Renewable and Sustainable Energy Reviews 90 (2018) 516–535

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Evaluation of renewable energy sources in peripheral areas and renewable energy-based rural development

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ARTICLE INFO

Keywords:
Renewable energy sources
Integrated biomass, solar and wind potential
Rural development

ABSTRACT

The context and background of this study are based on the growing role of policy-driven renewable energy sources in improving energy security, protecting the climate, and encouraging economic development. In many cases, these high expectations are undermined by the lack of an integrated methodology for the measurement of renewable energy potential. Therefore, we assumed as the main hypothesis, the possibility of developing a complex and integrated evaluation methodology for renewable energy potential. Accordingly, we employed evaluation methods based on mapping techniques, simulation software for wind farms, and the analytical tools offered by the Geographical Information System. The main novelty of this study is related to the integration of three renewable energy sources (biomass, solar, and wind) and the respective measurement of their total renewable energy potential.

The main results of the study consist of the estimation of three main renewable energy sources—solar, wind, and biomass energy—and the generation of maps showing the potential for solar, wind, and integrated biomass energy at a high spatial resolution. In addition, we have measured and mapped the total renewable energy potential available for supplying the local energy demand. The renewable energy potential maps, combined with a multidimensional index expressing the development level of localities, are good predictors of appropriate locations for the development of renewable energy source-based facilities. The study concludes with recommendations towards the use of the renewable energy potential maps as criteria for project allocation in future for renewable-based rural development, in order to achieve a more balanced regional development.

1. Introduction

The growth of renewable energy (RE) is largely a policy-driven process aimed at improving energy security, protecting the climate, and encouraging economic development [1]. The Lisbon Treaty added two new priorities to the European Union (EU) policy, namely energy and territorial cohesion, complementing the economic and social cohesion pillars of the previous Maastricht Treaty. Although the linkages between territorial cohesion and sustainable energy are further outlined by the new document "Towards a new energy strategy for Europe 2011–2020" [2], scientific work in this field remains scarce. According to Directive 2009/28/EC of the European Parliament and the Council on April 23, 2009, regarding the promotion of renewable energy sources (RESs), the Commission and the Member States should support regional development measures in this area, encourage academic research and the transfer of scientific research results to enterprises, and promote the use of structural funding. The United Nation's (UN's) Sustainable Energy for All (SE4All) initiative of 2012 focuses on energy policy and mobilizes action towards achieving universal access to modern energy services by 2030. Therefore, the territorial equilibration of production and consumption in the energy sector is crucial for regional development. The UN General Assembly declared 2014 the beginning of the 'Decade of Sustainable Energy for All', symbolizing heightened momentum and a call for a coherent, integrated approach to energy issues and synergy across the global energy agenda [3]. However, these ambitious global targets will not be easily achieved. The 2012 outlook of the International Energy Agency (IEA) indicates that, despite reducing the fraction of people without access to electricity by 20%, nearly 1 billion people will remain without a connection to the electricity grid in 2030 [4].

Meanwhile, it is usually stated that RESs contribute to the sustainability of specific areas. Before 2000, sustainable energy development was analyzed in seven areas: energy resources and development, efficiency assessment, clean air technologies, information technologies,

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https://doi.org/10.1016/j.rser.2018.03.020
Received 14 October 2016; Received in revised form 22 February 2018; Accepted 14 March 2018

List of acronyms

BIPV	Building-Integrated Photovoltaics
CFD	Computational Fluid Dynamics
CHP	Cogeneration Heat and Power Plant
DEM	Digital Elevation Model
DHS	District Heating System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information Systems
LHDI	Local Human Development Index
NUTS	Nomenclature of Units for Territorial Statistics
PVGIS	Photovoltaic Geographical Information Systems
RE	Renewable Energy
REP	Renewable Energy Potential
RES	Renewable Energy Source
SRTM	Shuttle Radar Topography Mission
SME	Small and Medium Enterprises

Measurement units

kWh	Kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
J	Joule
MJ	Megajoule
GJ	Gigajoule
PJ	Petajoule
Ha	Hectare

new and RE resources, environmental capacities, and mitigating the nuclear power threat to the environment [5]. Later, the general sustainability indicator was elaborated for RESs [6]. The use of RES, especially in rural territories [7], the local energy value chain development [8], and their positive impacts has been highlighted through case studies and reviews [9,10]. In addition, RES provides a wide variety of socioeconomic and environmental benefits, like local employment and welfare [10], income generation, mitigate the ageing of the people in rural areas [11], diversification of rural economic activities, increase in social cohesion, use of endogenous resources [12], mitigation of climate change, and creation of a healthier environment through the use of clean energy technologies [13].

Recent initiatives for developing RE clusters represent another approach [14] to support the idea that decentralized renewable-energy-based production may successfully contribute to regional development and territorial cohesion by providing income sources, while creating employment opportunities [15]. However, it appears that the establishment of these clusters by a combination of knowledge, high-technology activities, and traditional industries, faces numerous challenges [16], including a lack of common interests [17], low level of cooperation [18], and failing internationalization [19].

More recent studies have argued for the development of so-called appropriate technologies (wind, solar, and water energy) in order to transform local societies into energy-independent organizations, which can take the form of energy-independent villages with RE as the central concept [20,21]. One major aim of the use of such technologies is local growth, which includes the necessity of providing some support services such as education [22].

Other research groups have focused on the interaction between sociotechnical transition and certain types of regions called resource peripheries [23]. Sociotechnical transition can be understood as a co-evolutionary process represented by the transformation of energy production, consumption, and governance through the development of new energy production and distribution technologies.

Evolutionary economic geography has developed an interesting framework for analyzing the interaction between technology and the regional or local community. Its central concepts, which are path dependence and path creation, are useful tools for explaining how new technological pathways are created in spatially different settings [24,25]. The empirical results indicate significant national differences in the introduction of new RE-based technologies. Supporting government policies and intense R&D are playing a crucial role in the creation of new renewable-based technological paths [26].

De Madsen and Andersen [26] and de Laurentis [27] considered that the sub-national or regional level will have an increasing role in providing governance for economic processes and innovation. Low-carbon future is strongly dependent on small-scale [28,29], decentralized [30] and distributed generation in rural regions [31], solving local issues, while satisfying local energy demands [32] with community-owned renewable energy [33]. Locally developed and embedded energy projects are capable of providing benefits to local inhabitants and enterprises, while the security of the energy supply increases [34]. Several case studies suggest that the cooperation between local stakeholders provides the basis for the community-scale development of REs [35,36].

Moreover, there is an evident shift from studying the role of the state or capital in the transformation of rural peripheries towards a ‘new regionalism’, with a clear bottom-up approach. In this approach “the key issue in rural development is no longer the region's capacity to attract enterprises from outside the region, but the exploitation of its local resources to generate sustainable transformation” [37]. Local enterprises and community actors have been identified in this context as key factors in the adoption and institutionalization of electricity microgeneration using RE [38]. Domestic consulting companies, financial institutions [39], and national and/or local governments play a less important role than the residents who initiate RE development [40]. The fundamental idea behind building sustainable communities is that these communities contribute to domestic energy security, promote social innovation and social entrepreneurship, and increase employment and regional development opportunities. For example, wind energy projects with 100% local ownership generate twice the number of long-term jobs and 1–3 times the economic impact of absentee-owned wind projects [41]. Finally, but importantly, if the local inhabitants are involved in the development of an RE project in their community [40], they tend to become more aware of their personal energy use patterns [42,43]. Health issues [44,45] can also be addressed with the income from energy production [46]. Even if the institutional configuration of the energy sector is different in each country, the general developmental trend is to increase the institutional space for local community players [47].

In the case of resource peripheries in particular, REs (such as bioenergy and wind farms) may generate important socio-economic benefits [48], ensuring power supply using off-grid energy systems [49]. The expected positive effects relate to better employment and income opportunities, while the negative impacts are registered due to externalities generated by revenues leaking out from the peripheral regions [50].

Among the causes of failure of renewable-based development initiatives, the ones noteworthy and significant for our study are those mentioned by Katsaprakakis and Christakis [51]: the low maturity of RE projects, the disapproval of local communities, the difficulty in accessing the required environmental constraint exemptions, and the lack of measurements for renewable energy potential (REP). Bai et al. [52], who focused on evaluating the size and location of biomass potential, presented a similar line of argument in the peripheral region, with the aim of recommending sample projects that could create the highest