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GIS approach to the definition of capacity and generation ceilings of renewable energy technologies

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Abstract

There are no discrepancies about the advantages of achieving a sustainable energy system based on locally available natural resources. However, supporters of green energy generation system were lacking some scientific and consistent study to defend their proposals. In order to have such a study, Greenpeace commissioned Technology Research Institute at the Pontificia Comillas University to carry out a study to assess ceilings for the potential and generation of renewable technologies in Spain. It demonstrates firstly a far greater renewable potential than the targets set by long term policies, and secondly, the viability of meeting the entire electricity demand projected for 2050. GIS was used to add the geographical dimension to the original project in order to generate a technical analysis linked to the specific constrictions imposed by territory (natural and anthropogenic) and not just designed to cover a certain demand. Therefore, GIS spatial analysis took into account local conditions producing a more accurate assessment than evaluations made upon "virtual" electrical spaces. This approach could be applied to other small scale general studies in order to assess the maximum contribution of renewable energy sources to particular energy generation mix and to help set development policies supporting high participation of renewable technologies.

Keywords: Generation mix; Spatial analysis; Geographic information systems

1. Introduction

The globalized world we inhabit is facing an energetic crisis which becomes evident in environmental, economic, social and spatial aspects. There have been several proposals and attitudes adopted towards this crisis and there have been multitude organisations which have taken a stance based on an increasing share of energy produced by renewable sources. However, not enough studies have been carried out to determine renewables potentiality accurately.

Apart from hydroelectric, only wind energy has managed to overcome the barrier and be included within the commercial interests so private investments could help to develop a more efficient generation system. Other technologies like concentrated solar power (CSP), biomass, solar photovoltaic, solar chimneys and waves (all of them considered significant potential contributors to our electrical generation system) are quite far from being real contributors.

The maximum percentage that a particular technology could provide to generation system remains as a technical doubt that hinders the renewable energies support: is it feasible a system based completely in renewable sources? Is it absolutely needed to maintain nuclear or thermal contributions to control the generation system and the electricity transport? It is becoming imperative to find a technical solution to the current situation, which is mainly defined by partiality, empiricism and improvisation. It will be then possible to speed up the introduction of renewables within a planned process.

As an example, it was thought that wind energy could only contribute in 5% to electricity generation. Later it was proven to reach around 10% and nowadays it seems possible to contribute in 25%. Meanwhile, in Denmark

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they have already satisfactorily checked the viability of an electricity generation system with 50% of wind energy contribution. There is no doubt the hesitancy constitutes a significant obstacle for those technologies at earlier stage of development but with enormous prospects for large-scale development.

Generation technologies based on renewable energies involve an important technical challenge to the generation system and transport capacity of the electricity network due to the discontinuity and randomness of renewable sources. However, because of the great diversity in renewable generation technologies used in our country, it could be possible to reduce those technical restrictions taking advantage of the technological synergy and the spatial distribution.

2. The SIGER project

2.1. Definition and objectives

Greenpeace commissioned the Technology Research Institute at the Pontificia Comillas University (IIT) to carry out the SIGER project, "Technical analysis of the introduction of high percentage of renewable energies in Spanish electrical generation system"(García Casals et al., 2005a). With this project, Greenpeace intends to get an evaluation of the potential ceiling of renewable technologies that could be installed in each Spanish region (autonomous community) (Fig. 1).

The provincial distribution of the potential ceiling constitutes the main objective of SIGER in order to calculate the generation mix with maximum possible contribution of renewable energies at regional scale. Obviously, these aspects do not depend only on the defined renewable energy technology but also relies on the geographical features of the potential sittings because land is a critical resource for the achievement of this goal (Blok, 2006). This is the reason why the SIGER coordinator commissioned CIEMAT to execute the spatial analysis with GIS.

Concerning the methodology followed, the SIGER project took into account the availability of resources, environmental restrictions and other types of land use, the link between demand and generating potential and the transport capacity of the electricity network. Population and energy demand scenarios were first drawn up (38.32 millions inhabitants and a final energy demand of 109 kWh/inhabitant/day) based on those already published by other institutions (National Institute of Statistics). Starting from these hypotheses, standard power stations were designed as a means to delimitate the spatial dimension of every considered technological unit. From each technological unit (proportional to standard power stations) and the restrictions imposed by GIS, maximum area available in every autonomous community was estimated. This area was clearly related to maximum generation power and thus, to the definition of the capacity ceiling per autonomous community.

Current electricity transport system in Spain was considered as the starting point of the project. This system is characterized by its great development in Northern part of the country, giving evidences of the main generation sources location. However, existent power stations are not place in the regions with highest renewable generating potential (for instance, highest solar generation potential is located in the Southern part of Spain). In this sense, current electricity transport system clearly restricts spatial distribution and proposed generation mix based on renewables. Great adjustment of electricity network would significantly increase the renewable contribution but this option is not taken into account in this project. Nevertheless some improvements are suggested.

Fig. 1. Spanish autonomous communities.