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Assessment of the renewable energy-mix and land use trade-off at a regional level: A case study for the Kujawsko–Pomorskie Voivodship

Beata Sliz-Szkliniarz*

European Institute for Energy Research (EIFER) at the KIT, Emmy – Noetherstr. 11, 76131 Karlsruhe, Germany

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ABSTRACT

Renewable energy sources (RES) can undoubtedly contribute to protecting the environment and conserving fossil fuels, as well as enhancing regional and rural development opportunities. However, every energy production process affects the environment and involves the use of land resources. The risks linked to intensified RES use should be adequately taken into consideration in any planning process, as ill-conceived energy policies may adversely impact land and local ecosystems, and lead to increases in public spending. Therefore, before designing any instruments for the regulation of both RES and land-use, the most essential step is to explore investment possibilities in different contexts. This paper intends to locate and quantify the potentials of biomass, wind and solar as well as to explore some of the potential planning issues associated with their development. The methods and findings presented in this paper may help to build a vision for the development of an optimal RES portfolio and to highlight emerging problems associated with RES deployment.

Introduction

Over the past few decades, economic development has been accompanied by an intense increase in energy production, which has resulted in a depletion of fossil resources and has negatively affected the environment. Alternative energy resources have therefore increasingly gained in importance as a means to tackle the problems mentioned above. Despite their many benefits, renewable energy sources (RES) are not without environmental and socio-economic impacts. Compared to conventional fossil fuel-based energy systems, renewable energy sources are more space-intensive and their efficiency of energy production is highly geographically dependent (Seager et al., 2009; Dijkman and Benders, 2010). The limited availability of land as a production factor is a restraining element in the production of energy, food and other non-food goods. Thus planning at a regional level plays a key role in balancing competing interests for land resources and in managing the multiple uses of land (Helming et al., 2008). The methods and findings presented in this paper may help to build a vision for the development of an optimal RES portfolio and to highlight some of emerging problems associated with RES deployment.

RES targets and status-quo in Poland and in the Kujawsko–Pomorskie Voivodship

Poland has set ambitious goals for renewable energy production. According to the Polish National Renewable Energy Action Plan (NREAP) published in 2010, wind energy and biomass are expected to meet 47% and 44% of total electricity production (NREAP, 2010). The document "Development of agricultural biogas plants in Poland in 2010–2020" published by the Council of Ministers on 13 July 2010 (Ministry of Economy, 2010), promotes biogas production. This sets an objective of increasing biogas power capacity in Poland from 82 MW (including the capacity of 8.4 MW of 8 agricultural biogas power plants constructed by the end of 2010) to 2000 MW by 2020.

According to Kuś and Faber (2009) around 2.1 Mha of farmland (22% of the arable land in Poland) should be dedicated to energy generation to fulfill the biomass targets. It is designated accordingly: 0.5 Mha of good quality soil for biodiesel production based on oil seed rape, 0.6 Mha for bioethanol (cereals, sugar beets, potato), around 0.5 Mha for the production of solid biomass and, in addition, around 0.5–0.7 Mha for biogas development.

The Kujawsko–Pomorskie Voivodship is characterized by a high index of arable land per capita of 0.48 ha compared to the national average being 0.36 ha/cap, suitable pedoclimatic conditions and strong potential for animal by-products (K-PBPPiR, 2010). According to the Polish Agency for Restructuring and Modernization of Agriculture, which provided statistics on the growing area of energy

* Tel.: +49 0721 6105 1443; fax: +49 0721 6105 1332.
E-mail address: sliz@eifer.uni-karlsruhe.de

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dedicated crops, 52,408 ha in 2009 of the arable land in Poland were used to grow energy crops (ARiMR, 2010). About 10% of these national plantations were located in the region.

With respect to other types of alternative energy, the case study region is the third most favorable region for to wind regime conditions (Lorenc, 2005). The favorable wind and land conditions make the region suitable for the development of wind projects. By the end of the year 2010, 155 wind turbines with a total power capacity of 166 MW were in operation in the region (URE, 2010a).

In Poland, photovoltaic (PV) power still lacks the economic power to compete with other utilization technologies (ECBREC IEO, 2009). So far, around 1 MW_p of photovoltaic power has been installed (URE, 2010a). However, an upcoming amendment to the certificate system intends to enhance PV development (Ministry of Economy, 2011).

Poland is still at the beginning of a challenging path to meet the energy targets. RES development should be systematically and carefully addressed using financial and spatial policy instruments to enhance the development of sustainable energy systems based on locally available resources.

Introduction to renewable energy development and land-use trade-offs

Economic and demographic growth has resulted in increasing demand for land use (Helming and Pérez-Soba, 2011). Limited availability of land means that a balanced portfolio of social, economic, and environmental services are needed (Wiggering et al., 2006). Accordingly, different RES options compete with each other for land as well as competing with other uses of land, for example agriculture, leisure and ecological conservation.

Wind energy production has higher land use efficiency (energy yield per unit of land used) than biomass and solar energy. Moreover, unlike with energy crop production or solar farms, the land under a wind farm can be used for other purposes, such as agriculture, because wind turbines occupy only a fraction of a farm's surface. However, this type of energy generation may have adverse impacts on ecologically sensitive areas and on the esthetics of the landscape, thus affecting conservation and recreation (Krewitt and Nitsch, 2002).

Unlike wind parks, ground mounted PV systems only have a small negative impact on ecosystems, but they are incompatible with most other uses of the land (Tsoutsos et al., 2005; Günnewig et al., 2006; Chiabrando et al., 2009). The most crucial issue associated with solar power parks, highlighted by Tsoutsos et al. (2005), is the reduction of cultivable land. Chiabrando et al. (2009) suggest that solar farms should only be allowed if a building integrated installation is not economically viability or energy efficient. According to Dijkman and Benders (2010) the competition for arable land could be reduced if large PV parks were located on marginal ground, not suited to agricultural production. This would ensure there is no competition with food and biomass production. However, other competing needs for land use cannot be excluded.

By the same token, biomass energy production may affect land resources in other ways because it requires land for crop cultivation, storage and generation (Russi, 2008; Dijkman and Benders, 2010). Furthermore, intensive biomass production may deplete soil nutrients thus affecting the soil's productivity, and may contribute to the loss of biodiversity (Huston and Marland, 2003; Robertson et al., 2008; Sala et al., 2009). Biomass production not only conflicts with food and fodder production, but also with other energy crops. For instance, biomass may be used in different technologies resulting in electricity, heat or biofuels. Annual and perennial crops for energy or commercial material production compete for space with conventional plants.

All energy-related projects always result in some environmental burden. Most of them are associated with fragmentation of the countryside, visual impact on landscape and interference with flora and fauna (Chiabrando et al., 2009). The expansion of alternative energy sources is a compulsory EU target so its deployment must balance the multiple uses of land. The development of an optimal RES-mix requires administrative guidance and appropriate incentives (Directive 2009/28/EC). At the same time, regulations should not discourage investment in RES, and growth should enhance the benefits to environmental and socio-economic systems. Therefore, before designing any regional or local RES policy and regulation instruments, the most essential step is to explore the investment potential of RES.

Objective of the study

Research has been conducted to assess the potential of renewable energy sources, to identify geographic and socio-political barriers to development and to explore the potential effects of RES on socio-economic systems and on the environment (Kaltschnitt and Hartmann, 2001; Hoogwijk, 2004; BFE, 2007; EEA, 2007; Berndes et al., 2008; Hoogwijk and Graus, 2008; Krewitt et al., 2008; Stangeland, 2008; Igliński et al., 2009; Dees, 2010; Bronner, 2011). However, these studies do not offer an approach to evaluating the potential of the three main alternative resources: biomass, wind and solar in the context of the competition for land-use and environmental burdens. This study locates and quantifies the economic and technical potential of biomass, wind and solar. In addition, it explores some of the planning issues associated with their potential development. The approach was designed on a regional scale.

Methods and materials

Dataset

Supported by Geographic Information System (GIS) – ArcGIS 9.3 – the spatial analyses used the Corine Land Cover CLC 2006 data at a 1:100 000 scale (IGIK, 2009) and the datasets at a 1:750 000 scale, representing land-use (e.g. transport infrastructure, wetlands, forestlands etc.) obtained from the Office of Spatial Planning of the Kujawsko–Pomorskie Voivodeship (KPBPP, 2009).

Approach for analyzing the potential of renewable energy-mix

In a liberalized market, land is in hands of private investors and land-users, who look after their own interests. This often leads to competing renewable energy options and conflicting use of land. For this reason, the development of sustainable energy resources needs suitable guidance and management by administrative authorities, in order to balance the actions of private investors with the public interest. At the same time, regulation should not discourage potential investors and RES growth should benefit both environmental and socio-economic systems. Therefore, before designing any incentives or instruments of regulation, the first step must be to explore the investment possibilities of renewable energy sources.

The choice and deployment of RES is a complex issue. Marques and Fuinhas (2010, 2011) made empirical assessments of several socio-economic and political determinants that encourage and/or hamper the deployment of renewable energy. Alongside legal, technical and economic factors, there are social factors that influence the realizable potential of RES (Zoellner et al., 2008). Acceptance may be expressed in various forms: attitudes, behavior and – most importantly – investments (Wüstenhagen et al., 2007).

The focus of this study is on investors and the potential of investment in wind, biomass and solar energy. The analysis was carried