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Assessment of forest biomass for use as energy. GIS-based analysis of geographical availability and locations of wood-fired power plants in Portugal

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ABSTRACT

Following the European Union strategy concerning renewable energy (RE), Portugal established in their national policy programmes that the production of electrical energy from RE should reach 45% of the total supply by 2010. Since Portugal has large forest biomass resources, a significant part of this energy will be obtained from this source. In addition to the two existing electric power plants, with 22 MW of power capacity, 13 new power plants having a total of 86.4 MW capacity are in construction. Together these could generate a combination of electrical and thermal energy, known as combined heat and power (CHP) production. As these power plants will significantly increase the exploitation of forests resources, this article evaluates the potential quantities of available forest biomass residue for that purpose. In addition to examining the feasibility of producing both types of energy, we also examine the potential for producing only electric energy. Results show that if only electricity is generated some regions will need to have alternative fuel sources to fulfil the demand. However, if cogeneration is implemented the wood fuel resource will be sufficient to fulfill the required capacity demand.

1. Introduction

There is an emerging consensus on the need to reverse the trend of global warming associated with climate change. The main goal is to quickly reduce emissions of greenhouse gases.

The European Union (EU) is resolved to reduce member country greenhouse gas emissions (GGE) and is promoting the development of new energy policies as one important means to that end. These policies should lead both to the development of new and more secure energy sources and contribute to a reduction in the growing dependency of EU member states on imported fossil fuels.

1.1. Renewable energy strategy and policy

To implement its renewable energy (RE) strategy, in March 2007 [1] the EU formally committed to the "20–20–20" initiative, which set as target and objectives for 2020 [2,3]. These include (i) reducing greenhouse gas emissions by at least 20% of 1990 levels (30% if other developed countries commit to comparable cuts), (ii) increasing the share of RE (wind, solar, biomass, etc.) consumption to 20% compared to 8.5% today, and (iii) cutting energy consumption by 20% of projected 2020 levels by improving energy efficiency.

Renewable energy has gained greater importance over the years, and is today considered the solution to the energy future in Europe. Since 1990, the EU has been engaged in an ambitious and successful plan to become a world leader in RE production and use. The strategic energy plans and policies of the EU, as well as those individual member states, established concrete targets for exploitation of indigenous renewable energy sources (RES), and for bioenergy in particular. As a first step towards a strategy for RE the Commission adopted a Green Paper on 20 November 1996 [4]. The most ambitious strategic goals were defined in 1997 in a European Commission White Paper [5], where the EU set the target to increase the share of renewable up to 12% by 2010. The White Paper also contains a comprehensive Strategy and Action Plan setting out the means to reach this objective.

After the order Green Paper (2000) on security of energy supply [6], diverse and concrete proposals were made. One of these proposals, directive 2001/77/EC [7] on electricity production from renewable sources, was adopted in 2001. Under this directive 22% of the electricity consumed in the EU by 2010 should be produced from renewable energy sources.

According to the national targets for future consumption of electricity produced from renewable energy sources, defined for each member state, Portugal committed to 39% (including large hydro). These goals were also stated in the National E4 Programme (Energy Efficiency and Endogenous Energies) launched in 2001 [8], and subsequently in the National Strategy for the energy launched

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in 2003 [9] and 2005 [10]. In 2007 Portugal established a more ambitious strategic target in its National Strategy of Sustainable Development [11]. This new National Strategy for the energy establishes that 45% of the national energy consumption in 2010 should be exclusively produced from renewable energy sources. In this way Portugal intends to set an example in the fulfilment of the EU objectives to reduce emissions of greenhouse gases.

1.2. Biomass energy policy

Amongst renewable resources, paramount importance has been given to the bioenergy because it has low negative environmental impact in terms of CO_2 emissions for the entire fuel cycle and zero CO_2 emissions from fossil fuels during operation.

The European Commission White Paper [10] recognized bioenergy as the most promising areas within the biomass sector for several reasons. First, because it would increase the amount of people working in the forestry sector. Second, because the combined use of heat and power (CHP) has the greatest potential per unit volume among all renewable energy sources. They also issued the opinion that the contribution of biomass-derived energy to the primary energy mix should reach 10% by 2010. The European Commission's Green report (2000) [12], also recognized that biomass is a versatile energy resource, with a widespread availability through forest and agricultural residues that has so far not been fully exploited. Consistent with the Green report [13], emphasis is given to the electricity generation from biomass energy plants, and some successfully examples of implementation in some member states are presented.

The strongest incentive of the EU towards development of biomass energy was given in 2005 with the Biomass Action Plan [14]. In this plan, the EU stated that the increased use of renewable energy is essential for environmental and competitiveness reasons, and recognized that "biomass has many advantages over conventional energy sources, as well as over some other renewable energies, in particular, relatively low costs, less dependence on short-term weather changes, promotion of regional economic structures and provision of alternative sources of income for farmers" [14]. This action plan established several measures to promote biomass in heating, electricity and transport, followed by crosscutting measures affecting biomass supply, financing and research [14,15].

According to this EU strategy, the goal of reaching 45% of national energy consumption in 2010 from renewable energy sources will be achieved in part from biomass energy production. Hence, the Portuguese government decided to extend the current installed power (two electric power plants, with 22 MW of power) to 250 MW by 2010 [11]. Therefore, in 2006, fifteen new power plant (90 MW) exploration licenses were made available to achieve this aim. However, because only 13 licenses were applied for, presently new power plants will only provide 86.4 MW of additional power. These new power plants will be capable of generating both electrical and thermal energy, or CHP.

The new power plants locations were defined by the Portuguese government with the double objective of increasing the quota of renewable energy in the global production of electricity and to promote the development of forest residues harvesting. This will also serve to remove shrub competition in forest groves and reduce wildfire hazard [16].

These power plants will have variable power generation capabilities and combine different technologies, as appropriate to local circumstances. Two power plant models are planed: small units, with power production ranging from 1.8 to 4.5 MW, and large ones with power production ranging from 9 to 9.9 MW. Considering that wood-fuel demand will increase significantly and will be variable across regions, it will be necessary to apply rational resource exploitation actions associated with regional and local needs. For example, there may be significant competition in some areas due to the presence of pulp mills or other biomass consuming industries. In these cases special solutions and compromises will be needed, or it may not be feasible to construct a power plant in such a location. As stated in the 2005 EU's report '*The support of electricity from renewable energy sources*' [17] the future development of RES projects in a specific area must taken into account spatial aspects of planning. This is especially fundamental for projects in the field of wind and biomass.

In this context the objectives of this paper are to: (1) assess Portugal's current forest biomass resource potential for commercial generation of electricity at regional and national levels, (2) assess the spatial distribution of biomass availability, and (3) evaluate the suitability of existing and proposed wood-fired power plant locations in Portugal.

2. Study area

Portugal is located between the latitudes of 36° 57′ 23″ and 42° 09′ 15″N and the longitudes of 09° 30′ 40″ and 06° 10′ 45″ W. This area includes two distinctive bioclimatic regions: a Mediterranean bioclimate in everywhere except a small area in the North with a temperate bioclimate [18]. With four distinct weather seasons, the average annual temperatures range from about 7 °C in the highlands of the interior north and center and about 18 °C in the south coast. Average annual precipitation is more than 3000 mm in the north and <600 mm in the south.

With complex topography and elevations ranging from the sea level to 2000 m, and a small amount of suitable soils for agriculture, Portuguese land is well-suited for forest growth. Forest activity is a direct source of income for a vast forest products industry, which employs a significant part of the population.

3. Methodology

The framework of this study followed four main steps. The first step consisted of forest cover classification and mapping, within Portugal. In a second step, we estimated the available forest biomass and annual growth at national and regional levels. In the third step, the geographical location of existing power plants was evaluated, and a GIS-based analysis was applied to examine the relationship between existing biomass and the power plants wood-fuel demand. Finally, based on the available quantities of biomass and growth we compared the maximum theoretical potential of energy production for two scenarios (fully condensing plants and cogeneration plants).

3.1. Forest land cover of study area

To calculate woody biomass, it was necessary to identify and classify forest cover, as well as to characterize forest stand structure. In Portugal, forests cover approximately 3.4 million hectares [19] and represents 38% of the national territory.

The main trees species, which are widely planted for commercial purposes and capable of providing a regular supply to meet fuel demand, are *Pinus pinaster* (maritime pine) and *Eucalyptus globulus* (eucalyptus). Thus, only these stands (710.300 hectares of maritime pine and 646.700 hectares of eucalyptus, according to the National Forestry Inventory [19]) were considered in the calculations of potential biomass.

The spatial distribution of forested land cover was made at regional level, using a so-called NUT III sub-regions (Nomenclature of Territorial Units for Statistics) boundaries (Fig. 1). The pine and eucalyptus stands occur mainly in the north and center of Por-