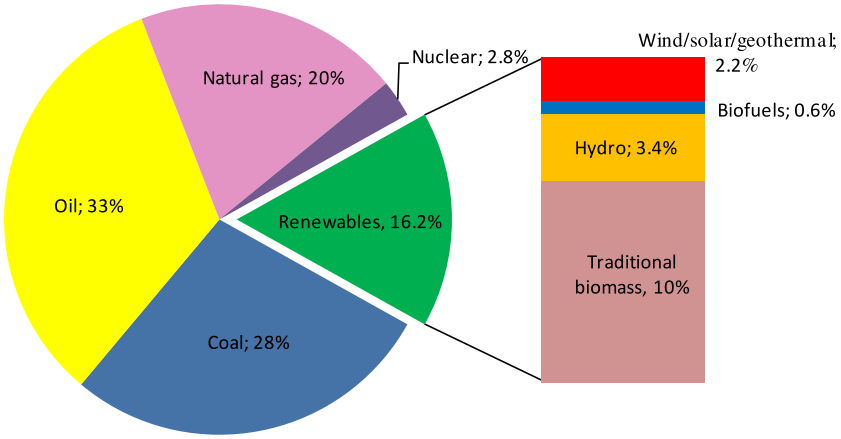

Fig. 1. Global energy mix split by primary sources, 2010 [3].

it officially started to promote the renewable energy sources as a key measure to contribute to the environmental protection and the sustainable development [9]. Furthermore, in 2003, the EU Commission established the European Photovoltaic Technology Research Advisory Council to spread the development of a global competitive PV industry. As a result of such efforts, since late 2010, EU is the leader in PV installations with 75% of the global generation capacity [3,10] (Fig. 2).

An effective strategy for the national institutions and governments to support the spread of the PV technology and to encourage the investors is the adoption of incentive schemes making profitable the energy production from the solar source. Such an energy policy strategy is adopted in almost all the main EU countries, even if differences exist. Dusonchet and Telaretti [11,12] and, recently, Avril et al. [13] review this issue in depth comparing different country's strategies and legislations.

In the literature, a wide set of contributions provides single country analyses of the current PV sector status. As example, Bernal-Agustin and Dufo-Lopez [14], Fernandez-Infantes et al. [15] and Hernàndez et al. [16] present detailed economic studies on PV systems for Spain, while Hammond et al. [17] focus on the United Kingdom context. Furthermore, Focacci [18] review the PV sector for Italy, Audenaert et al. [19] propose an economic evaluation of grid connected PV systems in Flanders, Belgium, and Šály et al. [20] review the status and conditions of PVs in Slovakia. Outside the EU area, several contributions refer to the US, China and other developed countries, e.g. Fthenakis et al. [21], Zhang et al. [22], Becerra-López and Golding [23], or, even, to developing countries belonging to the sun belt area where the potential of the solar energy is higher than elsewhere. Diarra and Akuffo [24] focus on Mali, Al-Salaymeh et al. [25] consider PV systems located in Jordan, Ghoneim et al. [26] investigate the scenario for Kuwait, Mitscher and Rüther [27] focus on the Brazilian region, while Nässén et al. [28] propose an assessment of solar PVs in northern Ghana.

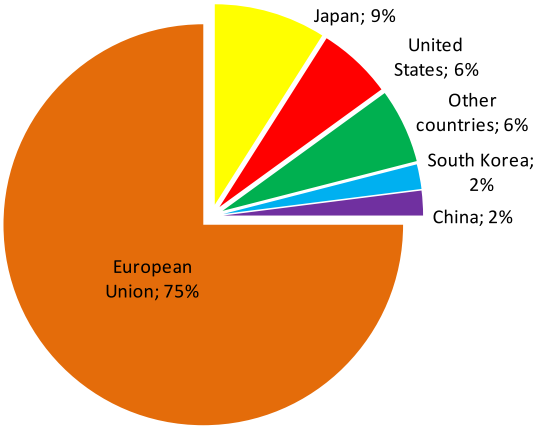

Fig. 2. Distribution of the global installed PV capacity, 2010 [3].

Furthermore, a parallel research field focuses on the comparison among countries considering single aspects of the PV energy sector. Several works discuss the national incentive policies highlighting similarities and differences among current legislations [29–34], while other studies evaluate the trend of the PV cell costs with a long-term horizon correlating the past trend of the PV system costs to the current state of the art of the PV cell manufacturing technologies in different countries [35–39].

The aforementioned contributions provide several analyses on such a topic even if very few studies cross simultaneously a wide range of parameters belonging to different categories, e.g. technical parameters, environmental conditions, national legislations, economic and financial conditions, and extend the analysis to several countries. No existing contributions integrate in one unique model both the country peculiarities and the technical, environmental and economic conditions of several PV system configurations.

Starting from a survey of the current status of the national legislations and the incentive schemes for supporting the PV sector and the current market conditions in eight relevant countries of the EU area, i.e. France, Germany, Greece, Italy, Spain, The Netherlands, Turkey and United Kingdom, this paper proposes a multi-parameter analysis to investigate the technical and economic features making PV investments potentially profitable. A Performance Cost Model (PCM), based on the Net Present Value (NPV) and Pay-Back (PB) capital budget indices, allows to quantify the net cash flows through the plant lifetime. The analysis considers a set of parameters potentially affecting the plant profitability with the purpose to highlight those which are the more critical than others. Several scenarios appear and are compared. As a consequence, the proposed multi-country and multi-parameter analysis, including recently updated available data, represents the most innovative contribution of the present paper.

According to the defined purpose, the remainder of this paper is organized as follows: Section 2 briefly overviews the current status and the key differences among the eight considered countries with reference to the PV sector, Section 3 presents the adopted PCM for the economic assessment of each considered scenario and provides a full description of the model parameters. The multi-country analysis is introduced in Section 4 and the obtained results are extensively discussed. The last Section 5 concludes the paper providing suggestions for further research.