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The potential for electricity generation from crop and forestry residues in Spain

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ABSTRACT

We assess the energy contents of agricultural and forestry residues in Spain, and the potential for the generation of electricity from them. The methodology employed is a hierarchical, GIS-based one, and leads through the physical, geographical and technical potential to the economic analysis. The results from the latter are crafted in the form of generation-cost curves, which provide a good indication of how the cost of the energy increases as the generation from these residues does. Geo-referenced data allow for the consideration of the opposing influences on the specific cost of the plant size and the transport costs, which are both incorporated in the model by means of a plant supply area. A representative cost is defined and used to compare costs among biomass sources and combustion technologies. The combined technical potential of agriculture and forestry residues is 118 PJ y^{-1} (equivalent to 11.25% of the net electric energy generated in Spain in 2008). The economic potential (defined as the potential with a cost smaller than the representative one) is 46.3 PJ y^{-1} (or 4.43% of net electric energy generated in Spain in 2008).

1. Introduction

In March 2007, the Council of the European Union approved an energy plan which includes an objective of 20% of renewable energy in the final energy consumption in Europe by 2020. The achievement of this challenging objective calls for the consideration of the potential contributions that every type of renewable energy (but particularly wind, solar and biomass) can make; and therefore, for a detailed and accurate estimation of the different resources and their energy-generating potential.

In this study a methodology is developed for the evaluation of energy potential of the agricultural and forestry residues in Spain and for an economic evaluation of the production of electricity from these residues. This methodology is implemented into a Geographic Information System (GIS) and the results obtained are geo-referenced. By applying this methodology, a plausibly-founded estimation of the energy potential from these residues is obtained; and generation-cost curves are constructed considering different technologies for the transformation of the residues into electricity: grate combustion/steam turbine (GC/ST), fluidized-bed combustion/steam turbine (FBC/ST) and biomass integrated gasification/combined cycle (BIG/CC).

A number of studies with estimates of the energy potential of agricultural [1–5] and forestry [6–9] residues have been published. Additional works address the evaluation of the biomass potential in different regions or countries [10–17], and as a partial result report the contribution of agricultural and forestry residues. The methodologies used in these references consist basically in the estimation of the crop production, followed by the application of residue coefficients (ie, ratios of residue to crop) and availability factors (ie, fraction of the residue that is effectively available for energy uses) to

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Nomenclature

a	annuitization coefficient
A_i	area of pixel i (h m^{-2})
C_A	unit cost of electricity generation in a biomass-supply area A (€ kWh^{-1})
C_M	biomass cost (€ t^{-1})
D_i	direct distance from pixel i to power plant (km)
E_i	annual energy per unit area (GJ h m^{-2} y^{-1})
I^P	specific investment cost (€ kW^{-1})
I^R	residue fraction
M_i	annual biomass production in a pixel i (t y^{-1})
N	investment lifetime (y)
P_A	nominal power of the plant installed in biomass-supply area A (MW)
P_p^{cn}	average productivity of cereal in the non-irrigated lands of a province (t hm^{-2})
P_p^{ci}	average productivity of cereal in the irrigated lands of a province (t hm^{-2})
Q	lower heating value (GJ t^{-1})
r	nominal discount rate
r_i^f	physical restriction
r_i^g	geographical restriction
r_i^t	technical restriction
T_i	transport cost of the residues from pixel i to the power plant (€ t^{-1})
α	fraction of the total capital investment as O&M cost
η	electric efficiency
η^R	fraction of residues dedicated to energy uses
η_i^p	residue productivity per unit area in pixel i (t hm^{-2})
η^t	technical efficiency
π_A	annual electricity generation in a plant installed in supply area A (PJ y^{-1})
π_f	physical limit (PJ y^{-1})
π_g	geographical limit (PJ y^{-1})
π_t	technical limit (PJ y^{-1})

Subscripts

A	supply area
i	pixel
p	province
M	residue

Superscripts

ci	cereal in irrigated land
cn	cereal in non-irrigated land
f	physical
g	geographical
p	productivity
P	power
R	residue
t	technical

Abbreviations

BIG/CC	Biomass integrated gasification/combined cycle
FBC/ST	Fluidized-bed combustion/steam turbine
GC/ST	Grate combustion/steam turbine
GIS	Geographic Information System
I	Irrigated
LHV	Lower Heating Value
MITYC	Spanish Ministry of Industry, Tourism and Trade
NI	Non-irrigated
OECD	Organisation for Economic Co-Operation and Development

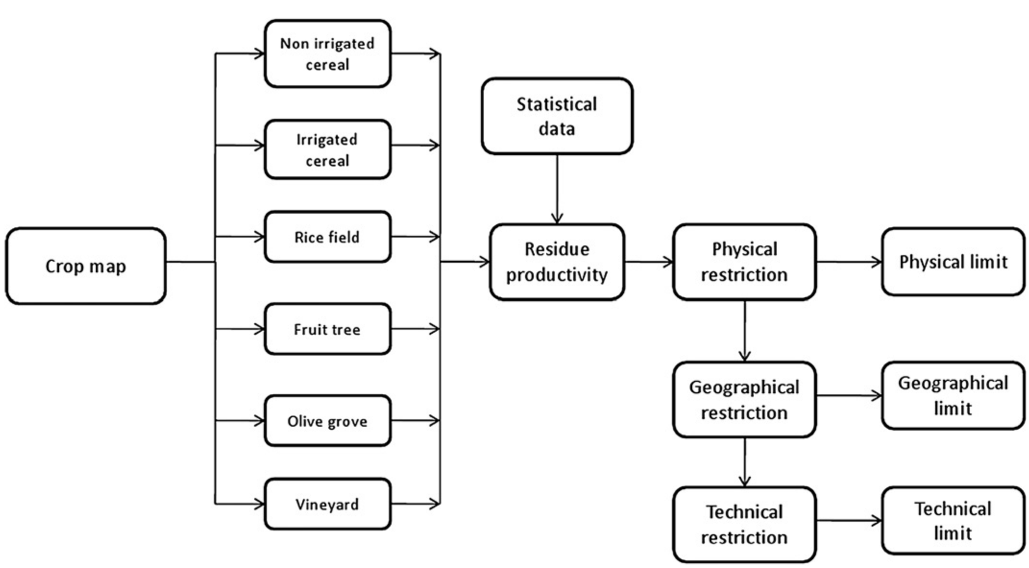

Fig. 1 – Methodology for the estimation of the energy potential from agricultural residues.