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Building Energy Opportunity with a Supply Chain Based on the Local Fuel-Producing Capacity

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Abstract: Studying and modeling plants for producing electric power obtained from vegetal wood cellulose biomass can become an opportunity for building a supply chain based on the local fuel-producing capacity. Focusing on energy-producing technologies, such as pyrolysis or gasification, the present work assessed the amount of vegetal biomass that may be used as fuel, both in terms of actual availability and supply price, in the Province of Rieti (Italy). The aim is to draw up a supply plan that has an intrinsic relationship with the local area. The results confirmed a production of 24 MW of project thermal power and 4 MW of project electric power. The ensuing plant was then studied following current norms about renewable energy, environmental consistency, and atmospheric emissions. An economic analysis of the cost investment was also carried out, where the total return is approximately of 19%. The results exposed that plant costs are acceptable only if short-supply chain fuel is purchased. The costs of generating energy from agroforestry biomass are certainly higher; however, the plant represents a significant territorial opportunity, especially for the economic sectors of agriculture and forestry. The employment effect plays a central role in the concession process, which is relevant for the interaction among renewable energy production and agriculture. The environmental impact of a biomass plant from agroforestry residues can be measured exclusively on atmospheric emissions: the plant must be placed in industrial areas without any landscape or naturalistic value.

Keywords: supply chain; biomass; energy; sustainable development

1. Introduction

The current energy guidelines requested by the European Community encourage the use of renewable resources as a potential alternative supply to traditional fossil fuels [1–4]. By supporting sustainable development, energy needs can be met through the conversion of agroforestry biomass into biofuels [5–10]. Therefore, a requirement for establishing sustainable production and consumption chains at the local level emerges [11,12]. Accurate planning becomes crucial to ensure the planning and establishment of agroenergy districts [2,13–15]. Such a procedure requires a careful analysis of potential energy capitals that can be obtained in each territorial area [9,16]. It should be reminisced that the primary sector in Europe (and more specifically in Italy) has suffered a severe decline in recent decades, e.g., the loss of employment and an increase of abandoned rural areas [16–19]. By re-establishing rural landscapes and promoting multifunctional agriculture, agroenergy districts arise as competitive and sustainable certainties for agricultural contexts [2,9,20].

In recent decades, the traditional use of biomass for the paper market has been accompanied by increasing demand in the energy sector [21–24]. The production of biomass for the energy industry is associated with specific silviculture [2,7,25,26], which is very often linked to artificial reforestation rather than to the development of natural forests [12]. In recent years, many studies have focused on bioenergy plants [2,6–8,24,27–29]. However, very often, only various aspects are considered, e.g., with engineering or energy performance nature, without understanding the impact that a bioenergy plant can generate in the surrounding area. Regarding bioenergy, it is indispensable to evaluate the (natural) resources available in the given region guaranteeing an adequate degree of environmental sustainability. The recovery of biomass for energy purposes is conditioned by many limiting factors, e.g., (i) difficulties in recovering (also residual) biomass and mechanizing harvesting; (ii) the absence of an industrial dimension; (iii) limits imposed by forest management rules, which in some cases prevent the recovery of the trash, and (iv) procurement costs [2,5,30,31]. In the present study, the first phase is to estimate the potential biomass that a definite area can assure, and therefore enable a suitable sustainable development. Then, the economic sustainability of the biomass plant, with its technical characteristics and performance, was calculated. Through a supply chain based on local fuel production capacity, innovative opportunities can be built by reusing biomass, which can be considered agricultural and forestry waste, and providing long-term job opportunities through a reliable and efficient bioenergy plant (both in economic and energy terms).

There are two statistical sources in Italy that provide information on forests: The National Forest Inventory (NFI) and National Institute of Statistics (ISTAT). The forest heritage of the Lazio region accounts for about 5% of the entire national forestry in Italy. The most affected areas are the Apennine and pre-Apennine ridge in Italy, which are mainly located in the marginal and internal areas of hills and mountains [2]. As exposed by the recent Energy Plan of the Lazio Region adopted in 2017, the quantities of biomass (such as forest pruning) available in the provinces of Rieti, Viterbo, and in the northern area of Rome are mostly adequate to establish a local supply chain based on the use of biomass to produce energy. About 25% of the forest cover is in the province of Rieti. Owing to the incidence of rich aquifers at minimum depths [32,33] and the current crisis of traditional crops [14,34,35], these contexts in the Lazio region own model topographies for developing energy crops, and thus agroenergy districts [2,36,37].

Italy has adopted many strategies toward sustainable development in recent years, including the use of renewable resources, e.g., biomass [11]. With the aim of protecting the surrounding environment, the plant designed for the present work aims to use the most efficient technologies available by examining the experiences of small-scale local installations [38,39]. The present work was based on an innovative framework based on the design of a complete plant for the energy production with a net power output of 4 MWe, which essentially consists of a combustion furnace with a mobile grid integrated by a superheated steam Rankine cycle (Hirn cycle), at an industrial site of the municipality of Rieti (Italy). The proposed plant is powered by combustible biomass (defined by the DPCM (Ministerial Decree) March 8, 2002 and modified by the DPCM 08/10/2004) with reference to biomass waste from agricultural, forestry, forestry and agro-industrial activities, and energy crops (short rotation forestry) treated exclusively with mechanical systems. The chief aim is to offer a complete investigation starting from a geographical analysis of the context, as it is often underestimated in earlier studies [16,20], moving to engineering, technical, economic, and environmental measures [12,15,27,28] so that the plant is really functionable. A strong focus was provided on two key themes for the plant: (i) biomass availability in the local contexts; and (ii) a feasibility study. Further objectives emerge such as that (i) the flue gas treatment system for the abatement of pollutants complies with the most restrictive requirements imposed by the regulations in force; that (ii) the ash and dust extracted are subjected to an inertization process and that (iii) all of the waste and meteoric water is collected and conveyed to the consortium purifier. Particularly, safeguarding the surrounding environment as far as the emission of pollutants is concerned, the plant was designed using the most efficient technologies with the objective of reducing pollutants and complying with the most restrictive requirements imposed by the current legislation.

Lastly, previous works habitually focused on monothematic subjects, e.g., studying bioenergy plants in terms of engineering or energy performance without weighing their socio-economic and environmental impacts [2,6–8,24,27–29]. Therefore, the present paper primarily deals with three tasks with the aim of: (i) assessing the biomass potential from a sustainable perspective; (ii) providing an economic accounting of an exemplary biomass plant in terms of its technical characteristics and performance; and (iii) evaluating social and environmental impacts.

2. Materials and Methods

2.1. Regional Energy Plan and the Potential of Biomass in the Lazio Region

By means of Regional Council Resolution no. 656 of 17 October 2017 (published in the Official Bulletin of the Lazio Region or BURL of 31 October 2017, No. 87, Suppl. Nos. 2, 3, and 4), the proposal for a "Regional Energy Plan" (P. E. R. Lazio) was adopted in the Lazio region. Biomasses can assume a crucial role in this plan. The main types of biomasses are related in this Italian region to:

- agricultural and agro-industrial residues (grass, pruning, shells, pomace);
- forestry;
- fermentable residues (pigs, cattle, cattle, slaughter waste, organic fraction).

In the present work, data relating to the potential availability of biomass was obtained from evaluations contained in several databases: (i) the Atlas of Biomasses about agricultural, agro-industrial, forestry, and fermentable residues excluding the organic fraction from municipal waste; (ii) the Regional Waste Plan, especially of the Lazio region; (iii) the Institute for Environmental Protection and Research (ISPRA) Waste Report; and (iv) the determination of vital requests (e.g., about the organic fraction of municipal waste and the fraction of waste sent to landfill). Furthermore, potentials of forestry biomass are reported from National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) data processing, describing the gross and net availability of current uses in terms of dry matter and disjointed energy potential at the provincial level (Figure 1).

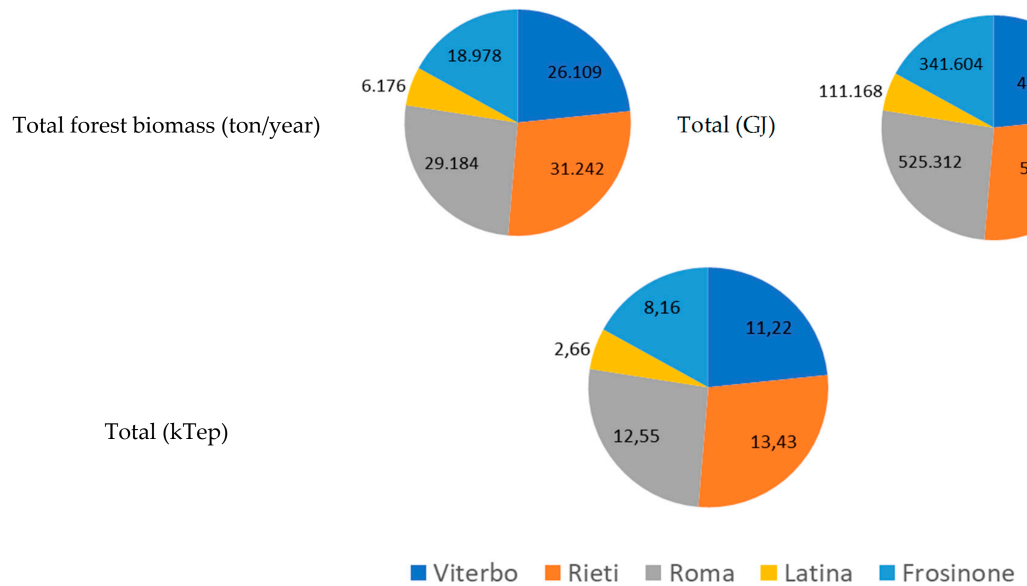

Figure 1. Gross potential for forestry biomass in each province of the Lazio region expressed in ton/year, GJ, and kTep. Source: elaboration from ENEA, Atlas of Biomasses.

2.2. Study Case

The research design concerns a plant to produce electricity, with a net power output of 4 MWe, fundamentally consisting of a combustion furnace with a movable grill integrated by a superheated steam Rankine cycle (Hirn cycle). As defined by the DPCM 8 March 2002 and modified by the DPCM 8 October 2004, the plant proposed can be fed by combustible biomass waste from agricultural, forestry, and agro-industrial activities obtained from local primary sector activities, and from specific energy crops treated exclusively with mechanical systems. The main types of biomass that may be used as fuel are: natural wood from silvicultural activities and forest maintenance, e.g., pruning of trees (e.g., olive groves); herbaceous residues from agricultural activities; hazelnuts and fruit shells (typical local cultivation); virgin and spent olive pomace from the activities of olive mills; sawdust, bark, shavings, chips, panels, veneers, and waste from primary and secondary wood processing (not chemically treated); and natural wood from poplar crops with annual and/or biennial rotation.

The investigated area initially covered the whole Province of Rieti. The latter area is an Italian central province situated in the Lazio region that has Rieti as its capital city, covering an area of about 3000 km^2 and including 73 municipalities. Envisaging the greatest location required considering which area could ensure a sufficient amount of biomass for energy sustainability and the operation of the plant. Considering the Energy Plan of the Lazio Region, the quantities of lignocellulosic biomasses (e.g., forest pruning, e.g., olive groves) available in the Province of Rieti are largely sufficient to feed the plant. In fact, following the inventory of National Forest Inventory (NFI) and ISTAT, about 25% of the forest cover of the Lazio region is in the province of Rieti, which is situated in the central area of Italy (Figure 2). The Province of Rieti has a mainly mountainous orography that is characterized by the presence of gorges, valleys, and plains. It is one of the richest Italian territories in water due to the number of lakes and rivers inserted in an environment characterized by woods, hills, and plains. The Province of Rieti, e.g., due to the water presence and the state of crisis of traditional crops, has ideal features for developing energy crops. Finally, the location of the plant was assumed to be in an industrial site in the province of Rieti. The location of the plant makes it possible to optimize the distribution of biomass to be used as energy fuel, both in terms of quantity and transport logistics.

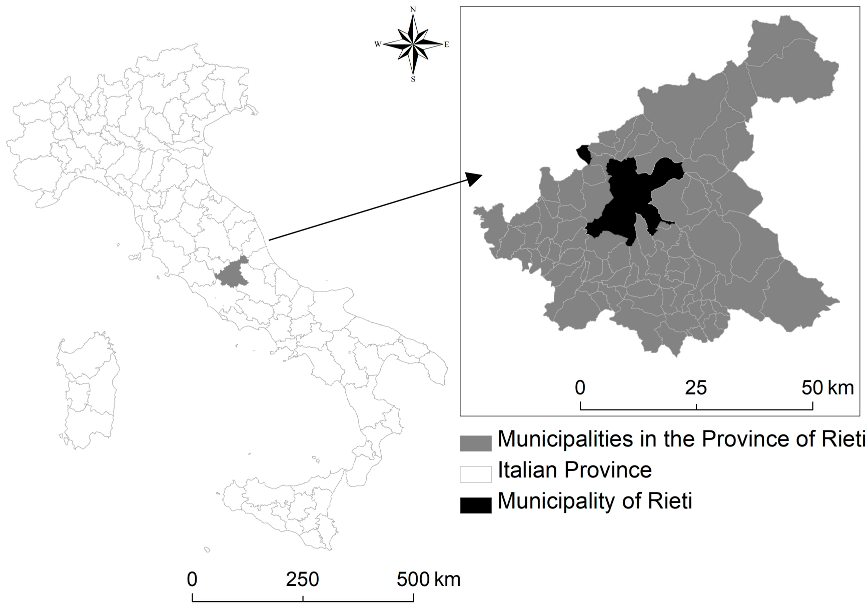

Figure 2. Territorial framework of the case studied.

The spatial evaluation was developed at the municipal scale based on a GIS procedure, provided by the arcMap program of ESRI [9]. Thanks to GIS technologies and official national documents, the optimal area can identify where place the proposed plant. Estimating how much biomass the territory can offer, optimizing energetic and even logistic processes, the provisions of the plan were designed for almost 60,000 tons of fuel where the chemical and physical characteristics are consistent with modern steam-producing boilers. The supply plan defines a mixture of local vegetal biomass made of fruit and olive tree thinning, waste matter from urban green areas, matter from forest handling, and poplar harvesting, according to short rotation forestry [40,41]. The territorial analysis was carried out for each one of the tree components. In this way, it is possible to identify the ideal context in which to locate the plant.

2.3. Economic and Financial Examination

Assessing the economic and financial performance, the following concepts will be applied in this research. Economic and financial investigation enabled estimating the calorific value (CV), price, and energy price, along with the resulting costs and consumption. Assuming the necessary quantity of biomass per year and the installable power, the size of the plant and therefore also the investment cost that should be sustained were projected. Furthermore, other key indicators were calculated, such as: electric energy (EE), selling price (€/MWh), and unit investment (both in €/kW and €/kWh).

The resulting return on equity (in percentage terms) can be incorporated in the fundamental concept of the finance of the WACC, which defines the weighted average of the cost of capital coming from both the equity and the debt [42,43]. The internal rate of return (IRR), the payback period, and the net present value (NPV) were calculated. Precisely, the work also applied the following formulas and definitions: (i) EBITDA (earnings before interest, taxes, depreciation, and amortization), which offers the ability to generate an economic margin in percentage terms by considering financial policies (interest income and expense) and budget techniques (e.g., amortization, depreciation, and taxation). It is indispensable for profitability analysis at a management level to estimate the profitability of an investment, and assists in the comparison of results from different businesses operating in the identical economic sector. Its application for each year (n) is specified according to the following equations:

$$\text{EBITDA (n)} = \text{Added value (n)} - \text{Cost of employees (n)}$$

$$\text{EBITDA \%} = \text{EBITDA (n)/Revenues (n)} \times 100$$

Then, (ii) the debt service coverage ratio (DSCR) was run to calculate the annual capacity of an activity to cover its debts, therefore highlighting how much of the investment can be financed through a financial structure (known as the bankability of the project):

$$\text{DSCR} = \text{FCO}/(\text{Df (n)} + \text{I (n)})$$

where 'FCO' is the cash flow; 'Df' is the principal repayments; 'I' represents the interest payments; and 'n' is the i_{th} year. Furthermore, DSCR can assume different values: >1 (positive capacity), or <1 (negative capacity) to finance the investment of expertise in n year.

The payback period embodies the number of years that are required to offset the investment. The payback period of a given investment (or project) is a central determinant of whether to proceed with the project, as longer payback periods are characteristically not desirable for investment positions. The examination was founded on the calculation of net present value (NPV) as the fundamental tool for choosing the optimal investment. This technique was applied to correlate the value of the plant with the ability to produce a level of financial flow that was adequate enough to meet an investor's expectation of remuneration. The calculation was applied in the classical formula: where NCF are the cash flows from operating activities; t is n years of investment; and r is the discount rate.

From the logistical standpoint, a transportation radius was calculated to cover all of the biomasses present in Rieti and the surrounding municipalities. Transport costs have been estimated in this way. Furthermore, additional charges were assessed, such as the average price Green

Certification (€/MWh), hypothesis price (€/MWh), concessions (€), and other costs and expenses (€), which involve maintenance, oil, water, insurance, etc.

The economic analysis has also made it possible to estimate: (i) the social impact, in terms of new jobs and thus granting new employment opportunities in Rieti; and (ii) an environmental influence to ensure adequate sustainable development, using renewable energy resources from the surrounding territory that are not of fossil origin.

3. Results

3.1. Biomass Availability

The proposal was the production of 24 MW of project thermal power and 4 MW of project electric power. The resulting plant was then reviewed from the viewpoint of the norms providing for renewable energy, environmental consistency, and emissions into the atmosphere.

Integrating the three databases (NFI, ISTAT, and the 2017 Energy Plan of Lazio Region), the potentially available biomass was identified at the municipal scale. The territorial analysis allowed detecting where the biomass is placed and its nearness to the bioenergy plant, with the aim of optimizing even the logistical processes. Forest assortments derive primarily from conifer wood (about 1287 tons). The studied plant can used waste material from poplar cultivation (143 tons), beech trees (143 tons), deciduous trees (excluding poplar and chestnut trees) (53 tons), and castanets (884 tons). Given the relevant amount of biomass available, it can be stated that the bioenergy market in Rieti is sufficiently competitive, particularly at the regional scale but also at the national level, since the energy plant avails sufficient biomass to properly operate over time. Furthermore, the operators who will work in this plant will enjoy a continuous work activity over time, also allowing new employment opportunities in the primary sector. The territorial analysis of where to place the plant was carried out with the elaboration of statistical data and GIS programs provided by ESRI. The analysis brought to light a fragmented spatial reality consisted by many villages located in the mountains in the province of Rieti. This situation makes clear the determination of two indicative peculiarities: (i) prevalently mountainous territory, with some hilly parts; and (ii) in a total of 73 municipalities in the province of Rieti, only four municipalities (Rieti, Poggio Mirteto, Fara in Sabina, and Cittaducale) exceed 5000 inhabitants, resulting from a typical mountain context.

Estimating the total amount of forestry biomass that is available and theoretically usable for energy purposes in the province of Rieti, the analysis excluded municipalities with a percentage ratio among the forest area and the municipal area that was less than 20%. For them, biomass concentrations are inadequate to rationalize the cost-effectiveness of large-scale biomass energy use. Then, all of the surfaces with resinous woodlands were removed, partly since they have a protection function, and therefore may only undergo slight operations. Also, municipalities with a total available biomass of less than 1000 t/year have been rejected. The final data found for each municipality pointed out that the total quantity of biomass available throughout the provincial territory is approximately 238,000 t/year. For instance, following the Regional Energy Plan, Rieti and Cittaducale occupy municipal areas of 20,652 hectares and 7095 hectares, respectively, offering about 24,906 and 8442 t/year.

3.2. Feasibility Study

Due to its ideal features, the plant was designated in the municipality of Rieti, as this municipality allows economic optimization, greater available resources, local nearness and compactness for users, and low transport costs. Table 1 summarizes biomass quantities that can be withdrawn from the forest sector in a hypothesis of adequate exploitation of the resources that are present in the municipality of Rieti, with a target price that is lower than the price of firewood, but still adequate to be able to exploit those biomasses with lower commercial value, which currently find a scarce if not zero outlet on the market. Through our elaboration, quantities of forest biomass derived from the municipal territory defined the total production for each kind of wood for supplying the plant (in tons).

Table 1. Biomass valuation for the plant in the municipality of Rieti (in tons).

Woodland Forests	Poplar Forests	Chestnut Trees	Deciduous Trees	Total
5985	537	2956	886	10,693

Considering a conservative average dry moisture content of 30/35% [40,41], the total biomass theoretically available is approximately 160,000 t/year in terms of dry matter.

From an economic viewpoint, the market in the Province of Rieti is affected by the distribution of the different forests. Oak coppice is always used where it has a good level of fertility and is grown on all suitable slopes. Chestnut and beech trees are used as firewood in the areas where they are most present. As far as prices are concerned, €6–8/quintal for imposed wood and €11–13/quintal for retail wood can be supposed. The imposed price, depending on the different cutting stations, is generally composed by soil cost (10–20 €/ton), cut operations (25–30 €/ton), and woodland (25–30 €/ton) for a total for 60–80 €/ton. Regarding transport processes, 10–20 €/ton can be considered in the short-brief range (some tens of kilometers), depending on the local road network. These values are all subject to variations linked to seasonal trends. However, prices have rarely reached values that could favor the valorization of the industrial energy sector in the market. At the purchase price of 50–60 €/ton, it is not conceivable to enter the firewood market. The supply of biomass power stations with assortments that could otherwise be used for the firewood market is rare; such cases have occurred under conditions of strong price contraction due to seasonal trends.

Data and assumptions of hypothetic prices of CV and energy are reported in Table 2, assuming a consumption of 12,000 tons of biomass. An analysis on the investment cost was carried out with an overall investment of €14 million. Average annual production is about 31,200,000 kWh, resulting into a final electric energy (EE) selling price that is the sum of the average price of Green Certification and the hypothesis price (GME) of EE (166 + 54 €/MWh).

Table 2. Data and assumptions of calorific value (CV) price and energy price and resulting costs and consumption. EE: electric energy; IRR: internal rate of return; NPV: net present value.

Variable	Unit	Value	Variable	Unit	Value
Installed power	MW	4	Biomass quantity per year	ton	60,000
Investment amount	€	14,000,000	Transportation cost (in 200 km)	€/ton	50
Average annual production	kWh	32,000,000	Staff cost per year	€	270,000
EE selling price	€/MWh	166 + 54	Average price Green Certification	€/MWh	166
Unit investment	€/kW	3500	Hypothesis price (GME) EE	€/MWh	54
Unit investment	€/kWh	0.45	Concessions	€	286,138
Equity	%	30	Other costs	€	390,000
Investment rate	€	1,304,000			
Financing duration	years	13			
Financing rate	%	4.01			
Discounting rate (WACC)	%	6.00			
Financed NPV	€	665,286			
IRR	%	7.01			
Pay back	year	14			

The life of the present plant is about 15 years, considering the technical life of the plant (and materials used). In an economic and financial analysis, many precautionary assumptions were adopted. A high leverage of 80% and a lease with a duration of 13 years, which is less than the incentive period, were considered. The purchase prices considered belong to the highest segment of the prices found on the market; moreover, the cost of biomass from green recovery has been set at 60 €/tons, which is higher than the real production cost.

The annual operating hours were 7800, which were lower than the operating hours of plants with similar technical characteristics. The sales values of energy and Green Certificates were 86 €/MWh and 80 €/MWh, respectively, and remained constant over 15 years; these are cautious values that are lower than the market averages of recent years. In addition, the short supply chain fuel at full capacity was set at 77% of the needs, leaving a large margin for the improvement of this model. The hypothesis is based on (i) the novelty of the supply chain mechanism and (ii) the presumed difficulty of crossing supply and demand with the local agricultural and forestry world.

Ancillary consumption reaches 18% of production, since only 83% of annual production contributes to incentivized revenue, while 17% is for auto-consumption to auxiliary cover, without contributing to revenue. The resulting return on equity (in percentage terms) can be incorporated in the fundamental concept in finance of the WACC. Analyzing the results of the economic and financial accounts, the investment exhibited positive profitability rates above the banks' lending rate of 6.5%. The NPV is reduced to zero in about six years, until reaching a value of approximately €665,286 at the end of the 15th year. The IRR is of 7.01%, while the payback period is 14 years. The total return is approximately 19%: plants with higher outputs would entail investments that could not be taken up by the increased electric efficiency. An economic and financial examination revealed the real feasibility of the plant, envisaging a return on investment of 8%. Biomass quantity per year was assumed to 60,000,000 tons. 50 €/ton is the cost, of which 10 are related to transport costs, if the supply range is a maximum of 200 km. Other operating costs (e.g., maintenance, oil, water, insurance, etc.) are estimated at €390,000.

Therefore, the construction of the plant proposed is concrete and profitable from an economic and financial standpoint. Furthermore, the core business has an EBITDA (earnings before interest, taxes, depreciation, and amortization) of over 30% (Figure 3). A comparable trend was also observed for the debt service coverage ratio (DSCR). The payback period embodies 14 years required to offset the investment.

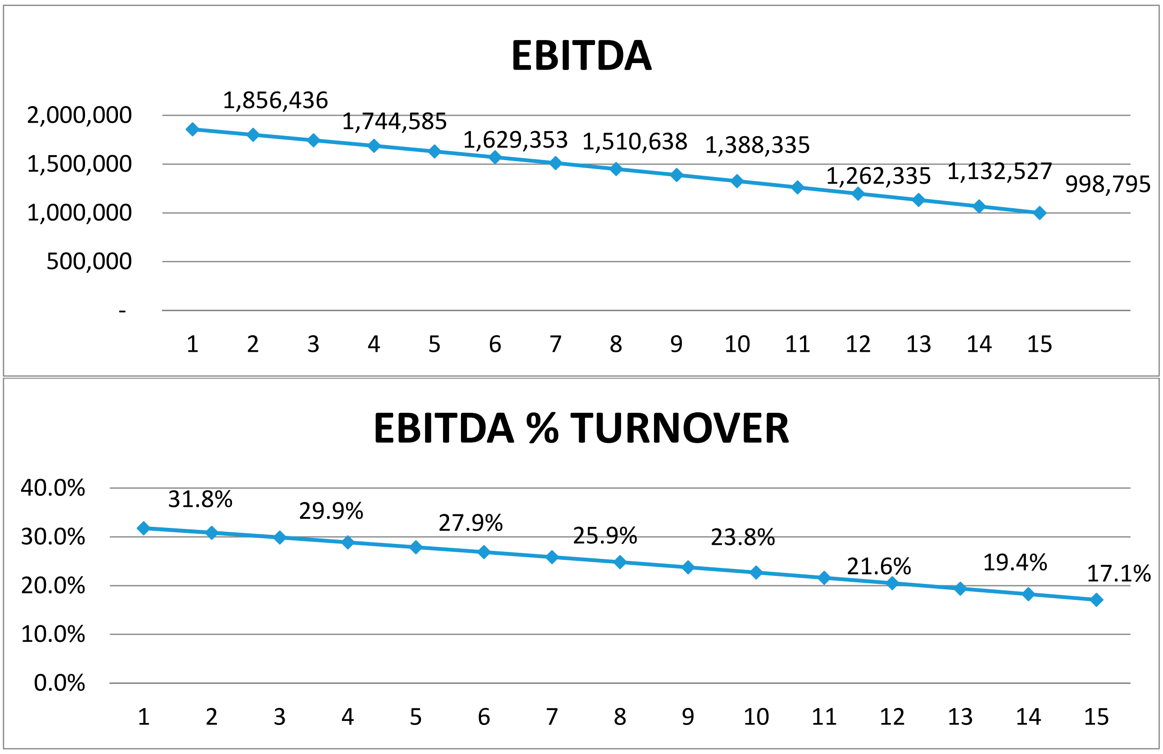

Figure 3. *Cont.*

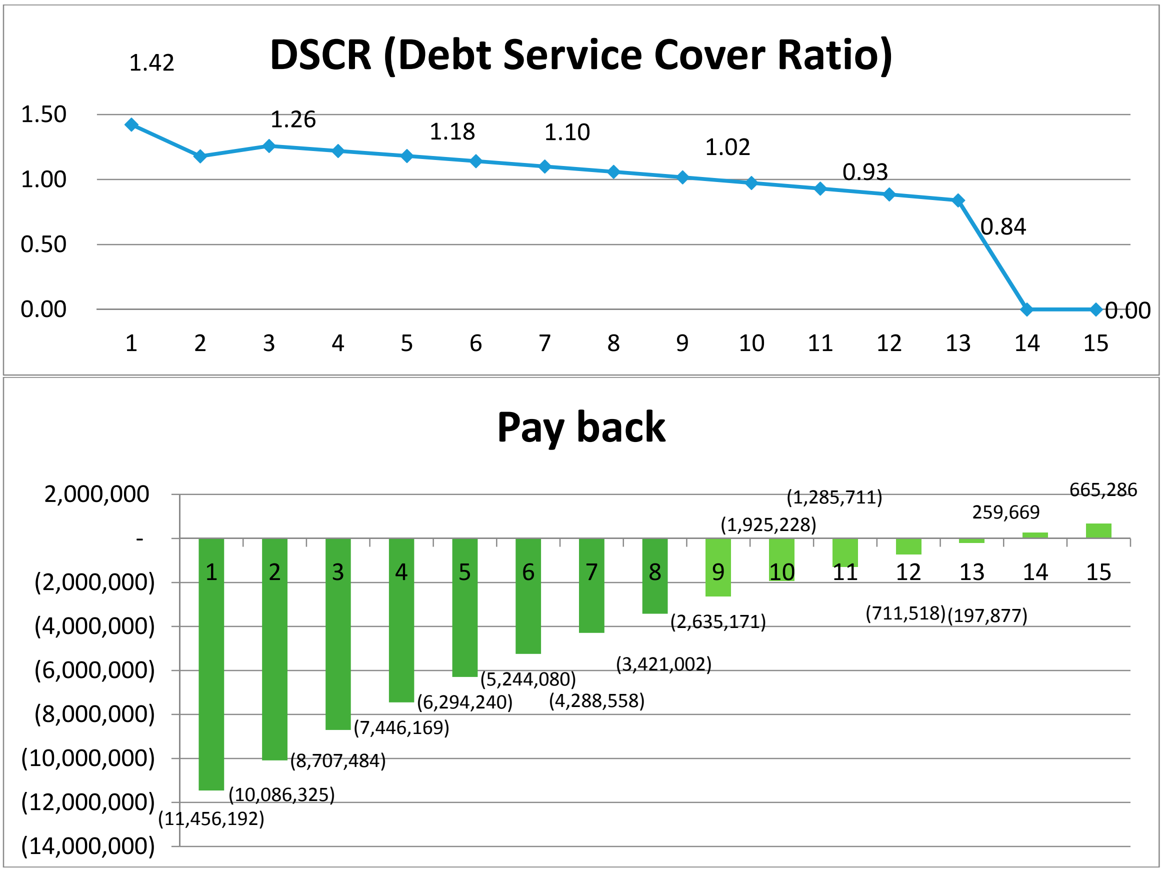

Figure 3. Results for earnings before interest, taxes, depreciation and amortization (EBITDA), its turnover, debt service coverage ratio (DSCR), and payback.

The staff costs is €270,000. The plant will be operated continuously (24 h in three 8-h periods). By law, the boiler requires a licensed operator on a rotating basis; three specialized workers are needed, and considering holidays and illnesses, a total of five licensed workers are needed to operate the boiler. Biomass handling and minor maintenance is carried out by a non-specialist operator per shift. This serves a total of five non-specialist operators. A standard business cost per operator of €30,000 per year was assumed. An administrative role is envisaged for the ordinary management of the business, handling incoming and outgoing invoices, whose annual cost is €40,000. The plant will be chaired by a chief manager, e.g., an engineer with experience in the sector, at a cost of €80,000 per year. Ordinary and extraordinary maintenance will be entrusted to the same supplier firms through specific contracts that regulate the list of repetitive interventions and their timing, and the methods of intervention in the event of extraordinary maintenance.

4. Discussion

Using renewable sources in the energy sector requires agreeing to meet the energetic demand while respecting the environment [44,45]. Agroenergy districts characterize a tangible chance for central realities in Italy toward sustainability and higher environmental quality, with the purpose of strengthening local socio-economic structures using new technologies [11]. Biomass utilization can support rural development [46]. The degree of sustainability of the agroenergy supply chains must be evaluated, as well as their networks of production processes [13].

Based on these premises, the present work focused on a forest biomass plant that represents a complex activity that involves territorial planning, logistic activity, suitable management of the energy production plant, and a vast commercial achievement dedicated to the purchase of energy fuel. The proposed model exposed that the tangible feasibility of the plant is linked to the ability to find fuel in the neighboring area (province of Rieti, Central Italy). Generally, the plant's profit can be active only in case of the purchase of fuel in the short supply chain [47,48]. In the present case, the results revealed that the studied plant can be sustainable over time, owing to the relevant incidence of forest biomass in the province of Rieti, which emerged thanks to territorial analysis. The transportation costs that resulted were not so excessive due to the closeness of the location of the proposed plant to biomass source regions. The energy plant considered can benefit from different waste material, e.g., poplar cultivation (143 tons), beech trees (143 tons), deciduous trees (excluding poplar and chestnut trees) (53 tons), and castanets (884 tons). In this way, it also allows the energy plant to continuously operate, also ensuring that its operators (initially about seven people, including five operators, an administrative person, and a chief engineer with experience in the bioenergy sector) work to endlessly strengthen the employment conditions in the agricultural sector [49–51].

Electric power is produced through a Rankine cycle using water as working fluid [52]. The choice is driven by the assumption that this is a cost-effective and reliable technology, which has reached quite a mature industrial level [53,54]. Indeed, the fuel procurement process is the driving factor for the establishment of the plant, since it is the real and actual innovating factor of the whole process [47]. Considering less consolidated energy-producing technologies, e.g., pyrolysis or gasification, would highly increase the risk of a lack of cost-effectiveness for the model, making it impracticable [48,55].

The threshold of 10 MW (or 50 MW thermal) signifies a limit line between suppliers, mainly boiler groups and accessories. The cost of the boiler is about 50% of the total cost of the installation; consequently, its impact on the return on investment is significant. The domestic market for suppliers of boilers below 50 MW is fragmented, consisting of a few firms that offer steam generation systems from other industrial sectors, e.g., steam generation for processes powered by cellulosic non-wood fuels. Above the threshold of 50 thermal MW, large national and international firms have an extensive experience in boilers, supporting the energy production of electricity. Many of them also act as general contractors, since the boiler is the most essential component of this energy system. Furthermore, the market for large boilers is unquestionably more structured and competitive, allowing costs that are less linked to the different product sectors for which the boilers are used [3,4]. The model of the present work requires that energy fuel must be supplied to the neighboring territory as territorial capacity involves the installable power [9,56–58]. The present study was focused on drawing up the biomass supply plan, which is strictly linked to the local territory. The fluctuating market trend affecting the entire agricultural sector requires planning activity [59,60]. Therefore, the energy potential of the investigated territory, the province, and the municipality of Rieti can be considered an interesting case study.

Environmentally, the impact of the proposed plant was measured exclusively on atmospheric emissions, as the plant is placed in industrial areas without landscape or naturalistic value [61,62]. The emissions levels of the plant are well below those required by law (the Legislative Decree of March 2006 sets out provisions concerning biomass combustion plants and the relative atmospheric emissions), representing a further positive element for obtaining the production authorization. Generally, the laws on renewable energy reward these kinds of plants; they provide energy efficiency rewards. From the environmental point of view, the plant is fully consistent with local and national laws, since emissions that concern the present plant are largely under legal thresholds thanks to the use of forest biomass as energy fuel, the enhanced combustion capacity of modern boilers, and the gas treatment that it envisages.

From an economic and financial viewpoint, an analysis of the investment cost was carried out with an overall investment of €14 million. The NPV is reduced to zero in about six years, until reaching a value of approximately €5 million at the end of the 15th year. The total return is approximately 19%: plants with higher outputs would entail investments that could not be taken up by the increased electric efficiency. An economic and financial examination to find out the real feasibility of the plant was carried out, envisaging a return on investment of 8%.

Regarding the purchase costs of the different types of biomass, prices appeared to be relatively stable. Boiler mouth biomass prices are the sum of several items, e.g., the raw material, its collection, cutting, chipping, transport, and storage. The latter stages are generally carried out by different actors. Speculative mechanisms are much more difficult in this context, since forest biomass has margins for cost reduction, as it practically represents an innovative market in Rieti's province.

The production of energy from vegetable biomass compared with production from other renewable sources, e.g., wind or hydroelectric sources, appears less profitable, but has an environmental impact that is generated exclusively by emissions, and a certainly higher employment impact, because it creates an induced link to the activities of biomass supply. A direct combustion biomass plant compared with a wind or hydroelectric plant with equal production capacity has an energy generation cost that is higher than 40% to 100% [63]. There are seven direct employment places that generate the biomass power plant under study, whose products are economic-induced and can be estimated as equal to the purchase value of biomass in the short supply chain. For the plant in question, this is equal to €2,500,000 annually for 15 years. The direct employment of a plant with the same wind or hydroelectric production capacity can be estimated at two units; meanwhile, the supply chain is almost zero.

Energy costs from forest biomass are therefore certainly higher [64–67]. However, the plant also represents a vital opportunity [68,69] for the territory of Rieti. It should also be noted that the supply chain supports the agricultural and forestry sector, which currently are in a structural crisis [10,70] in central Italy. The employment effect plays a significant role in the concession process due to the interaction among renewable energy production and agriculture [10,11,15]. Although the biomass power plant is less competitive than other renewable energy sources from a profit and loss point of view (e.g., solar plants), the greater ease of the concession process and the close interaction with the agricultural and forestry business environments are key strengths [71,72].

5. Conclusions

A biomass plant alimented by agroforestry residues represents a complex activity since it involves (i) the management of the energy production plant; (ii) a logistic plan; and (iii) a commercial achievement dedicated to the purchase of fuel. As a primary prerequisite, a tangible possibility of the plant is linked to the capability to find agroforestry residues in the neighboring areas. The territorial context therefore enacts the capacity and installed power. An economic and financial analysis provides a future perspective of the plant, which brings social and environmental benefits. Even if the costs of generating energy from agroforestry biomass are certainly higher, the plant represents a significant territorial opportunity, especially for the economic sectors of agriculture and forestry. The employment effect plays a central role in the concession process, which is relevant for the interaction among renewable energy production and agriculture. Furthermore, the environmental impact of a biomass plant, which was situated in industrial areas without any landscape or naturalistic value, proved the resulting atmospheric emissions that need to be estimated in a perspective of sustainable development.

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