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Shedding some light on photovoltaic solar energy in Africa – *A literature review*

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ABSTRACT

Bearing in mind that there is increasingly abundant literature on the evolution of photovoltaic solar energy in Africa, it is necessary to make a global assessment with a focus on the path already traveled. This article reviews the literature on solar energy within the context of the African continent between 1992 and 2016. Based on the diversity of the articles analyzed, there are three main axes which emerge, namely: (i) the current situation, (ii) specificities, and (iii) performance. These make it possible to pinpoint the challenges of the development of photovoltaic solar energy in a continent with a severe energy deficit. This review also allows us to better understand the extent to which photovoltaic solar energy contributes to the sustainable development of African countries.

1. Introduction

In 2006, Jason Spellberg announced, in "*Power of the Poor: the case for photovoltaics*", the opportunity that this renewable energy represents for developing countries [1]. Nearly ten years later, renewable energies (REs) are still a ray of hope for coping with climate change, not only for the poorest countries but also for the rest of the world. The overall impact of renewable energies, especially independent off-grid systems [2], on the sustainable development of developing countries is indeed an issue that has been discussed [3–5]. In Africa, the most promising role of renewable energies remains with the poorest or most remote populations of major centers [6]. However, the development of these energies faces several constraints, especially in Sub-Saharan Africa [7]: cultural aspects, level of education and training, unstable and weak economies as well as low foreign investment, high interest rates and inconsistency of energy policies. The development of solar PV energy does not escape these constraints. But its potential is particularly stimulated by multiple technological innovations whose recent and upcoming use allows for the improvement, collection, conversion and storage of energy. This is all thanks to increasingly lower manufacturing costs. In the context of the African countries with some of the highest solar irradiance in the world, PV represents an opportunity to respond to the continent's industrialization needs and other key aspects such as poverty and food security. It is within this framework that our literature review is centered in line with the sustainable energy "for all" initiative started by the United Nations in 2011. Our review focuses on the different aspects of PV solar energy (PV) within the framework of African countries. Our approach highlights the conclusions of this literature in order to identify the issues involved and how they can be interpreted, and to understand the extent to which PV solar energy contributes to the sustainable development (SD) of African countries. Our methodology is based on the analysis of 112 peer-reviewed articles from 11 journals identified between 1992 and 2016. Three main axes presented in Fig. 1 emerge from this review: (i) the current situation; (ii) specificities; (iii) performance. The content of these axes will be analyzed, followed by a discussion of the findings, and research leads will be proposed in conclusion. Table 1 presents a summary of the literature on REs in Africa and developing countries.

2. Methodology

Our methodology is primarily based on an explicit research question: To what extent does PV solar energy contribute to the sustainable development of African countries? The articles in this review were therefore selected whilst bearing this question in mind in relation to the following concepts: PV solar energy, sustainable development,

Abbreviations: DC, developing countries; LCOE, levelized cost of energy; PV, photovoltaic; kWp, kilowatt-peak; REs, renewable energies; SD, sustainable development; SSA, Sub-Saharan African countries

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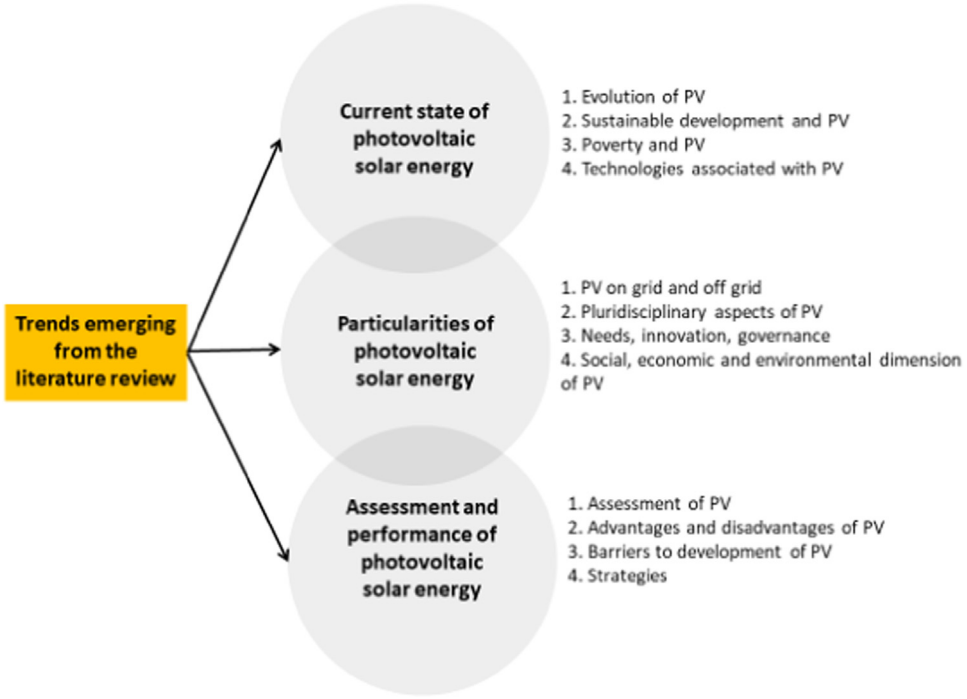

Fig. 1. Guidelines emerging from the literature review.

Table 1
Summary of the literature on REs in Africa and developing countries.

Status of renewable energies (REs)		
Status of REs (description, challenges, need for collaboration)	[7]	Sub-Saharan Africa
REs and sustainable development		
Relations between REs and sustainable development	[3] [5]	Africa
Measure of sustainable development in developing countries: poverty factor and energy factor	[8]	Developing countries
REs' impact on sustainable development at local level	[4]	
REs decentralized		
CASE (Center for Application of Solar Energy) at UNIDO	[9]	Developing countries
The role of REs at local level	[6]	
Methodology for off-grid	[10]	
REs and poverty		
REs and the needs of poor communities	[11]	Africa
Role of REs in poverty reduction	[12]	Nepal, Peru, Kenya
Social acceptability		
Social acceptability of innovations related to REs	[13]	
Social acceptability of REs	[14]	
Impacts of REs		
Impact of REs	[15]	
How to stimulate impact?	[16]	Morocco
Role of REs in environmental protection	[17]	
REs in a specific country		
REs assessment in Zambia	[18]	Zambia
Strategy for REs implementation	[19]	Senegal
Strategy to develop REs	[20]	Algeria
REs assessment – including solar energy	[21]	Kenya
REs assessment – conditions for success and challenges	[22]	Cameroon
Potential of REs in Ivory Coast	[23]	Ivory Coast

developing countries and Africa. This research was carried out on the SCOPUS database on October 17, 2016. It allowed us to identify 1343 articles published between 1992 and 2016. The most relevant articles for our research were selected in arriving at a range of 112 peer-reviewed articles. The selected articles were organized using the End Note software and then analyzed using Excel to show the topics covered according to their dates, the countries concerned and the authors identified. Tables have been made; simpler versions of which have been placed in the body of our literature review. Our selection has sometimes been rendered difficult by the fact that some elements of PV are found in more general articles on renewable energies. The 112 selected articles are from 11 journals listed in Table 2.

2.1. Exclusion

The following were excluded from our research: (i) conference articles, theses and book chapters; (ii) articles dealing with the assessment of solar radiation, solar water furnaces and heaters; (iii) case studies outside Africa. On the latter point however, the articles that contained a general review dealing globally with the developing countries were considered.

2.2. The literature reviews

Several literature reviews were identified with relevant references to our analysis. These are presented in Table 3. These literature reviews focus on renewable energies, sustainable development, off-grid and on-grid systems, or only on PV. Regarding REs, the reviews focus on their social acceptance [13,14], which has remained a recurring theme over the years, as well as their role in protecting the environment [17]. With regards to the adequacy of REs with sustainable development, this remains a surprisingly less discussed issue [3,5,24]. There is more literature about on and off-grid systems [25]. These literature reviews are fairly diverse and they handle the adequacy of off-grid systems in rural areas [2], and on-grid integration in transmission systems [26], not forgetting the on-grid and off-grid. As far as PV are concerned, the reviews focus on their evolution (especially technological developments) [27,28], and assessment of their implementation in developing countries, especially in the off-grid domain [29–32]. It is important to note that only two of the reviewed reviews relate to the situation in Africa; one on renewable energies and sustainable development in 4 countries [3], and the other on PV in 10 countries [33].