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Facilitating solid biomass production planning: Insights from a comparative analysis of Italian and German marginalized areas

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ABSTRACT

Solid biomass planning is a complex and multifaceted process, as it aims to achieve a large number of objectives while involving various stakeholders. This complexity heightens particularly in marginal areas, where socioeconomic weaknesses are critical obstacles to the sustainable development of these territories. This paper proposes an integrated method for dealing with such problem by using a combined optimization approach. This is done in order to implement the 'best' investment solution to be realized in marginal areas, and a benefit cost analysis to assess the feasibility of investment for each involved operator. The methodology of the study maximizes the utility of the stakeholders in the respect of the territory. The effectiveness of the proposed approach has been demonstrated through a twofold and comparative application, both in Italy and in Germany, in order to verify the results.

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1. Introduction

Over the time, the interest in energy has become a hot topic, so that its impact on the economy provides crucial elements in the development of policies for the progress of countries (IEA, 2016). Recently, the energy issues are a priority for many international organizations—such as the World Bank and the European Commission - in the economic and political agenda (Blazejczak et al., 2014). The Renewable Energy Directive (European Parliament, 2009) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets (European Parliament, 2015). Recently, in order to reach this objective, the debate is focused on—environmental, economic and social—sustainability of the current energy model that makes necessary interventions, in term of both policies to be implemented and infrastructure projects to be realized, such as to allow substantial improvements in terms of safety, costs, environmental and economic sustainability (Yigitcanlar et al., 2015).

This requirement should sway toward a reconversion of the energy model, which aims at 'alternative' energy production by maximizing the use of the renewable energy sources (RES), and that, in turn, could contribute to the economic growth (Kahia et al., 2017). Currently, this argument is supported by some of the economic literature that have corroborated both the energy-led growth hypothesis (Aslan, 2016). This is achieved by confirming the one-way causality direction relationship between the renewable energy consumption and the economic growth (Bhattacharya et al., 2016), and the feedback hypothesis on interdependent and complementary between the renewable energy use and economic growth as result of a two-way causality direction (Ahmed and Azam, 2016).

Among the renewable energy, the biomass is among those that have a largest positive impact on GDP (Armeanu et al., 2017). Currently, this renewable energy appears to be the most attractive among the available sources (Ben-Iwo et al., 2016): the relevance of the biomass is linked to both the possibility to storage allowing to meet seasonal heat demand and the investments to be realized, which, being part of the aggregate demand, play an essential role as driver for the local development (European Commission, 2014). According to Landolina and Maltsoglou (2017) the production of biomass, besides feedstock and downstream processes, determines further positive multiplier or spillover effects for the whole economy (i.e. by transporting biomass or biofuels to consumers or export markets or by creating new sources of income, which, if

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spent on consumer goods and services, creates a virtuous circle with additional demand for non-biofuel products). These motivations have moved the public authorities to implement a strong incentive policies for the production of biomass Energy by defining a coordinated program of action for implementing the feedstock and biomass (European Commission, 2005).

In fact, the biomass—being better realized in rural areas, where feedstock derives from energy crops and rural wastes—play an essential role on economic development of these areas for the generated impacts (Ahmed and Azam, 2016). The biomass plans support rural economies—affected by lower income levels, an unfavorable demographic situation, higher unemployment rates, a slower development of the tertiary sector, weaknesses in skills and human capital, a lack of opportunities for young people and a lack of necessary skills in parts of the agricultural sector and food processing industry—by creating jobs and providing an additional source of income (Demirbas, 2008).

However, planning of local biomass system can be very complex, because of multiple objectives and stakeholders. The growing complexity of socio economic system and the substantially increase of information have made more articulated the decision process, which can rely less and less on subjective judgment (Arbolino et al., 2018; Szopik-Depczyńska et al., 2017). In order to address this challenge and with the intention of decide, which plans are the most eligible, considered both exogenous constraints (availability of public funds-that are generally limited-emission retention, social acceptance, the side of usable lands, etc.) and constraints between variables, a decision support system (DSS) could be helpful (Marinakis et al., 2017). In so doing, decision-makers could consider priorities and factors that imply to choose between a wide range of proposals, evaluating impacts associated to the different variables. This procedure allows to find a best compromise solution among socially relevant objectives besides to quantify operative incomes and costs (Rostirolla, 1998). The economic evaluation has to be made before taking definitive decisions about the plan.

This paper describes the complexity of the planning problem by taking into account both economic, environmental and social impacts arising from the strategic choices. The purpose of this research is to provide a tool in order to evaluate both the goodness and the feasibility of an action plan by choosing, among alternative investments for the production of solid biomass energy, those that maximize the utility of the stakeholders in the respect of the territory. Thus, a methodology based on combined decision support tools is proposed.

At the first level, the approach incorporates a multi-objective optimization model, which allows to generate all the information the policymaker needs to support each decision step concerning the selection of the projects (Arbolino et al., 2017a); at the second level a direct and transparent cost benefit analysis allows to evaluate the feasibility of each involved actor—power company and farms—in order to lead a whole evaluation of biomass planning and to provide some reflections on the currently incentive system. In this context, the paper places Italy and Germany under the microscope to investigate their state to generate insights on the capability of the proposed approach. Literature highlights the suitability of these country contexts for this investigation (Arbolino et al., 2017b).

Our analysis participates to the debate on the methodologies to be apply for energy planning (Zhao, 2016). The importance of this issue, overall for the economic, social and environmental aftermath requires a deepen analysis of the tools to be used, which should focus not only on the choice of the projects that maximizing the social utility but also on the feasibility of the interventions (Santoyo-Castelazo and Azapagic, 2014). Given these weaknesses, our contribution consists of proposing an integrated approach to evaluate both sides, for considering the existent legislative framework and the incentive arrangements for better support policymakers. Moreover, a further innovative element is provided by the use of a disaggregated approach for operator in the application of the Cost Benefit Analysis, overcoming the classical approach that assesses the feasibility of the whole project without considering any redistributive effects (De Simone and Rostirolla, 2012).

The paper is structured as follows. Following this introduction section, the second section presents the main approaches for renewable energy planning. The third section describes the methodology applied and the data. The fourth section provides the results of the simulation implemented both in Italy and in Germany. The final section discusses the findings, provides policy suggestion, and concludes the paper.

2. Multicriteria decision-making methods for renewable energy planning

The political, social, economic and environmental relevance of energy sector, the features of the renewable (decentralized production, located costs, distributed benefits, involvement of stakeholders) and the complexity of the system to be analyzed require a decision support system in order to better solve the challenges of the energy planning (Banos et al., 2011). The purpose of DSS is to offer to the policy maker an ongoing support that allows to expand his capabilities from the formulation of the problems to the evaluation of the solutions, without imposes choices and default solutions (Gudes et al., 2010; Scott et al., 2012). Several methodologies exist in order to solve decisional problems. These methods can be distinguished in two categories: (a) techniques for alternatives elimination; (b) techniques for alternatives ranking. Among the most well-known procedures, in the first cluster belong conjunctive and disjunctive methods, (Yoon and Hwang, 1995); ELECTRE (Roy and Vincke, 1981); multiple attribute utility theory (MAUT) (Keeney and Raiffa, 1979); (c) in the second, analytic hierarchy process (AHP) (Saaty, 1990, 1980); preference ranking organization method for enrichment evaluation (PROMETHEE) (Brans and Vincke, 1985) and TOPSIS method (Yoon and Hwang, 1995).

A separate mention should be made for the optimization methodologies that involve many deterministic models with different objectives in the final choosing phase. These objectives are connected to the different applied algorithms and that can lead to choose among different alternatives, in order to achieve an 'optimal solution' or seek the best compromise solution (Zeng et al., 2011).

Decision Support systems and multi-criteria decision-making methods have been used to great effect in energy planning for assisting the decision makers due to the complex and interlinked data in this sector. Over the last two decades, there has been a notable increase of researches concerning energy planning by using DSS: until 1995 the survey on decision analysis (DA) in energy and environment counted 95 academic papers (Huang et al., 2015). Zhou (2015) has updating the counting discovering that about 160 more were carried out between 1995 and 2004.

Concerning the biomass sector, Marinakis et al. (2017) recently used MAUT in order to select sustainable renewable energy sources (RES), and rational use of energy (RUE) technologies. Sánchez-Lozano and Bernal-Conesa (2017) have suggested the implementation of the ELECTRE method, for the selection of renewable energy installations in order to promote the diffusion of such technologies to a regional level.

Delivand et al. (2015) applied the Analytical Hierarchy Process (AHP), integrated into a geographic information system (GIS), to determine the locations of a centralized and some decentralized power plants using biomass sources. Scott et al. (2015) integrated three aspects in a common framework: a stochastic approach,

multicriteria decision-making techniques and multiple stakeholder requirements by using a combined Analytic Hierarchy Process and Quality Function Deployment (AHP–QFD). Li and Zhao (2016) presented an effective approach combining fuzzy GRA-VIKOR and weighting techniques for evaluating performance of emerging eco-industrial plants in China, which is a complex multi-criteria decision-making problem. Yu et al. (2016) evaluated the development potential of forest biomass energy in Chinese provinces and cities, while combining the entropy weight method and TOPSIS. Panagiotidou et al. (2015) used the Promethee method in order to help decision-makers to choose among different strategies for a given class of agricultural land. Balaman and Selim (2016) proposed a MILP model, a mixed integer linear programming in order to determine an optimal biomass energy supply structure. Shabani and Sowlati (2016) proposed a hybrid, multi-stage stochastic programming-robust optimization model for the tactical supply chain planning of a power plant.

Considering the applications analyzed, their main weakness are: (a) Ambiguity caused by the misguided definition of the scores; (b) It is not always preferable to achieve a sort of alternative judged a priori all technically eligible (ELECTRE) instead of choosing a best solution; (c) Decision-makers involving in technical phases of formulation of models for the selection and or evaluation of alternatives, and; (d) The need to compare necessarily options among themselves, leading to questionable comparison due to lack of reliable data (hierarchical analysis). Our technique-choosing the solution of best compromise, by using weights that are not defined in a subjective manner by the policy makers but are generated through a mathematical model—allows to overcome methodological problems of others previously analyzed.

Moreover, the choice of the method to apply is always linked to the specific decisional problem: our research does not concern the choice of an alternative among several proposals, neither the definition of a ranking, but the practice and the implementation of efficient scenarios that represents the solution of best compromise among the remarkable objectives for the decision maker. In fact, our decisional problem concerns the characteristics and the articulation of an investment program: in this case the performance of the single project within the plan is not relevant but, on the contrary, the global impacts produced from the plan in its whole become the crucial task.

3. Methodology: multi-objective optimization method

The biomass represents a relevant sector both for the economic impacts generated in short term and for the effects on the technological progress and, thus, for the economic environmental -territorial impacts in long term.

Considering the importance of the impacts produced by the realization of energy planning, both in a long- and short-term, we propose a specific System of Support to the Decisions (DSS) that can be employed both in the phase of generation, and in evaluation and selection of punctual interventions to be realize through assigned financial resources.

DSS is based on aggregated approach consisting of a linear programming model and a cost benefit analysis. The first technique proposed is based on an iterative and interactive mathematical programming model, solvable through the use of the simplex algorithm (Dantzig and Thapa, 2003). It aims at transforming a multi-objective decision problem in a mono-objective one. DSS is a model with binary variables associated to each alternative of investment in the selection phase (it can be assumed the value equal to 1, that means the investment can be realized or equal to 0, that means the investment cannot be realized). It produces some proposals and provides a quantification of the impacts on objectives that are remarkable for the policy makers.

For every proposal produced by the model, the impacts on each objective are compared to ideal values, so that to be able to quantify the distance from such values. If the impacts are considered all acceptable/satisfactory ones, that proposal represents a satisfactory compromise among the pursues objectives; in contrary case, policy makers defines the objective to improve and the target to be reached. This indication is transposed in the model as a new constraint that should be satisfied by generating a new proposal. The interaction model or policy maker continues until reaching the satisfactory solution, if it exists, that realizes the good possible compromise among the pursues objectives. The implementation of the model requires the quantification of average impacts generated by using the allocated financial funds for the realization of the planning. The quantification of some coefficients, above all those related to the economic and territorial impacts, to be employ in the model can require *ad hoc* analysis besides the use of statistical data source. The possibility to appraise, at several decisional levels, the impacts on the objectives, allows a deepened evaluation of the single investment projects.

This technique generates Pareto optimal solutions from maximization or minimization of specific objectives, also considering the achievement of exogenous targets. The best solution will be the most desired under the decision-makers preferences. Then, in order to provide all useful information to an effective resources allocation, the economic and financial sustainability of each stakeholder involved in the decision-making process is assessed. Thus, a more detailed impacts assessment is carried out, using a 'disaggregated' approach of Cost Benefit Analysis (ACB) (De Simone and Rostirolla, 2012). The main aim of this last step of evaluation process is to verify if each stakeholder benefits (both in financial and economic terms) from the investment involving him. These recommendations could be useful to verify if there is an economic and financial advantage for each operator; if not this tool allows to provide policy indications in order to make the investment profitable.

3.1. The decision problem

To define our hypothetical decision problem, we start to consider the exploitation of biomass for renewable nergy production both as a good environmental strategy—for recovering deteriorated areas and disused rural ones—and an economic development opportunity, contributing to satisfy the energy demand and to address depopulation and environmental desertification in marginal areas (Bilgili and Ozturk, 2015). In Fig. 1 our hypothetical biomass system in a rural community is shown. It is comprised by biomass supply chain and bioenergy conversion plant; in each biomass chain the stakeholders involved are: (a) the farms that produce biomass; (b) one power company—an *ad hoc* entity—that builds and manages the biomass plant.

The biomass feedstock is derived from both energy crops and agriculture wastes. In the former case, the idea is that the creation of new farms can contribute to use and convert the brown field or degraded lands in the area. In the latter case, the study is referred to farms that are already active with food crops and they can recover pruning wastes to produce energy: so, the disposing of these wastes could be a benefit—in terms of supplementary income—and not just (both economic and environmental) a cost anymore. The research considers a small and medium scale cogeneration technology and the usable energy might be delivered to the local community as heat and electricity.

As regards to the territorial area, rural territories as well as mountainous areas are considered, getting relevant marginality factors. The marginality of a territory means "an involuntary

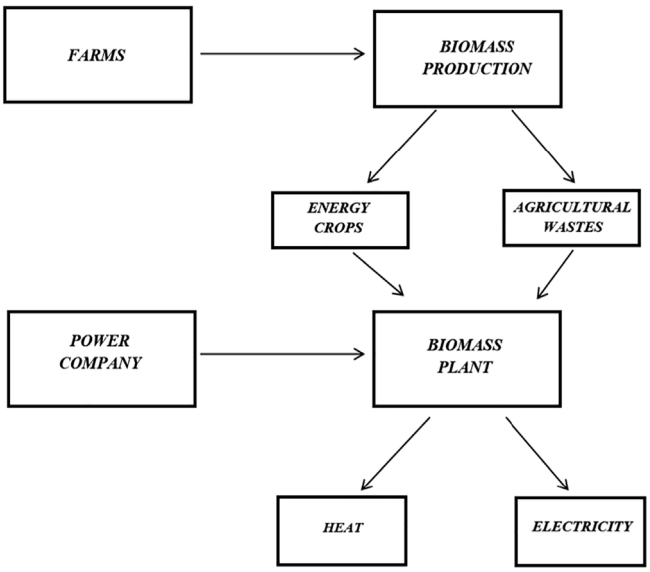

Fig. 1. Biomass system diagram in a rural community.

position and condition of an individual or group at the margins of social, political, economic, ecological and biophysical systems, preventing them from access to resources, assets, services, restraining freedom of choice, preventing the development of capabilities, and eventually causing extreme poverty" (Gatzweiler et al., 2011, p.3). Hence, this concept of marginality overlaps with poverty one, because of it also includes spatial dimensions based on physical location (Malek and Hossain, 2013).

Thus, the location of the plant is crucial in order to assess the profitability of the biomass conversion investments. The hypotheses of the study are: (a) if the biomass facility is located in a mountainous area, it is hard to supply heat to the local community[1], thus the revenues derive only from electricity supply; (b) if the plant is located downstream, the revenues for the power companies are generated both by heat and electricity production. This analysis is carried out by referring to the current legislation concerning renewable energy investments in Italy and Germany. At present, in both countries there are large subsidies on energy production from biomass respectively by in both countries feed—in tariff system is based on the power capacity size of the biomass plant. However, the Italian system is a bit more complex, since the incentive is differentiated on the basis of the kind of production (i.e. by energy crops and by agricultural wastes) as well as a premium is foreseen. Moreover, also the Rural Development Program (RDP) compensation system is more complex in Italy than in Germany, because it takes into account the mean declivity of the farm and the land use. The ultimate aim of these programs is defining an action plan by choosing a set of biomass management systems among 17 project alternatives that are differentiated by the two previous explained kinds of biomass chain systems.

Biomass conversion plants use a cogeneration technology and have a 15 years life period and they concern the power companies. The plant can present different features, described through the data, illustrated in Table 1. Each power company can sell just the electricity (if the plant is located on mountainous area) or also the heat (if the plant is located in downstream). In the first case the value of the dummy is equal to 1, in the second case is equal to 2. The farms produce solid biomass that can be derived by energy crops (value equal to 1) or by agricultural wastes (value equal to 2).

3.2. The optimization model

The procedure for solving multi-objective optimization is composed by three steps: (a) the formulation of the mathematical model; (b) the generation of the Pareto-efficient (or optimal) solution and its description in terms of impacts on objectives and deviation from ideal values; (c) the selection of the preferred solution. Following the first step, decision variables, impacts and constraints are determined. Then, a set of 'I' objectives is identified. In Table 2 the values of each *ith* objective on *'xj'* project—so called impacts coefficients *'cij'*—are illustrated as well as the objective functions *(f(x))* indicating if it will have to be maximized or minimized. Thus, a *'f(x)'* objective function is defined as a linear combination of decisional variables *'xj'*, following impact coefficients.

$$f(x) = \sum c_{1j} * x_j \qquad [1]$$

with. $j = 1, \ldots, J \;\; \forall \; i = 1, \ldots, I$

In the second step, the mathematical programming applies a simplex algorithm (Dantzig and Thapa, 2003) in order to generate Pareto optimal solution[2]: each coefficient c_{ij} is multiplied for the variable of existence x_i, assuming value zero for indicating the absence of the project in action plan configuration or value 1 for indicating its presence. Then an 'ideal vector' is computed by referring to the 'optimal' value of each objective ($F^*_{1, \ldots, } F^*_n$). These values are obtained by optimizing—in terms of maximization or minimization - the *'f (x)'* one by one [1] without any constraints on the target level of other objectives. So, the 'ideal' solution is computed as Table 3 shows.

Obviously, this 'ideal' solution is not realizable since the objectives conflict each other. In fact, a unique solution maximizing (or minimizing) the entire objectives at the same time does not exist. Thus, the purpose of the multi-objective mathematical programming is to seek solutions, among the eligible ones, that are not dominant or Pareto 'optimal': an alternative is believed not dominated or Pareto optimal, if another possible alternative—improving a response to a criterion without compromising one of the others - does not exist. The preferred solution will be the one as close as possible to 'ideal' one, such that, for each objective, the distance between the 'ideal' vector and the actually achieved one is the minimum.

In order to choose the solution of 'best compromise', the applied linear programming model is based on the Goal Programming (GP) approach proposed by Charnes and Cooper (1957) and applied in several studies (Jadidi et al., 2014; Romaro, 1991; Zhou, 2015). According with GP′ approach, on each objective (or some of them) a constraint on the minimum achievement level desired is imposed, and, then the minimum deviation from the 'ideal' value is calculated. The final solution will be the more 'desirable' one, in which for each objective the deviation from its ideal value is minimum. Thus, the multi-objective problem [1] is transformed into a mono-objective optimization problem, such as:

[1] We could have assumed to build biomass plant further downstream, and, so, to exploit heat by a small district heating network. However, there are several reasons why we do not take into account this option: (a) there could be additional environmental costs due to transportation, because of the further distance from energy crops; (b) there could be further economic costs for community, because of the need to purchase biomass boilers; (c) heat exploitation is profitable only if there is a high thermic load, because of heat consumption by schools, swimming pools, healthcare facilities, and so on, in a small area, where a short district heating network can be realized: it is hard to find these elements in a mountainous area.

[2] The optimization model is built using the "What's the best" software, produced by Lyndo System.

Table 1
Technical and economic features of project investments.

Items	U,M	A1	A2	A3	….	A16	A17
Power capacity	Mwe	0.99	0.2	0.1	….	0.9	0.43
Heat capacity	Mwt	4.95	1	0.5	….	4.5	2.2
Electricity production	kWhe	8,672,400	1,095,000	365,000	….	7,884,000	1,569,500
Heat production	kWht	43,362,000	5,475,000	1,825,000	….	39,420,000	7,847,500
Biomass plant employment	n,	45	2	2	….	27	2
Cogeneration system	dummy	1	2	2	….	1	2
Biomass supply chain	dummy	1	2	2	….	1	2
Agricultural area	ha	700	344	172	….	636	1111
Total investment cost	€	2,705,000	790,000	340000	….	2,480,000	827,500
Private co-financing	€	2,090,000	645,000	270,000	….	1,865,000	513,750
Public grants	€	615,000	145,000	70,000		615,000	313,750
Revenues	€	910,602	484,209	161,403	….	827,820	627,015
Avoided emissions	tonCO2/kWh	4,539	573	191	….	4,126	821

Table 2
Objectives, coefficients values and objective functions.

Objectives (I)	U.M	A1	A2	….	A16	A17	f(x)
Power capacity	Mwe	0.99	0.2	….	0.9	0.43	Max
Electricity production	kWhe	8,672,400	1,095,000	….	7,884,000	1,569,500	Max
Biomass plant employment	n,	45	2	….	27	2	Max
Total investment cost	€	2,705,000	790,000	….	2,480,000	827,500	Max
Private co-financing	€	2,090,000	645,000	….	1,865,000	513,750	Max
Public grants	€	615,000	145,000	….	615,000	313,750	Min
Revenues	€	910,602	484,209	….	827,820	627,015	Max
Avoided emissions	ton CO2/kWh	4,539	573	….	4,126	821	Max
Energy crops surface	ha	700	0	….	636	0	Max
Agricultural wastes surface	ha		344	….	0	1111	Max

Table 3
The 'ideal' solution.

f(x)		Objectives (I)	U,M,	'Ideal' solution
F^*_1	Max	Power capacity	Mwe	10.34
F^*_2	Max	Electricity production	kWeh	73,934,400
F^*_3	Max	Biomass plant employment	n,	249
F^*_4	Max	Total investment cost	€	26,777,500
F^*_5	Max	Private co-financing	€	18,960,000
F^*_6	Max	Revenues	€	10,591,925.88
F^*_7	Max	Avoided emissions	tonCO2/kWh	38,697.26
F^*_8	Max	Energy crops surface	ha	5,506.73
F^*_9	Max	Agricultural wastes surface	ha	5,106
F^*_9	Min	Public grants	€	5,500,000
		Total biomass chains selected	n.	18
		Energy crops chain project	n.	10
		Agricultural wastes chain project	n.	8

s.a.
– Exogenous constraints (2)
– Endogenous constraints

$$x_j(1 - x_j) = 0$$

$$w_i \geq 0$$

with

$$i = 1, \ldots\ldots, J; j = 1, \ldots\ldots, J$$

$$d_i(x) = \frac{\left| f_i^*(x) - f_i(x) \right|}{f_i^*(x)}$$

Where x represents the decisional variables that in our analysis are: the 17 projects x_j that means the j*th* project to be included in the Plan. d_i is the deviation of i*th* objective from 'ideal' value, with $f_i(x)$ means a general i*th* objective function and $f_i^*(x)$ means the i*th* 'ideal' objective function. w_i presents the weight assigned to each objective.

As opposite to other multicriteria techniques, in this case weights need not be explained ex ante to decision-maker since they are automatically computed by the algorithm (Dantzig and Thapa, 2003). So, the aim of this approach is not identifying trade-off values, but determining the achievement level for each objective. As exogenous constraints, both the available hectares for biomass production and an overall amount of public resources are considered: the first corresponds to an available area of 10,000 ha, divided by land for energy crops and land already in arable use (food production) in respective measures of 50%; the public budget as loan to facility investment (K) is assumed equal to 5 million Euro. As endogenous constraints, the realization at least one investment project for each type of biomass supply chain is established.

Table 4
The 'best compromise' solution and deviation from the 'ideal' solution.

f(x)	Objectives (I)	U.M.	The 'best compromise' solution	Ideal' solution	Deviation from the 'ideal' solution
MAX	Power capacity	Mwe	7.72	10.34	25%
MAX	Electricity production	kWeh	54,625,900,00	73,934,400,00	26%
MAX	Biomass plant employment	n,	183	249	27%
MAX	Total investment cost	€	21,362,500	26,777,500	20%
MAX	Private co-financing	€	15,900,000	18,960,000	16%
MAX	Revenues	€	8,441,455.38	10,591,925.88	20%
MAX	Avoided emissions	tonCO2/kWh	28,591,20	38,697.26	26%
MAX	Energy crops surface	ha	3,773.73	5,506.73	31%
MAX	Agricultural wastes surface	ha	4,934	5,106	3%
MIN	Public grants	€	5,462,500	5,500,000	1%
	Total biomass chains selected	n,	13	18	28%
	Energy crops chain project	n,	6	10	40%
	Agricultural wastes chain project	n,	7	8	13%

3.3. The "disaggregated" cost benefit analysis

Once the set of projects is selected, the economic and financial sustainability of the involved actors must be verified. Cost – Benefit Analysis (CBA), is a technique mostly used to assess investment project effects, according to a social logically point of view, by supporting to choose the best option in terms of economic efficiency. However, this technique, as usually used, shows limitation: it considers benefits and cost of the whole investment without taking into account the redistributive effects among the involved actors (Rostirolla, 1998). In this way, information about the advantage of each subject in the project of investment are not available. This limit required a different application of the CBA (Di Maio and Rostirolla, 2002) based on operator – disaggregate financial analysis allowing both to verify, for each operator, the existence of economic-financial advantages as regards the investment. According to this "disaggregate" approach, we can verify if there is an economic and financial advantage for each operator and eventually find weakness of the norm itself.

In view of our decisional problem, we evaluate the affordability for each operator to participate in realization of the investment, by considering the current incentive system to compensate for the obvious lack of sustainable economic income linked to a public utilities service.

According to such approach, if an operator obtains a positive financial balance using the incentive, surely s/he will adopt a collaborative behaviour with the rule; but, vice versa, if s/he does not obtain any financial advantage he will adopt a non-collaborative behaviour and other kind of incentives would be needed.

4. Results

The results of the optimization model are shown in Table 4. Each objective is expressed in their original unit of measure, with an indication about whether they should be maximized or minimized. The fourth and fifth columns show the value of the 'best compromise' solution and the 'ideal' solution, respectively. In the last the deviation from 'ideal' solution is represented.

The 'best compromise' solution, that represents the hypothetic best plan of investments, includes 13 biomass system projects: in six of them biomass feedstock derives by energy crops and, thus, these investments can be realized in mountainous areas; the other seven can be realized in downstream where agricultural wastes can be used to produce sustainable energy, that otherwise they would not have used. This simulation has been applied first to Italian marginal area; then the data about the incentive—being the other data unchanged since they concern the features of plant assumed by us—have been changed and the simulation was repeated for German marginal areas. The results obtained are equal in both case.

Once we identify the set of realizable investments, the economic and financial sustainability of each involved stakeholder is assessed. Thus, a more detailed impacts assessment is carried out, using a 'disaggregated' approach of Cost Benefit Analysis (ACB) (Rostirolla and De Simone, 2012). The 'disaggregated' ACB is based on the evaluation of current incentive to promote biomass energy production, both in Italy and in Germany, as in Tables 5 and 6. As

Table 5
Feed-in tariff value for biomass facilities in Italy and Germany.

	Power capacity	Basic tariff	Premium
Biomass from organic products (i.e. energy crops)	$0.001 < MW \leq 0.300$	21 cent€/kWh	0 cent€/kWh
	$0.300 < MW \leq 1$	14.25 cent€/kWh	0.75 cent€/kWh
	$1 < MW \leq 5$	10.92 cent€/kWh	0.57 cent€/kWh
	$MW > 5$	0 cent€/kWh	0 cent€/kWh
Biomass from organic by-products (i.e. agricultural wastes)	$0.001 < MW \leq 0.300$	24.60 cent€/kWh	0 cent€/kWh
	$0.300 < MW \leq 1$	17.57 cent€/kWh	0.92 cent€/kWh
	$1 < MW \leq 5$	13.30 cent€/kWh	0.70 cent€/kWh
	$MW > 5$	0 cent€/kWh	0 cent€/kWh
Germany			
	Power capacity	***Basic tariff***	
	$0.001 < MW < 0.150$	13.32 cent€/kWh	
	$0.151 < MW < 0.500$	11.49 cent€/kWh	
	$0.501 < MW < 5$	10.29 cent€/kWh	
	$5.01 < MW < 20$	5.71 cent€/kWh	

Italian Source: Ministerial Decree 23 June 2016; German Source: Gesetzfür den AusbauerneuerbarerEnergien (Erneuerbare-Energien-Gesetz - EEG, 2017).

Table 6
Complementary payment for mountainous areas.

Italy		
Payment value		
Mean declivity of farm	*Altitude*	
	≤ 600 mt	> 600 mt
≤ 20%	360 €/ha	405 €/ha
> 20%	405 €/ha	450 €/ha
Payment allocation		
Surface	%	
ha≤ 9.99	0%	
10 < ha≤49.99	56%	
50 < ha≤99.99	28%	
100 < ha≤300	14%	
ha>300	0%	
Germany		
Payment value		
Max	195 €/ha	
Payment allocation		
Surface	%	
ha≤ 300	100%	
300 < ha≤600	94%	
ha>600	88%	

Source: Italian and German Rural Development Programme 2014–2020

Table 7
Power company economic results—energy crops chain (mountainous areas).

Items	UM	A1	A4	A6	A9	A13	A16
Power capacity	Mwe	0.99	0.95	0.80	0.85	0.85	0.90
		Italy					
Applied feed-in tariff	€/kWeh	0.15	0.15	0.15	0.15	0.15	0.15
New feed-in tariff	€/kWeh	0.17	0.19	0.17	0.19	0.17	0.18
Δ tariff values	%	15.9%	25.0%	13.5%	24.6%	12.7%	23.2%
		Germany					
Applied feed-in tariff	€/kWeh	0.10	0.10	0.10	0.10	0.10	0.10
New feed-in tariff	€/kWeh	0.16	0.19	0.17	0.18	0.16	0.18
Δ tariff values	%	60.2%	82.2%	65.5%	75.6%	54.7%	79.7%

Table 7 shows, the power company benefits from feed-in tariff in both type of supply chain: agriculture waste and energy crops; instead, the benefits for farms by Italian and German Rural Development Program (RDP) compensation is given only to those located in mountainous areas. In fact, the biomass feedstock by agricultural wastes is a supplementary income without any investment costs for farms.

Table 7 presents the results for each power company that manage the planting energy crops, together with the others in the whole chain. Table 7 shows the currently applied tariff; then, that necessary in order to remunerate for each plant. The results show that in both the countries, the value of the current feed-in tariffs not enough and its integration is needed. Therefore, for the power company to remunerate the investment at a minimal rate of 7% gross, a Gross Operating Margin (GOM) is needed. The localization of plants in mountainous areas causes a disadvantage because of heat cannot feed-in, but it can use only for biomass drying process and for others internal functions of power company.

In order to achieve the integration, so to induce the private operator to make the investments, it is necessary that, in Italy, the all - inclusive tariff is equal to about 0.18 €/kWehthan 0.15€/kWeh under the Ministerial Decree 23 June 2016 (+19%); whereas, in Germany, the new feed-in tariff should be equal to 0.17 €/kWeh instead of 0.10€/kWeh under EEG 2017 (+70%). These results suggest that the Italian energy incentive framework is more generous than German one. Nevertheless, the need for feed-in tariff integration to increase the profitability of the investment shows that investment costs for this type of biomass plants are rather high, creating an obstacle to the full development to solid biomass energy production (IRENA, 2012).

On the contrary, in agriculture waste chain the decrease of the feed-in tariff may even be applied (Table 8): in Italy, this new incentive would be equal to 0.12 €/kWeh (−44%); in Germany, it would be equal to 0.07 €/kWeh (−41%).

To obtain a collaborative behavior of farms, it is necessary that the biomass production will provide adequate opportunities of income for farmers. Each code in Table 9 links the farm with the selected chain project. Additionally, in this case, the economic results of each alternative identified with the code AA, that is Agricultural Alternative have been quantified. The production of biomass from dedicated crops (see alternatives AA1, AA4, AA6, AA9, AA13, A16), appears to be less effective compared to the recovery of agricultural waste activities, in terms of investments and operational costs.

With regard to the operational phase, however, farms should generate revenue, as determined by the sale and transport of biomass, such as to cover the operating costs and to ensure a level of remuneration of labor of at least that of an unskilled farm worker. However, when biomass feedstock derives from energy crops, as Table 9 shows, the gross operating margin (GOM) of these farms is not such to fulfil this criterion, even if we imagine that these farms can benefit the allowance provided for by the RDP, measure 13.1, that provides a monetary compensation for farms in mountainous areas. It occurs both in Italy and in Germany. Please note that we have considered only the German measure, because in Italy this measure offers a compensation only to the smallest farms, with a land area is not larger than 300 ha. Therefore, the participation of farmers to the short chain can be secured only through integration in the GOM: in Germany, it would increase the value of the compensation of localization around 107 €/ha (+55%); in Italy, a new monetary benefit should be introduced: its value could be around 300€/ha.Table 10.

Table 8
Power company economic results—agricultural wastes chain (none mountainous areas).

Items	U,d,M	A2	A7	A8	A10	A14	A15	A17
Power capacity	Mwe	0.20	0.15	0.70	0.30	0.25	0.35	0.43
				Italy				
Applied feed-in tariff	€/kWeh	0.25	0.25	0.19	0.25	0.25	0.19	0.19
New feed-in tariff	€/kWeh	0.15	0.03	0.07	0.14	0.12	0.16	0.18
Δ tariff values	%	−38%	−87%	−62%	−43%	−50%	−11%	−0.2%
				Germany				
Applied feed-in tariff	€/kWeh	0.11	0.13	0.10	0.11	0.11	0.11	0.11
New feed-in tariff	€/kWeh	0.08	0.03	0.07	0.07	0.04	0.10	0.08
Δ tariff values	%	−29%	−77%	−32%	−40%	−67%	−11%	−26%

Table 9
Economic results of farms—energy crops chain (mountainous areas).

Farms	U.M.	AA1	AA4	AA6	AA9	AA13	AA16
			Italy				
GOM per staff	€/staff	9,523	9,573	10,845	9,577,	9,577,	9,523
GOM per ha	€/ha	5330	533	596	533	533	533
Market remuneration	€/staff	15,000	15,000	15,000	15,000	15,000	15,000
Integration per staff	€/staff	5,477	5,427	4,155	5,423	5,423	5,477
Total integration	€	120,497	113,962	66,481	97,619	97,619	109,543
Total integration/ha	€/ha	306.80	302.30	228.50	302.00	302.00	306.80
			Germany				
GOM per staff	€/staff	13,005	13,073	13,245	13,078	13,078	13,005
GOM per ha	€/ha	728	728	728	728	728	728
Market remuneration	€/staff	15,000	15,000,00	15.000	15,000	15,000	15,000
Integration per staff	€/staff	1,995	1,927	1,755	1,922	1,922	1,995
Total integration	€	43,898	40,458	28,073	34,592	34,592	39,907
Total integration/ha	€/ha	111.80	107.30	96.50	107	107	111.80

Table 10
Economic results of farms—agricultural wastes chains (none mountainous areas).

Farms	U.M.	AA2	AA7	AA8	AA10	AA14	AA15	AA17
				Italy				
GOM per staff	€/staff							
GOM per ha	€/ha	160	160	160	160	160	160	160
Market remuneration	€/staff							
Integration per staff	€/staff							
Total integration	€							
Total integration/ha	€/ha							
				Germany				
GOM per staff	€/staff							
GOM per ha	€/ha	160	160	160	160	160	160	160
Market remuneration	€/staff							
Integration per staff	€/staff							
Total integration	€							
Total integration/ha	€/ha							

In contrast, the production of biomass from agricultural residues can generate an integration of farm income, compared to the situation without the intervention. Actually, in current farm management, rural wastes are usually burnt in fields; legal treatment, on the contrary, involves costs for farm. In this paper, energy recovery of rural wastes allows both to save on disposal practices and to obtain an income integration (160 €/ha), so that farmers could decide to invest in this activity.

5. Discussion and conclusion

Biomass planning is an advanced decision process because of several economic, environmental and social impacts that its use to produce 'clean' energy generates. It is even more when it concerns a marginal area, where biomass could contribute to achieve a competitive dimension of the territory in order to contain the phenomenon of depopulation and to stem, indirectly, issues related to environmental protection and conservation of rural areas. Biomass generate many positive impacts for a local community, such as local revenue, local jobs, avoided emission; it is necessary that these elements as well as the complex technological features of energy conversion facilities are examined from a multi-criteria perspective (Huang et al., 2015).

Currently, in literature many multicriteria techniques have been implemented concerning the biomass investments (IRENA, 2012; Ahmad and Tahar, 2014). However, often these researches evaluate the feasibility of a single project to be included in the plan; instead our research identifies the projects mix capable of improving social wellness. Several troubles exist to achieve this methodological objective, especially if planning process is very multi-faceted and complex, as biomass system planning is (Panagiotidou et al., 2015).

The aim of this paper is to offer a methodological support to public policy maker engaged on energy planning. Our proposal is a combined evaluation approach of action plans and it is based on both multi-objective linear programming techniques for obtaining actionable solutions during the generation and evaluation of a plan (Jadidi et al., 2014), and the cost benefit analysis to assess the financial feasibility of each stakeholder involved for realizing the selected project investments (De Simone and Rostirolla, 2012).

The presented approach highlights how the full understanding of decisional problem as well as a good structuring of it based on the linkage between objectives and tools, are necessary features of any decisional process. So, it is possible to find effective and feasible solutions for a strategic and operative planning (Landolina and Maltsoglou, 2017)—by considering also that any energy planning process is complex by nature. In fact, several factors and their interactions are involved in these decision-making processes, with their uncertainties. Thus, the model takes into account these uncertainties that cannot be expressed as deterministic values (Zeng et al., 2011), and how the impacts, and, then, the final results, could be sensible to any variation of the demand and/or of the supply.

The choice of an integrated tool is justified by the necessity to offer to the policymaker a complete analysis of the realizable programming providing recommendation on the necessary changes. Each evaluation phase is essential in a context of biomass planning, because according to OECD (2012, p.7) "biomass energy requires the organization of a specific productive process, and involves a large number of people". The optimization model provides the hypothetic best plan of investments, by determining the achieved level of objectives, without considering the tradeoff values and thus

through an objective judgment rather than a subjective one.

Once chosen the projects, the analysis of project investments and the applied incentives (see Section 4), indeed, shows how in the most widespread cases, where both electricity and heat exploitation occur, the current feed-in tariff value is more than enough to encourage these kind of business; one might almost think about reducing it. On the contrary, when biomass plants are located in disadvantaged areas, such as mountainous areas, the current feed-in tariff value does not allow the feasibility of investment; in these cases, the integration to the feed-in tariff is needed. In our simulation, crucial elements become the definition by the decision-maker about incentive that needs to cover the investment costs. This tool is able, once identified the best solution of projects to be realized to address the institution to define a fair value (Nicolini and Tavoni, 2017). These results occur both in Italy and in Germany, that apply a similar feed-in tariff scheme to spur renewable development, but the model can be applicable elsewhere—with careful calibration and/or customization.

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