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1st International e-Conference on Energies
14 - 31 March 2014

http://sciforum.net/conference/ece-1

Conference Proceedings Paper - Energies „Whither Energy Conversion? Present Trends, Current Problems and Realistic Future Solutions”

Improving Sustainability of Energy Conversion from Biomass Resources: the Case of Bari Airport CHP (Combined Heat and Power) Fuelled with Bioenergy from Short Chain

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Received: 15 January 2014 / Accepted: 8 March 2014 / Published: 14 March 2014

Abstract: Harnessing biomass-derived energy can improve environmental and economic sustainability of a Combined Heat and Power production. The paper presents a new decision making policy and its application in meeting the energy up-grading needs of the Bari airport (300 kWe), based on an economic-environmental analysis related to the use of different bioenergy from short chain (<70 km). The main aim of this paper is to demonstrate how a “Zero Kilometer Energy” design model in a CHP plant represents a more sustainable alternative to the same conventional energy systems, regarding to the impact on the local socio-economic system. The study has been carried out in order to promote a synergistic and sustainable relationship between a territory and the infrastructures that service it, in terms of energy supply chain. For this purpose, three different bioenergy production systems (biomass from wood waste, vegetable oil / biodiesel and biogas from food waste) harnessing local agro-energy resources in Apulian region (Italy) were analyzed. The analysis has been integrated by a DCF (Discounted Cash Flow) Method, identifying the economic feasibility to make an informed choice. Finally the theoretical paybacks under different governmental incentive schemes, from 2012 to 2015, have been calculated along with estimated carbon savings to highlight the energy market trends for the different biomass resources.

Keywords: bioenergy; zero kilometer energy; CHP; biomass; economic sustainability; airport building; short chain

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1. Introduction

In response to predictions of increasingly global energy consumption and GHG emissions, one adaptation strategy that has been encouraged is the increased planning, design, and installation of bioenergy plants, such as biomass combustion, thermo-chemical conversion and biogas and biofuels production. In order to enable commercial availability of advanced bioenergy at large scale by 2020, European Union has adopted several measures [1] to aim at production costs allowing competitiveness with fossil fuels at the prevailing economic and regulatory market conditions.

A number of studies have been conducted to investigate bioenergy sustainability using environmental and socio-economic indicators [2,3] and life cycle assessment analysis [4]. While LCA studies have considered different key methodological issues and assumptions [5], for example, in relation to energy balance [6], land-use changes [7] and GHG savings [8], relatively little is yet known about the relationships between groups of factors [9], such as the sizes, types, and locations of bioenergy plants which together influence their effectiveness in improving territorial sustainability. Even a recent research article [10] shows that there is no rationale for discriminating between scales of stationary bioenergy plants related to environmental performances; but associated impact due to energy distribution has been considered decisive.

Although a large number of specific applications of bioenergy from dedicated crops are documented. Recently, several studies have focused on electricity production from dedicated short-rotation bioenergy crops [11-13]. One of these studies [12] has shown that there is no clear environmental advantage between some dedicated bioenergy crops (corn and miscanthus) and conventional fossil fuel for several energy-related products, although some advantages in terms of mitigating climate change, considering biogenic CO_2 emissions as carbon neutral. The future of biomass energy supply would lie in the optimization of current technologies evaluating capabilities of decentralized renewable combined heat and power production [14].

A recent scientific research [15], dealing with optimization of bioenergy scale, has focused on economic aspects; it has pointed out that there is a clear trade-off between economy of scale related to the energy production size and the biomass procurement costs due to increasing supply chain size, in particular the raise of transportation distances. Other links have been found between scales of deployment and life cycle environmental impact. For instance, another recent study [16], focusing on an energy distribution perspective, has highlighted the close relationship between the environmental assessment parameters and the operational losses of bioenergy systems. Therefore, the reduction of supply chain costs and cons is possible trough efficient proximity logic [17], promoting short production-consumption pathways for energy. Short chain is indeed not only a logic solution, but also a way to develop the role of territory in the bioenergy systems.

In order to improve sustainability level, it is necessary to investigate and build a new relationship with the territory, not only as the place of production and consumption. Just taking a holistic design approach allows to enhance the local impacts of energy production, meeting the territory needs, so that energy will be a driver for development.

This model, shown below, allows comparison at a social, economic, environmental sustainability level with the ability to develop suitable bioenergy profiles that are specific to a local context, hereinafter called "Territorial Energy Vocation" (TEV). In particular, it will be pointed out how a sustainable planning approach represents a viable alternative to ordinary energy design and management.

2. Methods

In order to achieve the sustainability goal, the specialized approach so far has focused on improving energy systems efficiency, by building many models [18] in relation to production, distribution and consumption, whereas separated from each other. The holistic approach tries to act simultaneously on the three sectors, taking advantage of the high-level policy attention on bioenergy as a driver to showcase the territorial energy vocation (TEV) and to pursue socially acceptable dynamics for the creation of the Energy Community [19]. It does not aim only to efficiency, but to optimize planning capacity in accordance with the legislative architecture in force [20].

2.1. The "Zero Kilometer Energy" model

The key assumption of this study is: Enhancing energy efficiency of a building infrastructure is only an integral part of a larger energy strategy to improve sustainability of a system. First of all, the purposed design process aims to analyze local economic dynamics and identify production chains and to find what factors could participate to the efficiency being involved as additional energy resources, strictly connected to the territorial system [21].

The following flow chart shows the different model phases.

Renewable Energy Development

V

TERRITORY

Hystorical Productions	Established Socioeconomics	Available Resources
V	V	V
Recovering Traditions	Exploiting Waste	Estimating Potential

V

Analysis of Energy Needs

V

Building Different Scenarios

V

Feasibility Evaluation by DCF method

V

Optimal Scenarios

First of all, the recognition of specific elements of the territory has been carried out to characterize the local context and to outline the "territorial vocations". Furthermore, in order to cope with the energy problem the method encourages the involvement of available waste and resources as part of energy supply chain. These material goods show the link between the territory in which they has been produced and the local energy infrastructure they will feed.

The identified biomass are the local bioenergy resources.

What the authors realized is an investigating model for the feasibility assessment of the energy efficiency improvement practices obtainable through the use of bioenergy.

The case study analyzed is a complex civil infrastructure: the airport of Bari Palese (Italy).

The adopted approach is based on a systemic-dynamic method consisting in a multi-criteria analysis focused on energy efficiency, environmental and economic aspects, as well as their spatial and temporal variability.

Spatial variability means here a quantification of the sustainability and efficiency contributions that can be realistically expected when a short chain system is adopted, that is a local resources optimization action, based on a preliminary study of the local characteristics found in the area occupied by the infrastructure.

As regards the aspects of temporal variability an annual scale study was conducted towards the energy consumption time series of the whole airport, and on the same scale, in respect of the availability cycles experienced for the eligible biomass: woodchips, biodiesel, vegetable oil and biogas. Then, the economic aspects have been studied taking into account the multiyear technical plant life and the whole discounted economical production period until 2036 (20 years starting from 2015).

The whole multi-criteria model bases its analysis and optimization system on a given starting dataset typical of the infrastructure analyzed, in turn, based on a preliminary statistical screening of its energy consumption performances and on the types of biomass likely to be available in the territory.

Just downstream of a typing action based on the real energy consumption time series, and on its monthly variability, is possible to apply the investigation model proposed. This is why the approach method described can be used for different kind of infrastructures and, at the same time, it maintains representativeness of the particular case study, providing a useful tool during the planning designing phase as capable of identify the most suitable technological solution.

2.2. The case study

As defined above, the first stage is to analyze the local context and recognize established socioeconomics and available resources.

Down line of a study focused on the climatic, pedologic and agrotechnic typical characteristics of Apulian territory close to the Bari Palese Airport, the most suitable biomass resources usable for the energy up-grading proposed have been identified.

Between the whole set of available bio resources analyzed the most appropriate turned out to be:

- wood chips from pruning of olive trees,
- cultivation of rapeseed and sunflower for the production of vegetable oil or biodiesel
- organic waste from food and agricultural supply chain for the production of biogas from anaerobic co-digestion.

As regards the availability of woody biomass, its frequent presence is due to the pruning remains coming from forests, agricultural activities, urban gardening and sawmill byproducts, particularly recurring in the Bari Province and in the airport areas.

In order to avoid any obstruction of the agricultural development potential, the authors decided to consider just the unexploited land surface. Depending on this condition, the available surface for the rapeseed and sunflower farming in the Bari Province is summarized in Table n.1 (a) and (b).

Finally, the widespread olive trees farming activities observed throughout the surrounding area of the airport draw the authors' attention towards the possibility to recover energy from the anaerobic digestion of olive pomace if co-digested with the organic waste (OFMSW) produced by the airport and fruit/vegetable waste coming from farming activities.

2.1.1. Environmental performances of analyzed bioenergy

An environmental comparison has been conducted from two different points of view, by the comparison between the primary energy consumption with and without the biomass energy co-digestion system, furthermore, comparing the total amount of CO2 emissions before and after the biomass technology up-grading.

Considering the energy amount producible by the 300 kW biomass co-generator, the energy primary comparison has been done in accordance with the calculation requirements defined by The Regulatory Authority for Electricity and Gas [22], the Italian Thermo-technical Committee CTI [23] and the National Law [24]. As regards for the CO2 emissions, the UNI standards established by the Italian Company for Standardization [25], the Integrated Pollution Prevention and Control Directive [26] and the Guest et al.'s assumptions for the conversion parameters have been adopted [10].

A distinction between the primary energy consumption due to the combustion of fossil fuels energy resources, woodchip, vegetable oil/biodiesel and biogas was made in order to point out the primary energy savings and the resulting CO2 avoided emissions.

In the following figures a summary of environmental effects for the 3 biomass technology implementation is reported:

Figure 1. (**a**) Primary energy saving and (**b**) Annual balance of CO2 emissions of energy production from Wood Chips.

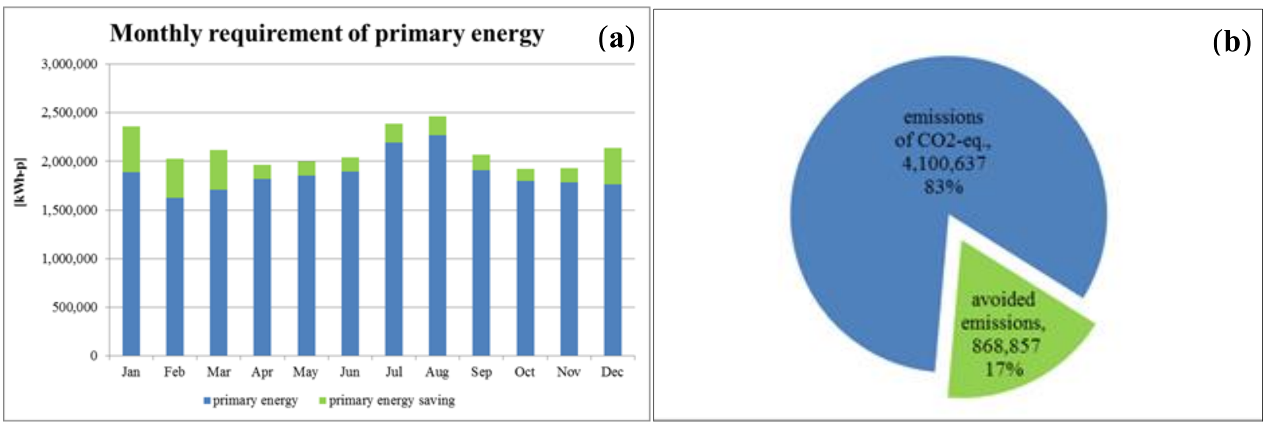


Figure 2. (**a**) Primary energy saving and (**b**) Annual balance of CO2 emissions of energy production from Vegetable Oil/Biodiesel.

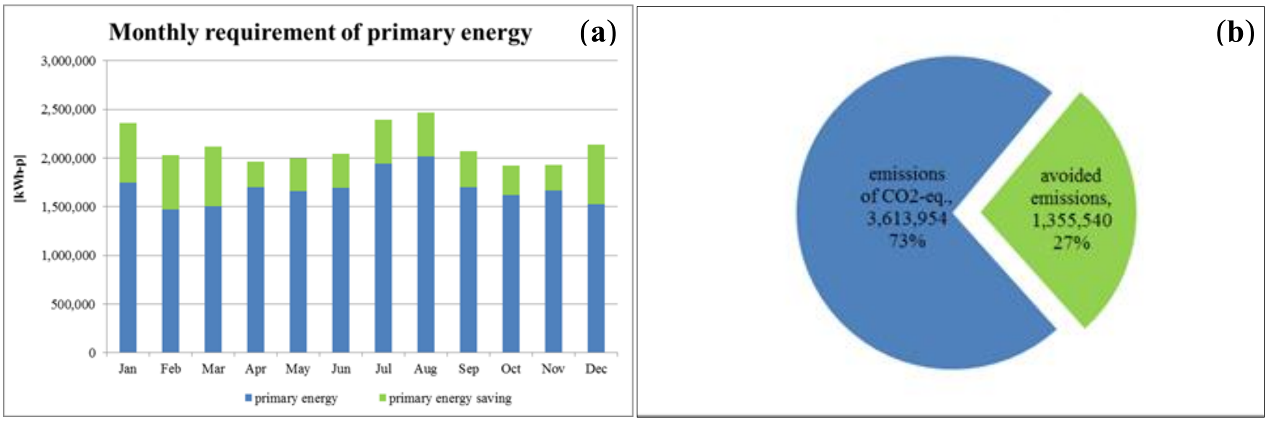
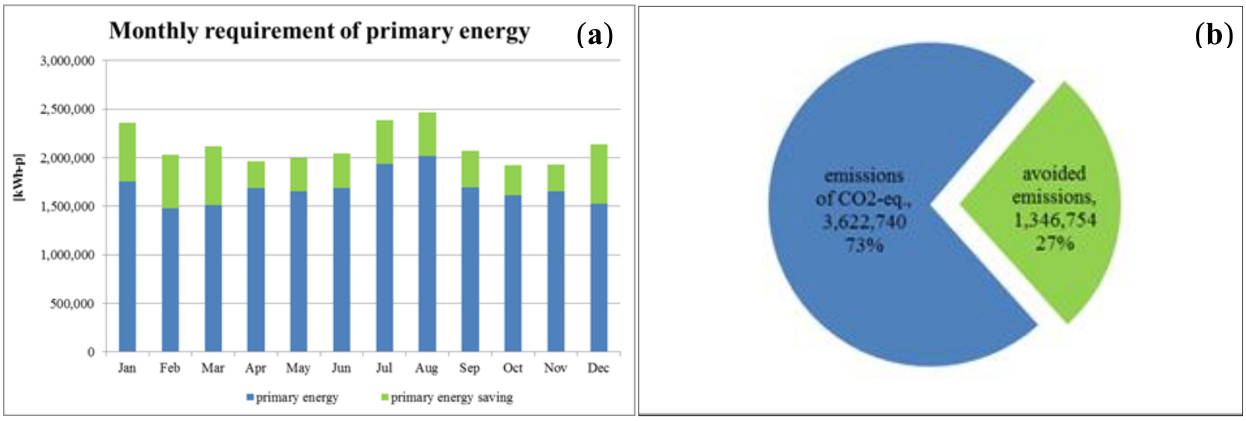


Figure 3. (**a**) Primary energy saving and (**b**) Annual balance of CO2 emissions of energy production from Biogas.



In terms of primary energy the saving effect is significant amounting to 20% in case of vegetable oil/biodiesel biomass solution, 11% in case of woodchip solution and 21% in case of biogas technology. The 11% value for the woodchip solution is due to the low plant efficiency typical for the incinerator technology that needs greater power system to reach best energy efficiency performances. Although, the CO2 emission saving is substantial due to the assumption that biomass is carbon neutral [10], considering its biogenic CO2 emissions during the whole biomass life cycle.

2.1.2. Energy characterization of airport building complex

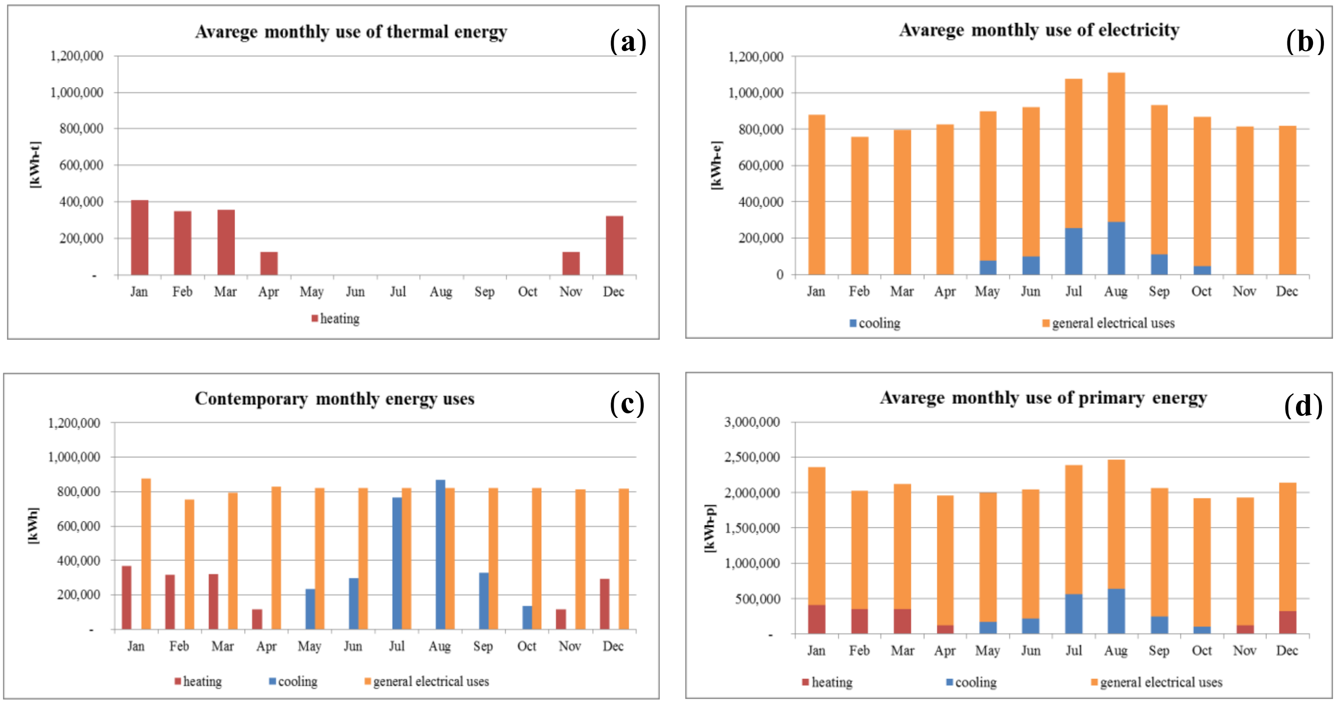
In order to identify the plant solution capable of maximizing the airport's energy, environmental and economic return, an energy consumption screening has been done related to its current plant configuration.

Thanks to a database assembling operation, formed by the real energy consumptions data billed to the airport infrastructure, the preliminary consumption study bases its foundation on a statistical analysis of representative real data properly stored and organized.

The statistical parameters obtained from the energy consumptions time series processing return a medium total annual consumption of 1,500 MWh.

The following histograms show up the monthly average value of thermal energy and electricity average consumption during one year.

Figure 4. (**a**) Average monthly consumption of thermal energy. (**b**) Average monthly consumption of electricity. (**c**) Contemporary monthly energy use highlighting. (**d**) Average monthly consumption of primary energy.



The primary energy values have been calculated in accordance with the requirements defined with the Deliberation EEN 3/08 of The Regulatory Authority for Electricity and Gas [22].

The average monthly cooling electricity has been estimated through a statistical method based on the average basic energy consumption per year, that when defined allow to the consequential splitting operation between Heating months (m_H) and Cooling months (m_C) as summarized in the following formulas:

$$\overline{E}_{base,j} = \frac{1}{m_{H,j}} \sum_{i=1}^{m_{H,j}} E_{i,m_H}$$

$$\overline{E}_{base} = \frac{1}{N} \sum_{j=1}^{N} \overline{E}_{base,j} = 821{,}542 kWh$$

Assuming that the energy consumption due to the domestic hot water is negligible (that is perfectly reasonable in the Bari Palese airport), the $\overline{E}_{base}$ formula returns a good approximation of the basic energy consumption, so it could be used to estimate the energy monthly rates due to the cooling system visible in Figure 4 (c) and (d).

$$e_{k,m_C} = E_{k,m_C} - \overline{E}_{base}$$

The result for the $\overline{E}_{base}$ value used to calculate the cooling energy is 800,000 kWh per month, than all the monthly values for cooling consumption have been obtained as reported in table n.1.

Table 1. Calculation of cooling electricity consumptions.

Month	Total Energy $E_{i,m}$	Cooling	Other uses
(-)	(kWh)	(kWh)	(kWh)
Jan	877,844		877,844
Feb	755,648		755,648
Mar	793,976		793,976
Apr	826,948		826,948
May	899,628	78,086	821,542
Jun	920,492	98,95	821,542
Jul	1,076,496	254,954	821,542
Aug	1,111,140	289,598	821,542
Sep	931,44	109,898	821,542
Oct	866,66	45,118	821,542
Nov	813,036		813,036
Dec	816,684		816,684
E_{tot}	10,689,992	876,602	9,813,390
E_{base}	821,542	8,20%	

Once the cooling and heating rates are known a critical observation of the Figure 4 (c) is possible, it represents the monthly trend of all the different types of use, and it highlights the following:

- the electric consumption is constant throughout the year and it’s always greater than both thermal and cooling consumption, with the exception of July and August;
- the thermal and cooling consumption alternate, shifting from winter to summer supply;
- in April, October and November both thermal and cooling consumption is low if compared to the electric one.

These are essential considerations for the following choosing phase where the most suitable biofuel is selected also by its availability in time. Further, the reported analysis allow to typify a Combined Heat and Power supply in case of tri-generation conditions, that is an optimized power plant able to produce at the same time electricity, thermal energy and cooling service.

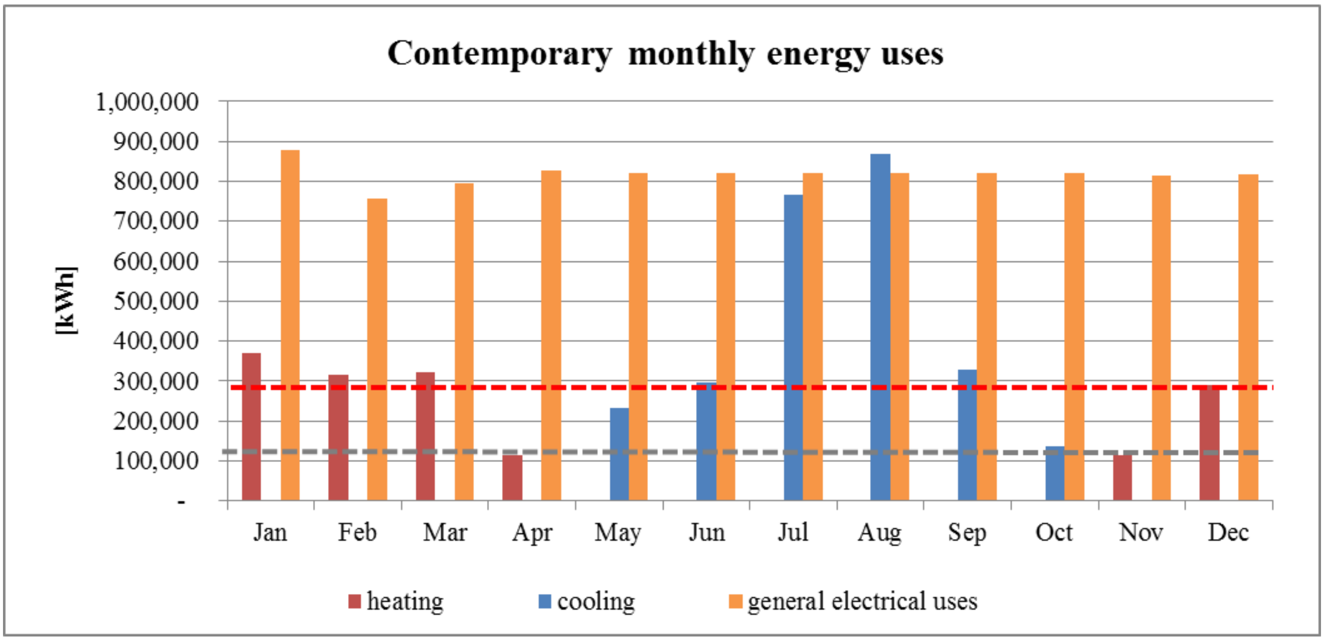
According to the results of the critical analysis on the airport consumption attitudes, a tri-generating energy group is the only technical solution allowing to a certain use, throughout the year, of the thermal energy produced by the co-generator system. An absorber, properly designed, will be responsible for the cooling energy requested in the summer period.

2.1.3. Sizing of the tri-generation plant

The size of the co-generating system proposed was made through the analysis of the real load curve registered for the infrastructure observed with the constraint of a complete and constant use of all the self-produced energy, both electrical and thermal.

Multi-scenario simulations have been analyzed in order to optimize the co-generator size taking into account the real data consumption registered for the airport terminal. In Fig. 5 is represented the graphical power sizing method used for the airport co-generation.

Figure 5. Contemporary monthly energy use and power ranges for energy consumption countervailing, P = 150 kW and P = 400kW.



The sizing graph has been built in order to identify by means of a graphical method the best installation power for the co-generation plant. The power break-line ploy discloses the real energy absorption capacity of the infrastructure subject matter of the research. Among all the simulated power hypothesis the 150 kW and the 400 kW have been reported in order to clarify and point out the utility property request.

As it's graphically deducible below the 150 kW "power break-line" all the energy produced is absorbed, and this happens every month. Above the 150 kW the thermal energy produced during April, October and November is excessive and the oversupply phenomena keep rising according to the power installed till the 400 kW threshold, where every month a certain rate of thermal energy is unused.

In conclusion, on the strength of what has been observed, the optimal co-generating power could not exceed 300 kW in order to prevent an excessive of energy waste.

3. Results and Discussion

The holistic approach described in the second section is the original core around which an economic analysis organized in sixteen scenarios for each available bioenergy is developed. Overall, the economic feasibility study evaluates forty-eight (48) scenarios, considering the three local bioenergy: (B) Biogas from food waste, (O) Vegetable Oil / Biodiesel and (W) Wood chips from pruning of olive trees. In order to describe the scenarios in the discussion, an alphanumeric code has been adopted (X X0 00). The initial letter of each bioenergy has been used in the first position (**X** *X0 00*) of the aforementioned code. After, two diversifying elements have been chosen: the calculation with the basic incentive (B) or the maximum obtainable incentive (M), taking into account the bonus incentive for improvement, and the estimated cost of biomass supply by the market (1) or by negotiation with the producers of short chain(+). These two characteristics, in this order, represented by the symbols in the parentheses, fill the second and third position (*X* **X0** *00*). Furthermore, four different start dates production have been considered: 2012 (12), 2013 (13), 2014 (14) and 2015 (15), which correspond to distinct incentive schemes [27,28]. The last two digits of the year of production beginning have been reported as the final digits of the code (*X X0* **00**).

Table 2. Table of alphanumeric codes of the scenarios.

Biogas				**Vegetable Oil / Biodiesel**				**Wood Chips**			
B B1 12	B B1 13	B B1 14	B B1 15	O B1 12	O B1 13	O B1 14	O B1 15	W B1 12	W B1 13	W B1 14	W B1 15
B B+ 12	B B+ 13	B B+ 14	B B+ 15	O B+ 12	O B+ 13	O B+ 14	O B+ 15	W B+ 12	W B+ 13	W B+ 14	W B+ 15
B M1 12	B M1 13	B M1 14	B M1 15	O M1 12	O M1 13	O M1 14	O M1 15	W M1 12	W M1 13	W M1 14	W M1 15
B M+ 12	B M+ 13	B M+ 14	B M+ 15	O M+ 12	O M+ 13	O M+ 14	O M+ 15	W M+ 12	W M+ 13	W M+ 14	W M+ 15

For instance, the first scenario as shown in the table 1, labeled by code B B1 12, is related to a biogas plant (**B** *B1 12*), funded by the basic incentive (*B* **B***1 12*), which caters to the market cost of biomass(*B B***1** *12*) and came into operation in 2012(*B B1* **12**).

3.1. The results of the Discounted Cash Flow (DCF)

The analysis has been carried out by a financial method, called Discounted Cash Flow, based on the concept of the time value of money. Financial incoming (incentives for energy sold, the high-efficiency CHP and sustainability) and outgoing (biomass supply chain, bioenergy plants and management phase) have been calculated for each year of energy production and their difference constitutes the cash flow. Each cash flow has been discounted by a Discount Rate to give its present value. This operation allows to compare the economic performances with respect to a predetermined time, the present. The Discount Rate has been estimated in four different values, strictly connected to the year of energy production beginning. In fact, the governmental incentive schemes support the bioenergy production for 15 years if the energy plants starts to produce in 2012 [27] and for 20 years if the same one starts in 2013, 2014 or 2015 [28]. Due to governmental nature of subsides, it seemed logical to link the risk rate of investment to the Rate of Return of Italian Treasury Bonds with a long-term maturity (BTP).

Table 3. Rate of Return of Italian Treasury Bonds with fifteen and twenty-year maturity.

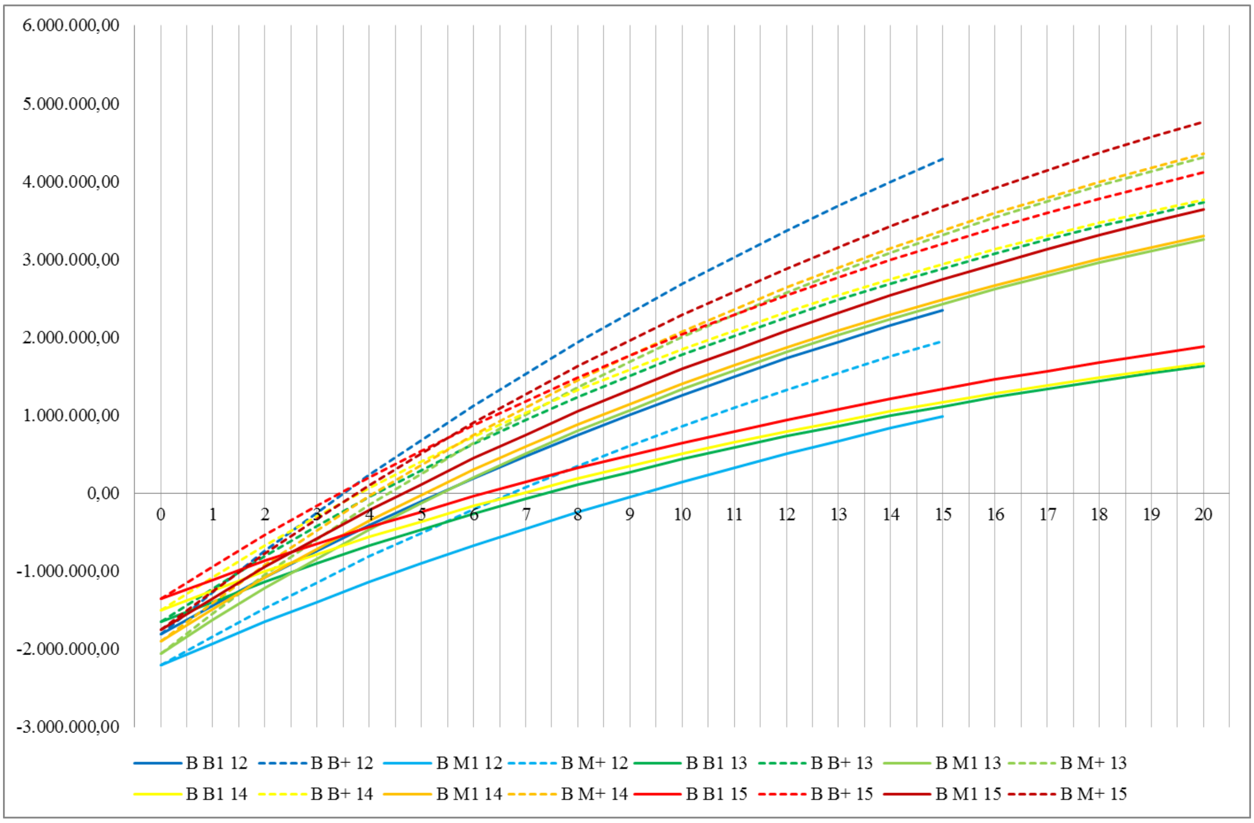
2012	**2013**	**2014**	**2015**
BTP (15 y)	*BTP (20 y)*		
BTP 2026	BTP 2032	BTP 2033	BTP 2034
4,50%	5,80%	5,75%	5,00%

As shown in Table 3, the rate varies between 4.5% and 5.8%, not invalidating the comparison between the Cumulative Discounted Cash Flows (CDCF).

The following figures report the results of DCF analysis. Vertical axis and horizontal axis represent respectively the amount of CDCF and the investment period in years. The graphs shows changes in the sixteen scenarios since 2012, year of first incentive schemes related to bioenergy sector in Italy, and forecasts trends up until 2015, deadline of the last Governmental Decree.

The eight conventional scenarios, where the profitability improvements depend on the achievement or otherwise of the maximum incentive, drawn with a continuous line, are located in the lower part of the figures. The least convenient scenarios in this economic simulation are the three ones (X B1 13, X B1 14, X B1 15) funded by the basic incentive from the Second Decree [28], and the one (X M1 12) funded by the maximum incentive from the First Decree [27], both cater to the market cost of biomass. This is explained by a proper evolution of policy instruments that reward, by raising the incentive, improvements in technological and environmental issues. At the same time, it highlights the limitations of the first incentive scheme for bioenergy, which does not take into account of real and high costs of technological improvements to match policy requirements. As a matter of fact, the shock in the market has been following the entry into force of the first incentive scheme, causing a reduction in the price of bioenergy plant solutions, only now economically encouraged. This shows a greater coherence of the next legislative measure.

Figure 6. Performances of Cumulative Discount Cash Flow (CDCF) of the 16 economic scenarios of energy from Biogas (**B** *X0 00*).



Whereas the eight scenarios implemented with the supply from short chain, drawn with a dotted line, occupy the top of the graph. The most convenient scenario, characterized by greater slope of the graph, is the one (X B+ 12) funded by the basic incentive from the First Decree, supplied with biomass from short chain. It is thus highlighted that the short chain has a strong impact in economic terms. The costs related to the advancement of technological progress are not reflected in the policy, while the construction of the bioenergy short chain allows, for the same incentive, to double the volume of business:

- Biogas, from € 2.480.000 (B B1 12) to € 4.300.000 (B B+ 12)
- Vegetable Oil / Biodiesel, from € 1.900.000 (O B1 12) to € 5.500.000 (O B+ 12)
- Wood Chips, from € 2.200.000 (W B1 12) to € 4.000.000 (W B+ 12).

In B and W scenarios (Fig. 6, Fig. 8) the range between highest and lowest values is about € 3.000.000, while it is about € 5.000.000 in O ones (Fig. 7). The wide experience in oil engines combined with a low price of technological devices encourage the choice of O solutions.

On the other hand, the extreme price volatility, the problem of undermining a food supply chain and alternative incentive scheme, considering O scenarios products as biofuels, highlight specific uncertainty of Oils investment. These scenarios become viable if they use non-food biomass.

Figure 7. Performances of Cumulative Discount Cash Flow (CDCF) of the 16 economic scenarios of energy from Vegetable Oil (**O** *X0 00*).

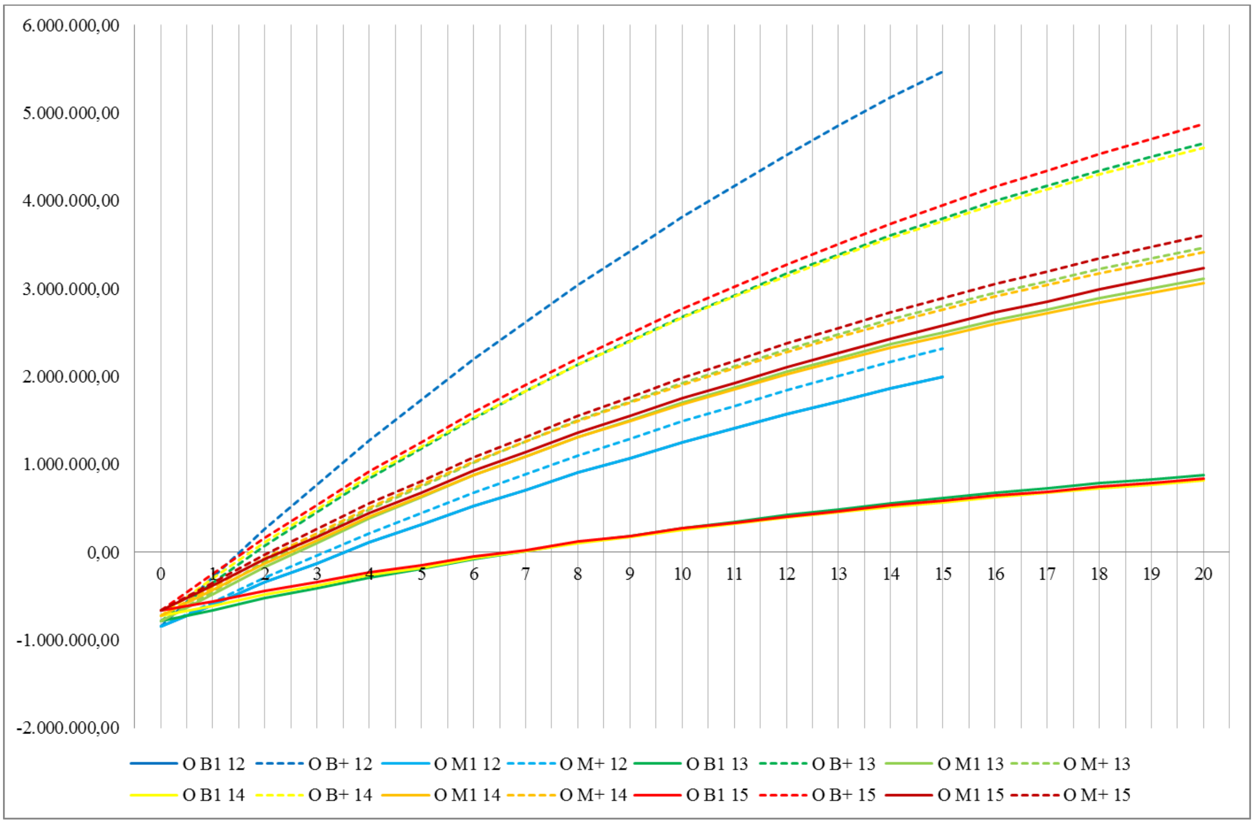
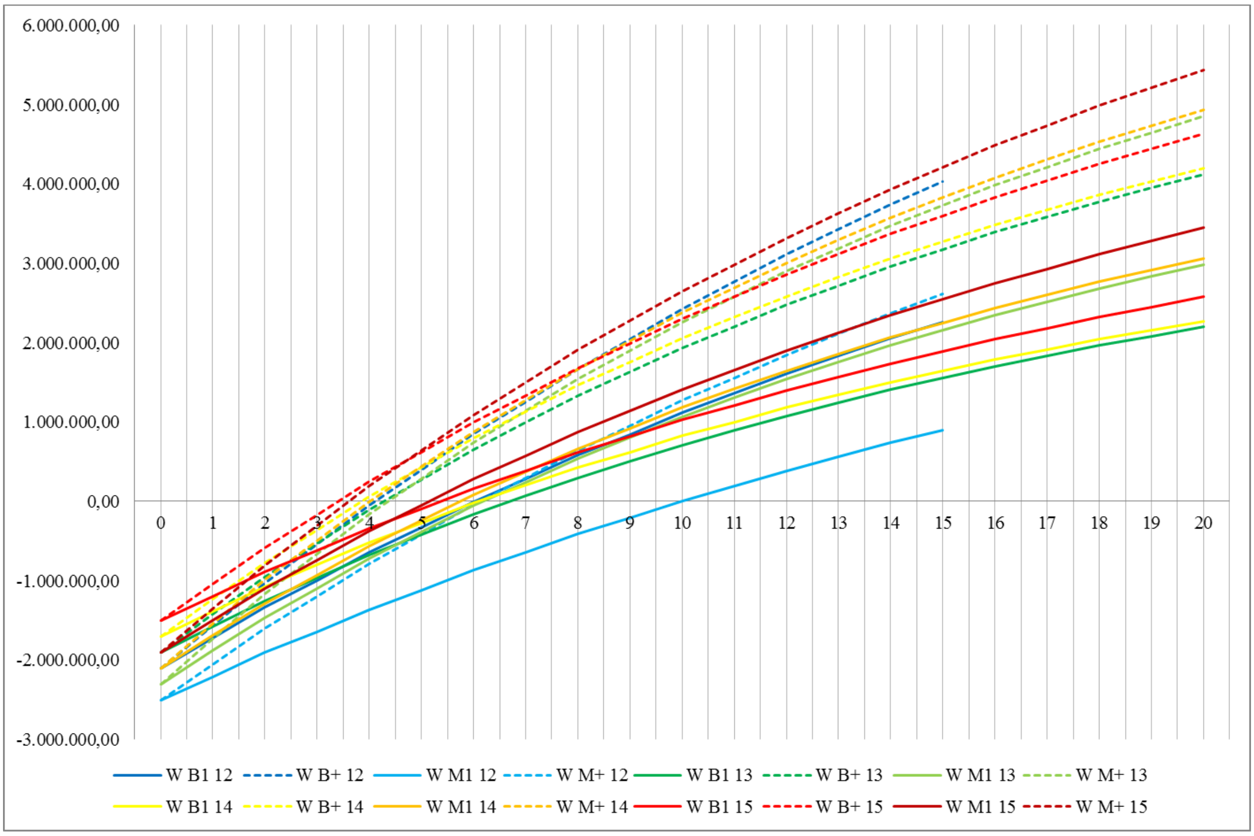


Figure 8. Performances of Cumulative Discount Cash Flow (CDCF) of the 16 economic scenarios of energy from Wood Chips (**W** *X0 00*).



3.2. The indicators PayBack Period (PBP) and Internal Rate of Return (IRR)

The DCF analysis allows the comparison between analyzed scenarios trough two indicators: PayBack Period (PBP) and Internal Rate of Return (IRR). The PBP describes the number of years needed to repay the investment: the lower the more convenient. The IRR is the specific return of the investment in percentage related to the economic incomings and outgoings: the higher the more profitable.

The following (Fig. 9-11 a) histograms, on the left column, describes the PBP of the sixteen scenarios for each bioenergy. It has been pointed out that the short chain supply allows the average reduction of three years between worst (X **B1** 00) and best performances (X **B+** 00). The average reduction is lower between scenarios funded by maximum incentive (X **M1** 00) and (X **M+** 00) due to the evolution of policy towards a less impact energy: in order to achieve the highest value of incentive the bioenergy system has to be designed following energy efficiency and effectiveness standards, more stringent than in the past. In V scenarios the variation of PBP parameter does not depend on the starting year of energy production: it needs to pay attention to the versatility of Vegetable Oil as essential factor to achieve Transport target of European 20-20-20 goals. The B and W scenarios are described by similar PBP parameters. The difference should be analyzed the CDCF parameter: the W CDCF is about € 600.000 higher than B one in any combination.

Figure 9. (**a**) Pay-Back Period (PBP) and (**b**) Internal Rate of Return (IRR) of the 16 economic scenarios of energy from Biogas (**B** *X0 00*).

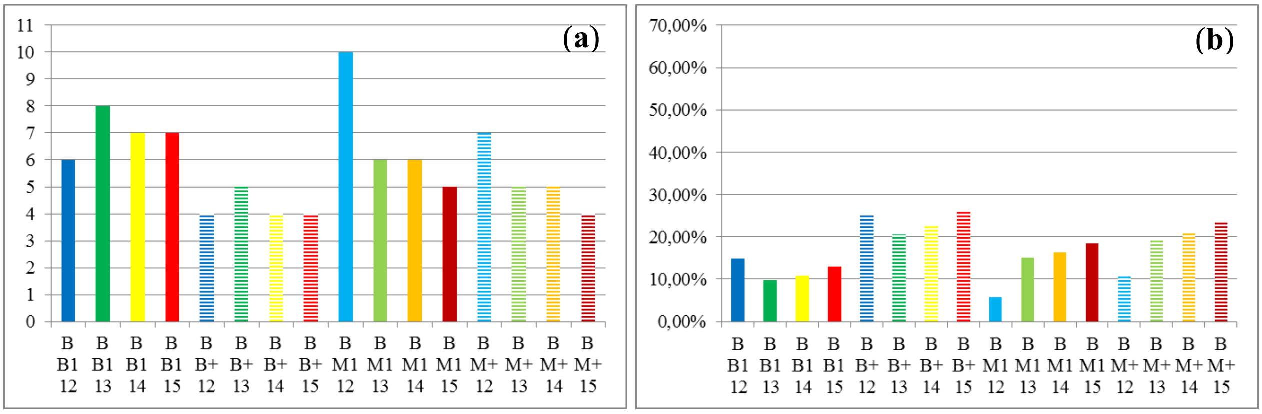


Figure 10. (**a**) Pay-Back Period (PBP) and (**b**) Internal Rate of Return (IRR) of the 16 economic scenarios of energy from Vegetable Oil.

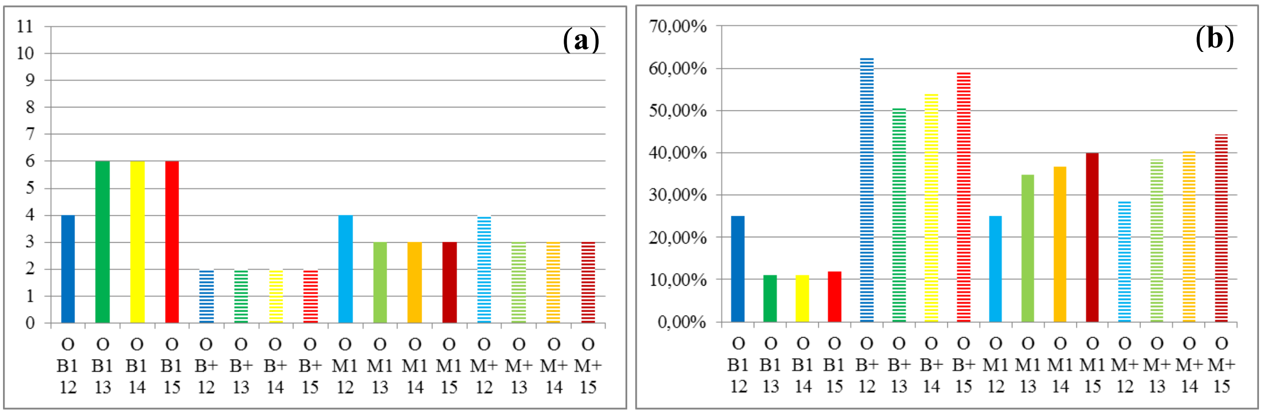
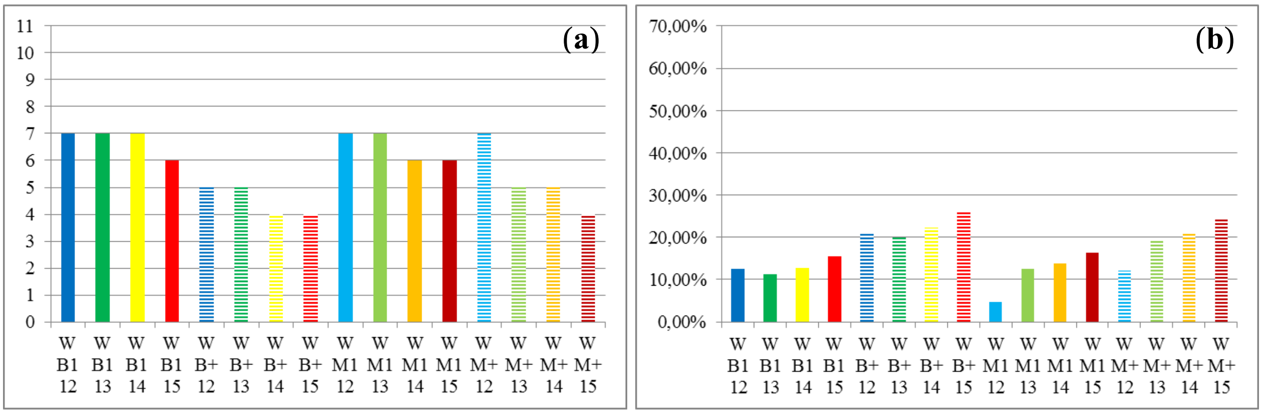


Figure 11. (**a**) Pay-Back Period (PBP) and (**b**) Internal Rate of Return (IRR) of the 16 economic scenarios of energy from Wood chips.



On the right column, the (Fig. 9-11 b) histograms represent the IRR performances. It is noted that the IRR increases starting energy production in subsequent years, due to the approaching deadline of

Europe 2020 Strategy. Incentive schemes have been reduced by 2% each year, as required by legislative architecture in force. Despite this decrease in financial incomings, the IRRs rise year by year: at the same time there is a cost reduction of bioenergy plant due to its spread, the greater supply of the market and to the age of technology. This phenomenon is larger than the reduction of 2%, provided by laws, and so the investment becomes more profitable.

The values of IRRs start from 10 % to 20% in all B and W scenarios, and in O scenarios funded by the basic incentive. The best performances belong to O scenarios implemented with short chain and/or funded by maximum achievable incentive: the average values are far above the 30%.

This large difference is due to both the reasons set out above and to the low initial investment required. The initial outlay is less than € 900.000 compared to € 2.000.000 for the other two bioenergy systems. The ratio of 1 to 2 between the initial costs is pointed out in an inversely proportional manner to the value of the IRR, 2 to 1. As mentioned above, O scenarios require further study, taking into account the compatibility of bioenergy production with the needs of biofuels to reach the Transport Sector goals of Europe 2020 Strategy.

3.3. The best local bioenergy

Overall, as evidenced by the economic analysis, the short chain is a profitable opportunity, being able to integrate with the local economics.

The main benefit of short chain is that the convenience does not depend on government subsidies but by the creation of a production facility for biomass supply. Thus, the new productive chain revitalizes the local socio-economic structure, produces further wealth by creating new jobs and adds to the local context a territorial energy vocation (TEV). So that sustainability means recognizing the local vocation to offer a development consistent with its resources and potential.

Highlighting the local formed economy, based on olive oil production and consequently the wide availability of pruning, allows to identify Wood Chips (W) as the most sustainable bioenergy resource.

4. Conclusions

In this paper, a new model to support the decision making during the process of planning a bioenergy supply chain has been presented. The case study of Bari airport (Italy) has been executed to introduce and evaluate sustainability level improvements of the supply chain different stages: the biomass supply, the operating cash flows, the governmental incentive schemes and territorial impacts.

Defining the question of an optimal and sustainable energy infrastructure as territorial problem and combining the biomass short chain, the production and distribution systems into one integrated model (ZKE) offer the possibility to systematically analyze the interdependencies between the land resources, the size of the bioenergy plant and the needed biomass in accordance with the local socio-economic context, so as to identify the "territorial energy vocation" (TEV).

Starting from local potential and available resources sets this new design concept.

In conclusion, this model allows to translate the different features of each territorial context, taking into account its economic actors and infrastructures and local resources availability in economic feasibility. By using DCF method, it is possible to assess the compatibility of various scenarios, highlighting the sustainability improvement of the capacity planning for a plant of local bioenergy, linked to the territory and its needs, and the creation of the sustainable energy communities network.

Thus, renewable energy is identified as a driver for sustainable development.

Conflicts of Interest

The authors declare no conflict of interest.

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