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Estimating the potential biomasses energy source of forest and agricultural residues in the Cinque Terre Italian National Park

Davide Astiaso Garcia[a], Silvia Sangiorgio[b,]*, Flavio Rosa[a]

[a] Dept. of Astronautical, Electrical and Energy Engineering (DIAEE), Sapienza University, Via Eudossiana 18, Rome 00184, Italy
[b] Dept. of Mechanical and Aerospace Engineering (DIMA), Sapienza University, Via Eudossiana 18, Rome 00184, Italy

Abstract

This paper aims to evaluate the feasibility of biomasses exploitation as an alternative Energy source, in areas characterized by high environmental, cultural and landscaping value. In particular, a methodology for assessing the energy potential from biomass was applied in protected areas, using Geographic Information System (GIS) software and data from European Program Corine Land Cover, jointly with other local data useful for analyzing the topography and the biomass availability of the chosen territory, as well as for an assessment of the necessary logistics for biomasses transportation. This methodology was applied to the Cinque Terre national park, obtaining as a result an estimation of the potential biomasses energy source coming from forest and agricultural residues.

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Keywords: biomass potential, GIS (Geographic Information System), CLC (Corine Land Cover) analysis

Introduction

The Italian territory under natural constraints is about 10% of the whole national surface, which includes 24 national parks covering 1,465,681 hectares. Considering energy management, protected areas should include clean and low impact sources for energy production [1-2], as well as adequate strategies for reducing energy consumptions [3-7]. Exploiting biomass from protected areas means the use of resources already available at local scale, with a zero emissions balance, generating energy for self

* Corresponding author. Tel.: +39 06 44585271;
E-mail address: silvia.sangiorgio@uniroma1.it

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consumption or trade, and improving at the same time a sustainable management of the considered areas. Protected areas can provide different types of biomass: from forests (residues resulting from pruning), from agriculture (crop residues), animal (residues from farms). So they can be used in different types of plants and for different application. Within these considerations, the main aim of this paper is to assess the suitable potential biomasses energy source of forest and agricultural residues and in a high environmental value area, the Cinque Terre Italian National Park, considering the conservation of local ecosystems and biodiversity, as well as the preservation of its typical landscape linked to its cultural heritage. Cinque Terre is a National park in Liguria, a northwestern region of Italy, that includes coastal and mountain ecosystems, jointly with a typical agricultural landscape due to terracing.

Methodology

The bio-energy chains of any analysed area have to be realized considering the available biomass typologies as well as the technologies to achieve the best outcomes. Therefore the following two paragraphs give some indication about these two aspects.

2.1 Territorial data gathering for the estimation of biomasses typologies and quantification

The first step of the adopted methodology foresees a land cover analysis of the natural protected area in examination using a GIS (Geographic Information System) software. Land cover data could be obtained analyzing the databases realized under the Corine Land Cover (CLC) European programme which include an inventory of land cover in 44 classes [8-9]. In this way it will be possible to identify at the outset what are the biomass types available in the territory, pinpointing the areas with forest and agricultural biomasses. Moreover CLC analysis allows a first classification of the forest and agricultural biomasses typology of each highlighted area. This step is essential for the following choice of the most suitable technology for energy production considering the biomass typologies and availability. Considering forest residues (tops and branches) the amount of biomass from each class could be calculated by multiplying the surface of the considered class by the corresponding residue productivity index (I) measured in t_{dm}/ha, where t_{dm} are tons of dry matters. The same approach could be used for the assessment of biomasses residues from agricultural CLC classes (straw, vegetable and fruit peels), considering the harvest indexes of their residues as the residues production index, measured in t_{dm}/ha; moreover, the following parameters should be considered [10]: Residual Ratio (RR) - main product/residue; Harvest Moisture (HM)[%]; Lower Heating Value (LHV) [MJ/Kg_{dm}]. In conclusion, the biomasses production (BP) of an analyzed area could be calculated using equation 1.

$$BP = \sum_{i=1}^{i=n} I_i \cdot s_i \quad (1)$$

Where BP is the biomass production; I_i is the residues production index related to the i-th CLC class and S_i is the surface of the i-th CLC class. Starting from the data reported in an handbook prepared by the partnership members within the frame of the ENER SUPPLY (ENergy Efficiency and Renewables– SUPporting Policies in Local level for EnergY) project, it is possible to estimate residuals production of agricultural crops and forest areas, making reference to CLC classes. After the CLC analysis, for forest biomasses, a slope analysis is important for the estimation of the biomasses hauling distance: a study [11] recommend a maximum hauling distance of 300 meters for slopes up to 30%, while a maximum hauling distance of only 60 meters is recommended for slopes higher than 30%. GIS should be used also for an angle of slope analysis, processing a ground elevation model. In addition, the extraction of forest access roads from the topographic data was carried out. All these data have been implemented in a GIS database for the elaboration of queried digital maps [12-16] containing the main information for evaluating the feasibility of biomasses as local energy source. GIS is widely used in these kind of studies, and can be the basis of a decision support system for the management of biomasses, and can be an evaluation instrument for the feasibility of bioenergy projects [17]. Then, an intervention scenario should be prepared, assessing the real feasibility of each possible intervention, by the analysis of the following aspects: The distances from biomasses availability and their potential use for energy production should be as short as possible; Promotion by local authorities and associations to reduce operating and management of the supply chain; Presence of small plants; Feasibility of cogeneration and / or trigeneration plants inside the area under examination; Analysis of the environmental and landscaping local constraints for the conservation and protection of the natural heritage and landscape. One of the most important barriers in increased biomass utilization in energy supply is the cost of the respective supply chain and the technology to convert biomass into useful forms of Energy.

2.2. Technological choice

There are numerous ongoing technological developments in the field of biomass energy conversion. A distinction can be made between the energy carriers produced from biomass by their ability to provide heat, electricity and engine fuels. Biomass and fossil fuels can be compared in terms of their O:C and H:C ratios, known as a Van Krevelen diagram: the lower the respective ratios the greater the energy content of the material. Considering the energy production using biomasses by residues, the most common technologies are incineration, anaerobic digestion, pyrolysis and gasification. According to Demirbas [18], the technology choice should prefer ones with the lowest life cycle cost, which needs the least land areas, and which are able to produce more power with less waste production and air or land pollution.

Results and discussions

3.1. Territorial data gathering for the estimation of biomasses typologies and quantification

Table 1 show the CLC analysis of the 5 Terre National Park, highlighting that the most) widespread forest typology is the Broad-leaved forest, while, considering agricultural areas, vineyards are the most commons. Tables 2 summarize residuals production of forest areas and agricultural crops for each CLC class of the 5 Terre National Park.

Table 1: Residual values of Forest sector for each CLC class of the 5 Terre National Park

CORINE LAND COVER surfaces	Hectares (ha)
2.2.1 Vineyards	334
2.4.3 Principally agriculture, with natural vegetation	306
3.1.1 Broad-leaved forest	6006
3.1.2 Coniferous forest	1892
3.1.3 Mixed Forest	2118
3.2.3 Sclerophyllus vegetation	401
3.2.4 Transitional Woodland shrubs	240
3.3.3 Sparsely vegetated areas	135
3.3.4 Burnt Areas	109

Table 2: Residual values of Forest sector for each CLC class in the 5 Terre National Park

Land use (CLC classes)	Type of Biomass	I_i (T_{dm}/ha)	Harvest moisture (%)	LHV (MJ/kg_{dm})
3.1.1 Broad-leaved forest	tops and branches	3	25 – 60, 40	18.5 – 19.2
3.1.2 Coniferous forest	tops and branches	4	25 – 60, 40	18.8 – 19.8
3.1.3 Mixed Forest	tops and branches	2	25 – 60, 40	-

Table 3: Residual values of agricultural Crops for each CLC class in the 5 Terre National park

Land use (CLC classes)	Type of Biomass	Residual Ratio (Residue/principal product)	I_i (T_{dm}/ha)	Harvest moisture (%)	LHV (MJ/kg_{dm})
2.2.1 Vineyards	Prunings	0.39 – 0.45	2.5	45 –50	18.4
2.4.3 Principally agriculture, with natural vegetation	Cereals	1 – 1.66	3	14	17.5 – 19.5

Therefore, applying Eq (1) to the Cinque Terre National Park, it is possible to estimate the biomass production (BP) for each CLC class, as reported in Table 4.

Table 4: Estimate available forest and agricultural biomass production (BP) in the 5 Terre National Park

CORINE LAND COVER surfaces	Hectares (ha)	I_i (T_{dm}/ha)	BP (t_{dm})
2.2.1 Vineyards	334	2.5	835
2.4.3 Principally agriculture, with natural vegetation	306	3	918
3.1.1 Broad-leaved forest	6006	3	18018
3.1.2 Coniferous forest	1892	4	7568
3.1.3 Mixed Forest	2118	2	4236
Total	10656		31575

In addition, analyzing the orographic data, the Cinque Terre coastal slope is very steep, so that in some places the distance from the shoreline of the watershed is reduced even at 750-800 meters, with the top of the ridge that still persist about 600-700 meters. The analysis of slopes using GIS has allowed to highlight how the topography of the park of the Cinque Terre necessitates a careful evaluation of the methods of supply of biomass given the steepness of the slopes and not easily accessible areas.

3.2. Best technological choices for the 5 Terre National Park

The land use analysis highlights that the most suitable biomass for energy production is the one deriving from the pruning of vines. The shoots, collected and properly reduced in chips, may be used for energy production, via different types of process or plant. This choice is only one of a set, because a lot of types of biomass are available in the studied area. Using vine shoots is a good way to manage in a better way all the local wine industry, with a good care of the farming and the creation of job position. After the analysis of the anthropic characteristics of the examined areas, the use of the monorails presently utilized by local agricultural was considered for the transportation of the biomasses localized in the more sloping areas. The major types of large scale biomass boilers use one of the following technologies: grate combustion systems (stationary or travelling), pulverised fuel (PF) systems or fluidised bed combustion (FBC) systems. BIOTEC project has highlighted the BAT (Best Available Technologies) for heat generators that use prunings of vines. The vine shoots combustion produce a high ash content, an average of 3.85% of dry matter that influences the boiler choice.

Table 5: Prune of vines qualitative characterization

Parameters	Woodchips vineyard	wood
Average water content (%)	13,04	2
Ash content (% as it is)	4,11	-
Ash content (% dry matter MJ/kg)	4,73	2,1
Caloric value net (as it is MJ/kg)	15,9	-
Caloric value net (dry matter MJ/kg)	19,91	18,7

In addition, Table 6 presents experiments data carried out on generators with electrostatic fueled by wood chips and vine shoots and wood pellets.

Table 6: emission data on generators with electrostatic fueled by wood chips and vine shoots and wood pellets

[mg/Nm^3]	Wood chips		Vineyard pruning chips		Wood pellet	Vineyard pruning pellet	Italian limits legislation	European limits legislation
Electric Filter	off	on	off	on	off	Off		
PM	37,6	9,6	131,8	96	8,9	10,4	200	150
Total Organic Carbon	2,1	1,5	6,1	2,1	1,1	1	30	-
CO	484,5	394,8	>1000	>1000	200	208,7	350	2500
NO_2	213,4	294,2	376,9	443,2	86,3	77,7	500	-
SO_2	8,1	13,9	41	24,7	5	2,1	200	-

The major types of large scale biomass boilers use one of the following technologies: grate combustion systems (stationary or travelling), pulverised fuel (PF) systems or fluidised bed combustion (FBC) systems [14]. A first distinction for choosing type generators is to evaluate the possibility that these have to burn materials with more or less variables moisture and sizes.

More appropriate to the generator burning vine shoots or a mixture of sticks and wood chips is the solution to moving grate. This solution reduces the problems related to the management of the ash and slag in the combustion process. The GIS analysis has highlighted the preliminary potential energy crop screw in the area of the park summarized in Table 7.

Table 7: estimating potential biomasses energy from GIS analysis

Vineyards (ha)	334
Pruning producibility (1.8 t/ha)	601
Energy (MJ, 19910 MJ/ton)	11969800
Equivalent diesel (litre)	332497
Dwellings (average 270 m^3)	158

Conclusions

Biomasses are intended to be a more and more important source of energy in Europe, and every State is trying to make them a good alternative to classic sources, even if their cost is not competitive in many cases. There are many types of biomass, but lignocellulosic one is very widespread in lands like Italy, which has a large amount of parks and protected areas. Their management is not always easy, and represents a cost for the community, due to the complex features of every area and the need of security to be maintained, so the realization of an energy supply chain contributes to the maintenance of territory, has economic benefits, reduces risks and CO2 emissions. Analyzing data, it is possible to visualize the characteristics of the territory and availability of biomass, and basing on seasonality of forestry biomass, it is possible to set a supply chain from collection to energy exploitation of the resources. The obtained results stored on a GIS database represent a useful tool for bioenergy chain managing and design.

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Biography

Silvia Sangiorgio, Mechanical Engineer, Ph.D in Energetics. Her studies concern energy efficiency and renewable, with a particular focus on biomasses and land use. Another research area regards smart cities, and, in particular, sustainable buildings.