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# Biomass utilisation in energy process

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## Abstract.

Vegetal residues constitute the most abundant biomass of our planet. Some $10^{11}$ metric tons are produced annually in the biosphere with an energy content of 2.425 × 1018 kJ. The methods for utilizing biomass residues have always been of great interest, but this interest has recently grown in Europe and the USA, due to the potential value of forest residues as a source of useful energy. The high cost of fossil fuels and technological progress have made possible the appearance of energy development of biomass systems that allow us to obtain energy directly or indirectly by means of combustion, pyrolysis or gasification processes. These development systems are becoming more and more efficient, reliable and clean. Due to this fact, biomass is currently being taken into account as a total or partial alternative to fossil fuels. The target of this work is to quantify and to map the biomass power potential of residual biomass coming from most representative forest species in Bizkaia (Spain), using like tool a Geographic Information Systems (GIS). The quantity of forestal biomass residue (Tons/year) is determined after considering two factors: the quantity of forestal residue (Tons/ha-year) of the main forestall species, and the surface (ha) occupied by such species

**Key words** GIS, biomass, forestall residues, resources map.

## 1. Introduction

During the last years, the power applications related to residues originated in forestal treatments applied to forest masses have become in an increasing interest. This is due to 3 characteristics:

(1) Neutral balance of emitted carbon dioxide during combustion, since the $CO_2$ of the living biomass forms part of a flow of continuous circulation between atmosphere and vegetation.
(2) Relative abundance and uniformity to a world-wide level. The exploitation of residual biomass means to change a residue into an energy resource.
(3) The combustion of residual biomass does not emit either sulphured or nitrogenous pollutants, or hardly solid particles, thus being much more respectful with the environment. [1,2, 3].

Forestall biomass includes two types of forest products that nowadays have almost no exploitation and as a result of this they are considered residues:

a) Vegetable residues from different forest treatments such as pruning, bud selection, fitosanitarium cuttings and underbrush cleaning.
b) Wood exploitation residues, either from final o from intermediate cuttings, or vegetal matter from energetic cultivation installed in forest fields.

Forestall residues have low potentially-fermentative sugar contents in the form of high molecular weight polymers. The characteristics and composition of these vegetable residues let us obtain several products, provided that adequate separating techniques are used, such as ethanol, sugars,..., with different applications, as it is shown in figure 1.

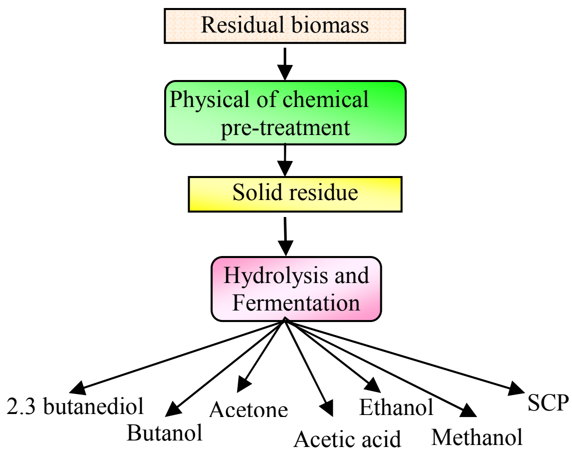


Figure 1 - Obtention of different products from lignocellulosic residues

These last years, a growing interest in the study of biochemical processes has arisen, mainly those that lead us to the obtention of ethanol and to the production of biomass (molecular microbial protein, SCP. [4].

With the massive use of fossil fuels, the energy development of biomass started diminishing steadily. However, during the last years, energy panorama has varied remarkably worldwide. The use of biomass as a source of energy is a possible alternative for mineral oil and, moreover, it could decrease environmental pollution. Forestall biomass is a substantial renewable resource that can be used as a fuel to generate electric power and useful thermal output [5].

## 2. Energetic potential of biomass

The overall energetic potential of biomass the biosphere would be able to generate annually is estimated at 68.08 Gtoe. This represents an enormous biomass production potential worldwide [6]. The energy potential of residual biomass in Spain is about 26 Mtoe/year (table I).

Table I. - Resources of potential residual biomass in Spain

| Type of residue | Energy potential Mtoe/year | Useful resources Mt*/year |
|---|---|---|
| Forest resources | 8.1 | 17 |
| Agricultural resources | 12.1 | 35 |
| Agricultural/industrial | 2.5 | 26 |
| Cattle and slaughterhouse residues | 1.3 | 95 |
| Solid urban residues | 1.8 | 15 |
| Totals | 25.8 | 188 |

In the Autonomous Community of the Basque Country, an estimate of 795,000 tep biomass global exploitation is expected for 2010. Due to this, the necessary investment is estimated to be worth € 396 million (table II).

Table II. - Energetic objectives for 2010 in the Autonomous Community of the Basque Country

| Biomass type | 2010 objective (toe)* | Investment M€ 2001-2010 |
|---|---|---|
| Wood residues and black bleaches | 297,200 | - |
| Forest residues | 96,300 | 58.8 |
| Agricultural residues | 22,900 | 15.0 |
| Cattle residues | 3,100 | 2.1 |
| Urban residues | 198,600 | 129.4 |
| Biofuels | 177,000 | 191.0 |
| TOTAL | 795,100 | 396.3 |

* Toe : tonn of oil

During the last years, the power applications related to residues originated in forestall treatments applied to forest masses have become in an increasing interest. The use of biomass with energy purposes means a series of advantages over fossil fuels:

- The exploitation of residual biomass means to change a residue into an energy resource.
- Decrease of external dependence on fuel supply.
- Technological innovation processes will let optimize the energy yield of biomass

Forestall biomass includes two types of forest products that nowadays have almost no exploitation and as a result of this they are considered residues:
a) Vegetable residues from different forest treatments such as pruning, bud selection, fitosanitarium cuttings and underbrush cleaning and
b) Wood exploitation residues, either from final o from intermediate cuttings, or vegetal matter from energetic cultivation installed in forest fields.

The target of this work is mapping the potential energy production from forestall residues in the Region of Bizkaia , Spain, using GIS tools. A GIS is composed of digital geographic data (digital maps and tables of attributes linked to map identities) and the hardware and software needed to manipulate and display the data in a mapped format [7].

## 3. Methodology

In this work, the biomass resources considered has been those produced in the forestry sector as consequence of field operations.
After analyzing and reviewing those methods used by different researchers when evaluating forest biomass residues by means of SIG [8, 9, 10, 11 and 12] the most adequate methodology for estimating biomass residue in Bizkaia is defined [Project PIV0822 financed by the University of the Basque Country].
Geographic Information Systems (GIS) are useful tools for understanding the geographic context of a wide range of issues pertinent to bioenergy, especially energy demand and biomass supplies.

### 3.1. Data sources

A geographic data base is worked out within the initial phase of the project. This is carried out by gathering data from several sources of information so that a “Map of Energetic Resources of forest biomass in Bizkaia” is obtained (Inventario Forestal CAE 2005, Tercer Inventario Forestal Nacional (IFN3), Mapa Forestal del País Vasco 2004-2005 at a scale of 1:50.000 (MFE50), Mapa de Pendientes de Bizkaia, among others).

### 3.2. Selection of the main forestall wooded species

Data from IFN3 show that the territory of *Vizcaya* presents a mean wooded surface of 152 $m^3$/ha. Some 80% of this surface corresponds to conifers and a mere 20% to leafy trees. The specie that concentrates higher stocks is pine radiate (figures I), this followed by oak groves and eucalyptus. Taking into account the high prices of by-products from leafy trees, they are not considered adequate for energetic valuation. For this reason, this study focuses on pine forests and eucalyptus groves. Table 3 shows this distribution.

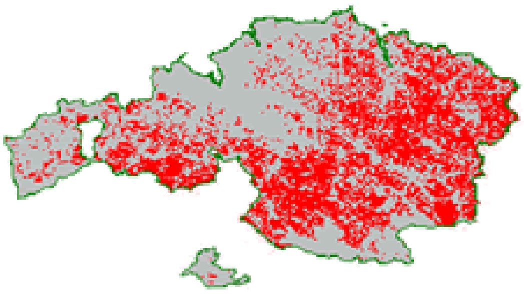

Figure 1. Pine radiate in Bizkaia

Table III. Main forestal species that exist in Bizkaia

| TYPOLOGY OF VEGETAL MASS | % |
|---|---|
| Plantations of pine radiata | 53.02 |
| Mixed masses ( pine radiata with other species of conifers) | 1.91 |
| Plantations of aloctone conifers | 3.81 |
| Pine grove of pine pinaster (Pinus pinaster) | 4.06 |
| Pine grove of Scotch pine and laricius) | 1.91 |
| Plantations of Eucalyptus globulus y Eucalyptus nitens | 10.69 |
| Beech grove (Fagus sylvatica) | 2.73 |
| Grove of holm oaks (Quercus ilex) | 2.65 |
| Oak groves and other leafy trees | 12.84 |
| Shore forests | 3.65 |
| Brushwood and thin woodland | 2.73 |
| **Total** | 100 |

### 3.4. Evaluation of forestall biomass residue

Once the space distribution of the main tree species has been determined, their residue production values are calculated.

Estimations of forestall above-ground biomass can be made by either direct or indirect methods. The direct method consists of weighing the biomass in a number of parcels and extrapolating the results to larger areas. It is a destructive and very laborious procedure, unless it can be performed in conjunction with silvicultural tasks [12].

In this work, indirect methods have been used. The indirect method utilizes equations whose predictor parameters are obtained from forest inventories. Biomass equations are developed by correlating the weight of crown biomass or other non-merchantable tree parts (bark, roots, etc.) with other tree parameters such as the DBH (Diameter at breast height), stem volumes (V), or tree height (H). Such parameters can be readily found in forest inventories.

According to different authors allometric equations have been applied with acceptable accuracy ([13]; [14]; [15]; [16]; [17] and [18]), the equations for the biomass estimation of the pine radiate y eucalyptus globulus are, according to this study, those that are shown in Table IV:

TABLE IV. Equations for the biomass estimation in PR and EG plantations

| Fraction | Equation EG | $R^2$ | Equation PR | $R^2$ |
|---|---|---|---|---|
| Wood | $W = 0{,}0062 * d^{2{,}35} * h^{1{,}001}$ | 0,97 | $LnW = -4.83 + 1.72 LnDn + 1.43 LnH$ | 0.99 |
| Crust | $W = 0{,}0093 * d^{2{,}46}$ | 0,71 | $LnW = 1.11 - 0.80\ LnDn$ | 0.91 |
| Big branches | $W = 0{,}0076 * d^{3{,}39} * G^{-0{,}83}$ | 0,70 | $LnW = -3.75 + 2.01\ LnDn$ | 0.65 |
| Medium branches | $W = 0{,}0264 * d^{2{,}63} * G^{-0{,}81}$ | 0,85 | $LnW = -3.99 + 1.89\ LnDn$ | 0.79 |
| Small branches | $W = 0{,}0451 * d^{3{,}08} * G^{-1{,}59}$ | 0,76 | $LnW = -4.94 + 1.96\ LnDn$ | 0.66 |
| Leaves | $W = 0{,}0043 * d^{3{,}69} * G^{-1{,}22}$ | 0,75 | $LnW = -4.05 + 1.97\ LnDn$ | 0.73 |
| Brotes ($d \leq 5cm$) | $W = 0{,}2536 * d^{2{,}4579}$ | 0,99 | - | |

W: dry weight in kg; d: normal diameter in cm; h: h:overall height in m; G: basimetrical area in m2/ha

In forestal biomass from trees, that part of biomass susceptible of being exploited for generating energy is the residue left in the forest after all the woodland treatments.

The quantity of forestal biomass residue (Tons/year) is determined after considering two factors: the quantity of forestal residue (Tons/ha-year) of the main forestall species, and the surface (ha) occupied by such species (figure 2).

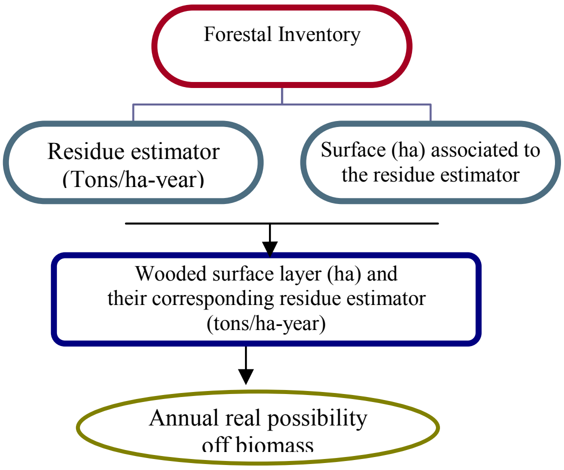


Figure 2 . Potential biomass residue estimator

The calculated forestal residue estimator will depend not only on the specie's productivity being dealt with, but also on the treatments

### 3.4.- Forestal biomass residue energetic potential estimation

The energetic potential of wooded species selected in petrol equivalent tons (pet) is obtained from equation [19, 20]:

$$P = S(ha) \,.\, Er(t / ha \,.\, year) \,.\, PCI(Kcal / kg) \,.1000 kg / t \,.1 tep / 10^7 \, Kcal \quad (1)$$

Where

S: surface in hectares

Er: forestal wet residue estimator in tons/year

PCI: biomass inferior caloric power in wet base (the moisture at which the PCI is measured must be the same as the one at which productivity is considered)

The measuring of PCI will be carried out either through direct methods (calorimeter in the laboratory) or through indirect methods (based on the application of equations) in order to determine the mean PCI value of each forestall specie.

### 3.5.- Integration of the methodology of forestal biomass energetic estimation in the SIG

The potential energy of biomass expressed in kJ/ha is calculated by using SIG tools (Ackview GISTM). In order to carry it out, the forestal species distribution vectorial information is pasterized with a spatial resolution pixel of 1 ha in terms of its most characteristic specie. All the methodology carried out can be schematized in figure 4.

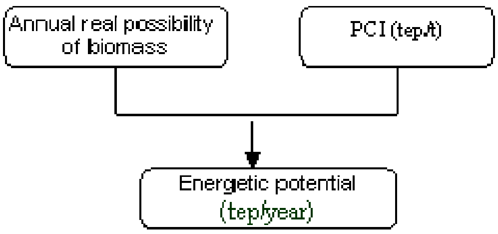


Figure 4. Residual biomass potential estimation

## 4. Conclusions

SIG is a powerful as well as useful tool for evaluating biomass forestal resources since they combine efficiently both cartographic data and data from different censuses that facilitate the cartography of results

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## References

[1] IPCC, 2007: Climate Change 2007, Report of the Intergovernmental Panel on Climate Change [ Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, 996 pp.

[2] Pérez, S., Renedo, C.J., Ortiz, A., Mañana, M. Silió, D. and Tejedor, C.:"Eucalyptus globulus and the eucalyptus nitens as energy crops" Congreso Icrepq, Sevilla, 2007.

[3] Faaij, A., "Energy from biomass ans wastes. Dissertation University, Utrech, 1997.

[4] Camps M., Marcos, F.: "Los biocombustibles", Ed. Mundi-Prensa, Madrid, 2002

[5] Mateos E., González, J.: "Biomass: Potential source of useful energy", International Conference on Renewable Energy and Power Quality (ICREPQ¨07), Book of Summaries Pag. 199-200, 2007.

[6] Fernández, J. 2007. Biomasa. Energías renovables. Cuaderno: Energías renovables para todos: Biomasa. Disponible en: http://www.energiasrenovables.

[7] Graham, R. L., English, B. C. and Noon, C. E. A "Geographic Information System-based modeling system for evaluating the cost of delivered energy crop feedstock". *Biomass and Bioenergy. 18 (4)*, 309-329, 2000

[8] Domínguez Bravo, J. et al.: "Evaluación de la biomasa potencial como recurso energético en la región de Navarra". Geofocus: *Rev. Int. de Ciencia y Tecnología de la Inf. Geográfica.* n º3, pp 1-10, 2003.

[9] Calvo, L. F., D.Blanco, Gómez, J. M., Otero, A. and Morán, A. "A GIS based method for evaluating exploitable biomass in Castilla y León (Spain), *World Renewable Energy Congress IX*, 2006.

[10] Masera, O., Ghilardi, A., Drigo, R. and A. Trossero, M. WISDOM: A GIS-based supply demand mapping tool for woodfuel management. *Biomass and Bioenergy. 30 (7)*, 618-637, 2006.

[11] García Martín, A., Pérez Cabello, F. y de la Riva Fernández, J. (2006): "Evaluación de los recursos de biomasa residual forestal mediante imágenes del satélite Landsat y SIG", *GeoFocus* (Artículos), nº 6, p. 205-230. ISSN: 1578-5157.

[12] Esteban L.S. García, R., Ciria, P. and Carrasco, J.: "Biomass Resources and Costs in Spain and Southern EU Countries" Clean Hydrogen-rich Synthesis Gas Report, Chrisgras fuels from biomass, Nº 1 Deliverable Nº 36, CIEMAT, 2009.

[13]Araújo, T., Higuchi, N. And Andrade, J. Comparison of formulae for biomass content determination in a tropical rain forest site in the state of Pará, Brazil, Forest Ecology and Management (117)1-3 pp. 43-52., 1999.

[14] Silva. R, Tavares. M, Pascoa. F.: "Residual Biomass of Forest Stands. Pinus pinaster Ait. And Eucalyptus globules Labill". 10º Congreso Forestal Mundial. Actas nº 5. París, 1991

[15] Esteban, L., 2000. Evaluation of crown biomass production in thinnings of cluster pine (Pinus pinaster. Ait) in the Spanish Northern plateau. Proceedings of 1st World Conference on Biomass for Energy and industry. Seville, Spain, 5-9 June 2000.. Ed. James & James, London, UK"

[16] Keller, M., and Hurtt, G. Biomass estimation in the Tapajos National Forest, Brazil, *Forest Ecology and Management* (154)3 (2001) pp. 371-382

[17] Ter-Mikaelian, M.T. and. Korzukhin, M.D. Biomass equations for sixty-five North American tree species, Forest Ecology and Management (97)1 (1997) pp. 1-24

[18] Zianis, D., Mencuccini, M., On simplifying algometric analyses of forest biomass. Forest Ecology and Management, (2004) 187, 311-332.

[19] R. Rodríguez-Soalleiro1*, M. Balboa2, J. G. Álvarez-González2, A. Merino3 and F. Sánchez1: Efecto de la selvicultura en la extracción de nutrientes a lo largo del turno en plantaciones de tres especies de crecimiento rápido en el norte de España" Invest Agrar: Sist Recur For (2004) Fuera de serie, 114-126.
[20] Merino, A, Rey C., Brañas, J., Rodríguez-Soalleiro, R.: "Biomasa arbórea y acumulación de nutrientes en plantaciones de *Pinus radiata* D. Don en Galicia" Invest. Agraria.: Sist. Recur. For. (2003) 12 (2) , 85-98