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Stakeholders' appraisal of biomass-based energy development at local scale

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Bioenergy has a key role in the European Union (EU) policy aimed at enhancing energy security and mitigating climate change. In the implementation of EU policy at national, and—especially—at regional and local levels, the inclusion of stakeholders' opinions is crucial to increase social acceptance and to reduce conflicts between the parties. This study analyzes stakeholders' opinions of biomass-based energy development at the local level (Sarentino valley, South Tyrol region, Italy) by using the SWOT (Strengths, Weaknesses, Opportunities, Threats)-AHP (Analytical Hierarchy Process) approach. SWOT-AHP methodology was implemented in three stages: stakeholders analysis, identification of the SWOT factors, and evaluation of the SWOT factors. Strategic factors were evaluated using the outcomes of a questionnaire administered to five groups of stakeholders (public administrations, NGO and associations, academia, farmers, and forest-wood chain actors). The results showed a firm prevalence for the strengths (33.3%) and opportunities (32.9%) over the potential threats (18.8%) and weaknesses (15%) of the actual bioenergy supply chain in Sarentino valley. SWOT-AHP methodology could be useful in the development and implementation of a local and regional participatory decision making process in the forest-wood-energy supply chain as it can provide structural and quantified analysis of the subjective preferences of the stakeholders.
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I. INTRODUCTION

As a response to the increasing cross-cutting issues related to fossil fuel energy use, initiatives on biomass-based energy development have grown in the recent years at national and regional level (Farinelli, 2004; Faaij, 2006; and Marangon *et al.*, 2009). The increasing importance of using biomass for energy is due to its multiple potential benefits that include: reduction of carbon emissions when biomass is used instead of fossil fuels (Hall, 2002), increased utilization of residues along the bioenergy supply chain, creation of new jobs and coverage of part of the energy needs by local communities (Shabani *et al.*, 2013).

According to the World Energy Outlook 2013 by International Energy Agency (2014), bioenergy—energy from agricultural crops and residues, forest residues, wood, and municipal wastes—has the highest share among the renewable alternatives in the world energy demand (80%) and constitutes about 10% of the world's energy budget with 50 EJ per year, which is projected to increase up to 400 EJ per year by 2050 (de Vries *et al.*, 2007 and Heinimö and Junginger, 2009).

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In Europe, bioenergy currently accounts for about 60% of the total renewable energy (European Biomass Association, 2013). This percentage is expected to rise as a response to the European Union (EU) countries commitment to have 20% contribution of renewable energy resources in the energy consumption by 2020 (Renewable Energy Directive 2009/28/EC). In order to achieve the target established by Directive 2009/28/EC, wood biomass from forests could play an important role in the future as pointed out by some studies (Panichelli and Gnansounou, 2008; Frombo *et al*., 2009; and Sacchelli *et al*., 2014). EUwood have estimated that the EU's forest biomass supply would increase by 11% from 2010 to 2030, while the demand for forest biomass would increase by 73% (Mantau *et al.,* 2010). Beurskens *et al.* (2011) and Dees *et al*. (2011) estimated an increase in the use of renewable biomass equal to the 8% of expected total increase in renewable energy use in EU member countries by 2020.

In Italy, the share of renewable energy source in total energy consumption was of 11.2% in 2011, while the energy from biomass accounted for about 50% of the energy consumption from renewables. Wood and wood waste (residues) based energy amounted for about 25% of the total renewable energies with 150 district heating plants (DHPs) located in Italy (ENEA, 2011 and European Biomass Association, 2013). According to Italian Biomass Association (ITABIA, 2008), the setup of an optimal forest management for energy purposes, using suitable working practices and mechanization, could lead to higher wood energy availability.

The new Italian National Energy Strategy aimed at covering 17% of gross final energy consumption by 2020 with renewable energy and by 2010 it succeeded in fulfilling the first interim target with 10.4% share of renewable energy. The local public administrations (i.e., regions and provinces) are obliged to implement Italian National Energy Strategy through the definition of Regional Energy Plans (REPs). REPs are designed to introduce and expand the use of renewable energy sources at regional level with the involvement of the local stakeholders. This means that the implementation of local bioenergy policy could be more easily conveyed if stakeholders' perspective on the policy and information of the current situation are to be included in the planning or monitoring stage (Laihanen *et al*., 2013). Moreover, stakeholders' insights combined with expert knowledge could provide enriched information as a support tool for developing and implementing new effective policies or revisiting existing strategies (Adams, 2004 and Johansson and Turkenburg, 2004). In addition, understanding perceptions of stakeholders at local scale could help reduce conflicts, increase social sustainability, and evoke cooperation among the different stakeholder groups (Simmons and Lovegrove, 2005 and Bruña-García and Marey-Pérez, 2014).

In the literature, many techniques have been proposed to analyze stakeholders' opinions and preferences (Mendoza and Prabhu, 2006; Kangas *et al*., 2006; Domínguez, 2011; and Ananda and Herath, 2008). One of the techniques currently used to assess stakeholders' opinions is the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. The aim of using SWOT analysis to a participative decision making process is to develop and adopt a strategy that represents best the internal and external factors that are evidenced by the stakeholders. Recently, SWOT analysis was combined with different MCDS (Multiple Criteria Decision Support) methods—such as AHP (Analytic Hierarchy Process), SMART (Simple Multi-Attribute Rating Technique), and SMAA (Stochastic Multi-criteria Acceptability Analysis) methods—to assess the relative importance of the SWOT factors (Kajanus *et al*., 2012). In particular, SWOT-AHP was applied for the first time to evaluate local stakeholders' opinions on adopting certification schemes in private forest farm (Kurttila *et al*., 2000). Subsequently, this methodology has found application in various fields: Pesonen *et al*. (2001) analyzed the experts' opinions on the possibility of Finnish forest industry to invest in North America, while Duchelle *et al*. (2012) have analyzed the perceptions of different stakeholder groups of developing integrated management of timber and Brazil nuts in South America. Conversely, few case studies have used SWOT-AHP methodology to assess different stakeholders' perspectives on the use of forest biomass for energy. Dwivedi and Alavalapati (2009) assessed stakeholders' perceptions of the potentials for biomass based energy in southern United States, while Catron *et al*. (2013) used mixed SWOT-ANP (Analytic Network Process) to quantify expert based perceptive on bioenergy development in Kentucky. However, the use of SWOT-AHP to highlight the stakeholders' perspectives of the use of forest biomass for energy in European countries is very limited both at national and local level.

Starting from these considerations, the first aim of the present paper is to apply the SWOT-AHP methodology at local level in order to identify and analyze the opinions of different groups of stakeholders (i.e., public administrations, NGO and associations, actors of private sector). The second aim of the paper is to give the premises for using SWOT-AHP methodology on regional or national level, especially in places where there are potentials of creating and enhancing such supply chain. In order to achieve these aims, SWOT-AHP methodology was tested in a case study in an Alpine valley (Sarentino valley, South Tyrol province, Italy) characterized by a high potential of biomass extraction.

We believe that the identification of significant stakeholders' groups that support particular functions in specific network of actors and practices could have much influence in implementation of bioenergy policy and, therefore, their perspectives should be more carefully addressed. Our hypothesis is that positive features, in terms of social or economic outcome of the implementation of forest-wood-bioenergy (FWB) chain are recognized across different stakeholders groups, since the activity under investigation has been set up using a bottom-up approach (Bruña-García and Marey-Pérez, 2014).

II. MATERIAL AND METHODS

A. Study area

South Tyrol province (North-East of Italy) commits to increase the energy efficiency and to reduce the carbon dioxide emission using renewable energy sources up to 75% of the total energy sources by 2020 and about 90% by 2050 (PAB, 2011). Bioenergy, using wood as biomass feedstock, accounts for around 32% in the energy consumption on regional level. There are 71 biomass district heating plants in South Tyrol that mainly use local wood and wood residues, and supply 734 GW h of heat per year to various hamlets and municipalities. According to Mühlberg and Stauder (2013) in South Tyrol, there is a considerable potential for using forest biomass, even though robust data are still absent.

The study area—Sarentino valley—is the most territorially extended valley in the province with a total surface of 30 250 ha. The main land uses are forests (45.8%) and pastures (26.4%). The forest standing stock amounts to 3.2×10^6 m^3, while the annual volume increment is 51 239 m^3/year. About 75% of the harvested wood (24 000 m^3) is used for the timber industry, while the remaining—low quality timber and residues (i.e., branches, barks, and top)—is used to satisfy mainly the local energy demand (district heating and household self-consumption). The average harvesting rate of wood for timber production and energy purposes is around 62% of annual volume increment. The typical forest management consists in close-to-nature management with selective cuttings. There are around 600 private forest owners each owning, on average, 23 ha of forest area. Part of them (80–100 owners) are members of the DHP Sarnthein and are actively involved in the management of the DHP.

Low quality timber and wood residues from locally based forest activities (tops and branches) are the main biomass feedstock for the bioenergy generation. In 2013, the DHP used 7130 m^3 woodchips to provide about 9×10^6 kW h of heat. The length of the DHP net is 14.6 km and the network serves 890 users, representing 53% of the buildings in three most populated hamlets (the rest of the households use biomass-fed stoves). The DHP was established as a result of bottom-up driven idea to valorize the use of wood residues and low quality timber and to meet the local energy demand: premises on upgrading the actual structure into co-generation plant have been recently set up.

There are also 10 carpentries that use the local timber in their production system and only one of them provides the DHP with around 30 m^3 of sawdust. Besides, there is one sawmill (84 employees) that annually produces about 50 000 m^3 of volume of sawn timber and 30 000 m^3 of sawmill by-products, mostly of which are sold out of the valley and the national borders.

Sarentino valley (Figure 1) was selected due to the existence of substantial forest area in its territory, the potential role that the valley could have in meeting future local and regional demand for cellulosic biomass and energy needs, as well as the public administration support in promoting cellulosic biomass as a sustainable energy source.

FIG. 1. Sarentino valley and location of the Sarentino DHP.

B. SWOT-AHP methodology

SWOT analysis is a qualitative method that structurally evaluates internal and external strategic factors that influence a new or existing activity in order to provide basis for adopting a decision (Helms and Nixon, 2010). The strategic factors are grouped in four SWOT categories called: strengths, weaknesses, opportunities and threats. The implementation of SWOT analysis does not require high number of participants. Still, the selected interviewees should be very familiar or knowledgeable on the activity (product, service, or process) under investigation (Dwivedi and Alavalapati, 2009 and Catron, 2013). SWOT analysis is considered as an important step for the strategic management: it can be easily understood and, if structured to include high quality information and involve different stakeholders groups, it could identify relevant issues and priorities (Kangas *et al*., 2001).

The main drawback of SWOT analysis is that it assesses qualitatively the preferences for a factor or category, but it lacks in quantifying the effect of each factor on the proposed plan or strategy. Consequently, the importance of each factor or category in decision making cannot be measured quantitatively (Shrestha *et al*., 2004). Thus, it is combined with AHP, which allows to implement SWOT more analytically, by quantifying the relative importance of each factor identified within and among the SWOT categories (Kurttila *et al*., 2000; Shrestha *et al*., 2004; and Catron *et al*., 2013). This hybrid methodology between SWOT and AHP—called SWOT-AHP or A'WOT—provides a quantitative measure of importance of each factor or category on decision-making through pair-wise comparison (Kurttila *et al*., 2000).

1. Implementing SWOT-AHP

According to Shrestha *et al*. (2004), SWOT-AHP methodology can be implemented in three stages: (1) stakeholders analysis; (2) identification of the SWOT factors; and (3) pairwise comparison and evaluation of the SWOT factors.

During the first stage, all the stakeholders in the study area were identified in a brainstorm session between the researchers and regionally based experts (i.e., representatives of local

TABLE I. SWOT factors and categories.

SWOT factors and categories	Description
Strengths	
S1: Major propensity for collaboration between the actors along the FWB chain	The bottom-up idea of the forest owners to create an added value to wood and wood residues harvest resulted in the establishment of Sarentino DHP. This has, in turn, introduced a collaboration among the forest owners, and between the forest owners and other actors along the chain (e.g., forest enterprises).
S2: Use of local wood for bioenergy purposes	The biomass feedstock consists of locally available wood residues and low quality timber located within about 20 km distance from the DHP.
S3: Additional income over time for private forest owners	The price for the woodchips for the DHP is around 65 €/m^3 whereas the costs of wood extraction can range from 25 €/m^3 to 40 €/m^3, depending on the machinery used.
Weaknesses	
W1: High wood extraction and transport costs	Multiple factors, e.g., high altitude, and slope, poor accessibility to the forest roads, changes in prices of fossil fuels, absence of qualified workforce could have adverse effects on the productivity and efficiency in the wood extraction, leading to higher operation costs.
W2: High transactional costs for the DHP to ensure local biomass availability	In order to obtain constant flow of forest biomass feedstock, the DHP has to stipulate and revisit contracting terms and logistics' issues with each supplier of woodchips, which could increase the transactional costs for the DHP itself.
W3: Absence of standards on the biomass quality (moisture and size) on regional level	Every DHP within South Tyrol adopts different standards on biomass quality (e.g., percentage of moisture, size of woodchips), which could influence on the environmental performance of the DHP
Opportunities	
O1: Continuity of this wood-bioenergy to maintain the active forest management in line with traditional practices	Optimal wood harvesting for energy purposes within the sustainability constraints (the harvesting rate should not exceed the annual increment) would enhance forest management, while still maintaining a satisfactory rate of deadwood for the biodiversity conservation and soil fertility. In addition, this type of forest management should reduce the risk of forest fire.
O2: Major use of wood residues of the local timber industry to increase the efficiency of wood use along the forest-wood-energy chain	Wood residues from the sawmill and carpentries located in the valley are often exported outside the borders of the valley. Increased use of these residues (in addition to the wood residues from forest activity) could close the loop of the wood valorization in the valley.
O3: Development of shared forest management strategies among small forest owners	Small-forest owners could be involved in cooperation activities in order to increase the efficiency and decrease forest management costs.
Threats	
T1: Upgrading of the DHP (co-generation) could increase wood biomass demand and wood biomass extraction followed by major environmental negative impacts	The current utilization rate is 62% of the annual increment. Increased use of wood (up to 100% of the annual increment) for bioenergy purposes could induce trade-offs between the wood extraction and other forest ecosystem services (carbon sequestration, hydrogeological protection, flora and fauna).
T2: High presence of regional funding could distort economically sustainable wood extraction	Present and potential uses of regional or European funding for improved forest management or participation in projects regarding bioenergy generation could distort the vision of which forest and bioenergy activities are economically sustainable, thus making the bioenergy supply chain vulnerable in crises periods.

TABLE I. (*Continued.*)

SWOT factors and categories	Description
T3: Possible interruption in bioenergy provision	As the future local energy demand will increase, possible interruption of the energy provision could be expected. This possible disservice could be of particular attention if considering the remote geographic position of the valley.

Forest Service and Department of Mountain Economics of Bolzano). After this preliminary stage 56 stakeholders were identified and classified in five main groups: representatives of public administrations (14), members of research institutes and universities (7), NGOs and local associations, namely, environmental associations and tourist associations (12), farmers and other actors of the local and regional agro-forestry sector (15), and actors of the Sarentino forest sector (private forest owners, DHP, forest enterprises, farmers, wood artisans) directly involved in the forest-wood-bioenergy chain (8).

In the second stage, a preliminary list of SWOT factors was made based on the outcomes of regional projects and on literature that investigated the regional forest biomass supply for energy purposes (Mühlberg and Stauder, 2013). Next, the list was given to regionally based experts that have already worked on the valorization of the forest-wood-energy chain in the valley. Based on their observations, we modified the SWOT factors in order to resemble as much as possible the forest-wood-energy chain in the valley. The final version of the SWOT factors and categories and the respective explanation is shown in Table I.

In the third stage, the above mentioned SWOT factors were used to develop a questionnaire for pairwise comparison by using SWOT-AHP methodology. Before the submission of the questionnaire, respondents were briefly introduced to the aim of the study and to the description of the current situation of the forest-wood-energy supply chain in South Tyrol province in general and Sarentino valley in particular. Questionnaire was submitted face-to-face and it contained pairwise comparison between each factor and all other factors within the SWOT category, and between each category and other categories in the SWOT. Respondents were asked to reflect which of the two factors (or categories) under comparison was more important, and then to assign a weight using "equal," "moderate," "strong," "very strong" terms.

2. Data analysis

The SWOT-AHP analysis includes three steps. The first step is the stakeholder analysis, followed by the identification of the SWOT factors that focus on a particular strategy or decision. The second step includes pairwise comparison for all factors followed by a calculation of the priority value of each factor using the eigenvalue method. The outcomes of the pairwise comparison are represented in a reciprocal matrix where the relative weight is expressed by a_{ij} located at the right side of the diagonal and its reciprocal as $1/a_{ij}$ is located in the opposite side of the diagonal

$$A = (a_{ij}) = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix}. \tag{1}$$

In the matrix, the row indicates the relative weight of each factor with respect to the others. When $i = j$, then $a_{ij} = 1$. Next, the transpose of the vector of the weights w is multiplied by matrix A to obtain the vector represented by $\lambda_{max}w$, that follows the principle

$$(A - \lambda_{max} I)w = 0, \tag{2}$$

where λ_{max} is largest eigenvalue of matrix A and I is the identity matrix of size n. The value of λ_{max} is always positive, equal or higher than n (number of rows or columns in the matrix). The consistency of the respondents information depends on how much the value of λ_{max} deviates from the value of n. In cases where λ_{max} equals n, the responses are perfectly consistent (Saaty, 1987). The matrix A is, thus, tested for consistency using the following formula:

$$CI = (\lambda_{max} - n)/(n - 1), \tag{3}$$

$$CR = CI/RI, \tag{4}$$

where CR is the consistency ratio, RI is the expected consistency index obtained from random generated comparisons of the same order n, and CR is the consistency ratio. Saaty (1987) has computed and presented a list of RI estimates for positive reciprocal matrices of orders 2–14 (in our case $RI = 0.58$). The value of CR should be lower or equal to 0.1 (10%) in order to have consistency of the matrix A.

The third step involves the computation of the overall priority of the SWOT factors. The global or overall priority score of the factor consists in multiplying the relative priority score of the factor within the category group with the priority score of its corresponding category in the overall SWOT category. In our case, the preference of each stakeholder group for a factor (category) was calculated as a geometric mean of the individual preferences for the same factor (category) provided by the members of the group.

III. RESULTS

Table II summarizes the results of overall priority scores of the factors for all the respondents and for each stakeholders group. For the majority of the comparisons, the consistency ratio resulted less than 0.1 (the only exception was the consistency ratio for the comparison between factors in the category opportunity provided by the Academia members). Overall, respondents emphasized the positive aspects (strengths and opportunities) of the valorization of forest biomass for energy purposes (Fig. 2(a)). As an example, in Table II in the first stakeholders group (public administrations), the global priority scores of the strengths (0.3979 or around 40%) and opportunities (0.2884 or around 30%) accounted for about 70% and of the overall perception of using the forest biomass for bioenergy purposes. The same interpretation is used for the relative priority scores. For instance, the priority score of 0.3698 attributed to the *continuity of the wood-bioenergy to maintain the active forest management in line with traditional practices* accounted for about 37% of the overall opportunity group.

A. Public administrations

The second and third columns in Table II summarize the relative and global priority score attributed by the representatives of public administrations, while Figure 2(b) highlights the predominance of the strengths (39.7%) and opportunities (28.9%) of the existing strategy of using forest biomass for bioenergy purposes. For these stakeholders, the *use of local wood for bioenergy purposes* was the key strength factor (about 41% of the category), while the c*ontinuity of the wood-bioenergy to maintain the active forest management in line with traditional practices* was seen as the dominant factor among opportunities (37% as relative priority score). On the other side, as a potential future threat was mainly the *high presence of regional funding could distort economically sustainable wood extraction* with 48%, and as current weakness was the *high wood extraction and transport costs* with 40%. Combined, the threats and weaknesses groups accounted for about 31.3% of the overall public administrations' perception.

TABLE II. Priorities of the SWOT factors and categories. The numbers highlighted in bold indicate the factors of the SWOT categories with highest scores, while the underlined numbers represent the highest overall priority scores of the category. N.S. = not significant (CI = 0.145 > 0.10).

	Public administrations		NGO and associations		Academia		Farmers		Actors in the forest sector	
SWOT categories	Priority score	Global priority	Priority score	Global priority	Priority score	Global priority	Priority score	Global priority	Priority score	Global priority
Strengths		0.3979		0.2212		0.3779		0.3679		0.4150
S_1	0.2565	0.1020	0.3282	0.0726	0.2784	0.1052	0.3118	0.1148	0.1487	0.0617
S_2	**0.4102**	0.1632	0.3003	0.0664	0.2828	0.1069	0.2876	0.1058	0.3654	0.1517
S_3	0.3333	0.1326	**0.3716**	0.0822	**0.4389**	0.1658	**0.4006**	0.1474	**0.4859**	0.2017
Weaknesses		0.1454		0.1664		0.0844		0.1421		0.1288
W_1	**0.3959**	0.0576	**0.3989**	0.0664	**0.4873**	0.0411	**0.4197**	0.0597	**0.4128**	0.0532
W_2	0.3178	0.0462	0.3951	0.0657	0.1897	0.0160	0.3388	0.0482	0.2713	0.0349
W_3	0.2863	0.0416	0.2060	0.0343	0.3230	0.0273	0.2415	0.0343	0.3159	0.0407
Opportunities		0.2884		0.3878	N.S.	0.3837		0.3198		0.3653
O_1	**0.3698**	0.1066	0.2942	0.1141	0.4933	0.1893	0.2793	0.0893	**0.4505**	0.1646
O_2	0.3148	0.0908	**0.4080**	0.1582	0.1689	0.0648	0.1906	0.0610	0.1852	0.0676
O_3	0.3154	0.0910	0.2978	0.1155	0.3377	0.1295	**0.5301**	0.1696	0.3644	0.1331
Threats		0.1683		0.2246		0.1540		0.1701		0.0909
T_1	0.3317	0.0558	0.4242	0.0953	0.2514	0.0387	0.3261	0.0555	0.3195	0.0290
T_2	**0.4749**	0.0799	0.2626	0.0590	**0.6330**	0.0975	**0.3775**	0.0642	0.3062	0.0278
T_3	0.1933	0.0325	0.3132	0.0704	0.1156	0.0178	0.2963	0.0504	**0.3743**	0.0340

B. NGOs and associations

For this stakeholders group, the future potentials (38.8%) outweigh the strengths (22.1%) among the positive characteristics of the existing bioenergy scheme. The *major use of wood residues of the local timber industry to increase the efficiency of wood use along the FWB chain*—41% within the category—was seen as a predominant opportunity that could optimize the flow of wood residues for local bioenergy purposes. Threats (22.5%) were slightly higher than strengths (22.1%). In particular, within the threat category, this group has shown concerns that *upgrading the DHP (co-generation) could increase wood biomass demand and wood biomass extraction followed by major environmental negative impacts* (42.2%). The *additional income over time for private forest owners* has obtained the 37.2% of the overall perception of the strengths of the actual bioenergy supply chain, while the *high wood extraction and transport costs* dominated the weaknesses category with 40%. A summarized perception map including the overall priority schemes is shown in Figure 2(c).

C. Academia members

Perception map that includes the overall priority scores of each SWOT factor is shown in Figure 2(d).

It is important to stress that the consistency ratio for the category opportunity resulted in 0.145 which is higher than 0.1, meaning that there is some inconsistency in the responses provided by the interviewees. Still, for the purpose of providing the complete photography of the opinions of all different stakeholders, we decided to provide the results also for this category.

Opportunities (38.4%) and strengths (37.8%) dominated in this group perception of the forest biomass bioenergy chain. Academia members chose as their key opportunity factor the *continuity of the wood-bioenergy to maintain the active forest management in line with traditional practices* with 49.3% share among the other factors. Similarly to the second stakeholders group, the Academia members preferred the *additional income over time for private forest owners* (43%) as a current strength in bioenergy supply chain. Among the threats (15.4% of the overall SWOT categories), the *high presence of regional funding could distort economically sustainable wood extraction* has obtained around 63% of the overall potential future obstacles. Similar to what stated by the previous stakeholders groups the *high wood extraction and transport costs* has dominated in the weaknesses category with 48.7%.

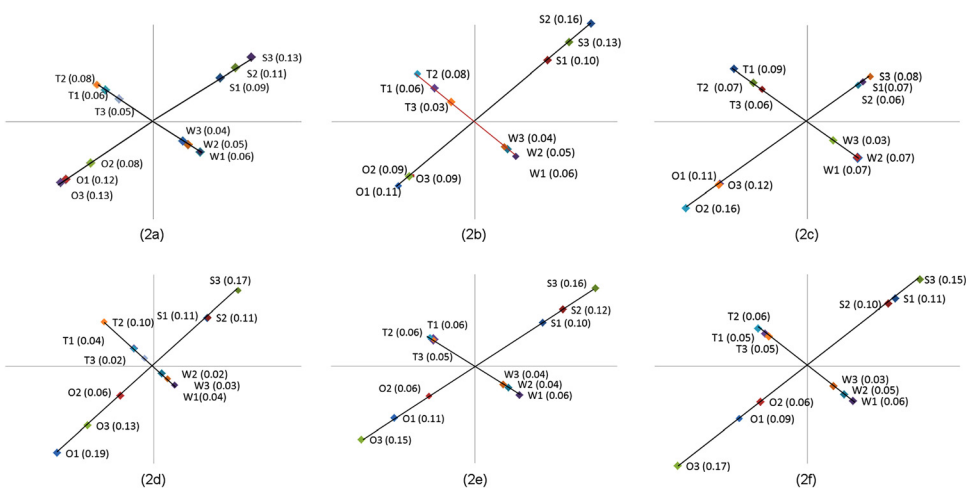

FIG. 2. Perception maps of five stakeholders groups. SWOT factors further away from the origin are relatively more important than factors closer to the origin. The graphic presentation of the factors was made using the corresponding global priority values. (a) All stakeholders; (b) members of local and regional administration; (c) NGOs and associations; (d) academia members; (e) farmers; and (f) actors in the forest sector.

D. Farmers

A graphic summary of the relative and global priority score attributed by farmers is presented in Figure 2(e). Results highlight the prevalence of the strengths (36.8%) and opportunities (32%) of using forest biomass for bioenergy purposes. For these stakeholders, the *additional income over time for private forest owners* is the dominant strength factor (about 41% of the category), while the *development of shared forest management strategies among small forest owners* is seen as the most important factor among opportunities (53% as relative priority score). The *high presence of regional funding could distort economically sustainable wood extraction* is evidenced as main threat with 38%, while the *high wood extraction and transport costs* is perceived as major weakness with 42%. Combined, the threats and weaknesses groups account for about 31% of the overall farmers' perception.

E. Forest sector actors

The actors of the forest sector directly involved with the bioenergy supply chain preferred the strength (41.5%) and the opportunities (36.5%) over the weaknesses (12.9%) and threats (9%) associated with the actual bioenergy strategy. In particular, economic aspects (*additional income over time for private forest owners*) and enhanced forest management (*continuity of this wood-bioenergy to maintain the active forest management in line with traditional practices*) obtained the highest priority scores in strength (48.6%) and opportunity category (45.1%), respectively. The *possible interruption in bioenergy provision* was the most significant factor in threats category (37.4%), while the *high wood extraction and transport costs* (41.3%) was confirmed as the key weakness factor. Overlook of the stated perception of the proposed SWOT categories is presented in Figure 2(f).

IV. DISCUSSION

This paper uses SWOT-AHP approach to assess the perceptions of five groups of stakeholders related to the existence of forest biomass-based bioenergy chain in Sarentino valley. The consistency ratio was higher than 0.1 (0.145) only in the stated perceptions of the Academia members regarding the factors priority within the opportunities category. The first reason for this inconsistency could be closely related to the existence of different (even opposing) preferences for and prioritization of the management and logistic strategies to be adopted along the biomass supply chain. The members of the Academia group have different fields of expertise ranging from wood harvesting and technology to protection and security of Alpine environment, which could in some cases lead to divergent future options for the forest-wood-energy chain. In addition, Margles *et al.* (2010) stated that, due to the high subjectivity in the human preferences, one could expect that even participants within similar interest groups could have different levels of strengths of preference for individual SWOT factors, leading to possible inconsistency.

Overall, the results suggested that the stakeholders favored the strengths (33.3%) and opportunities (32.9%) over the potential threats (18.8%) and weaknesses (15.0%) of the actual bioenergy supply chain in Sarentino valley.

In particular, the presence of such chain, as perceived by the stakeholders, generates and could potentially trigger a rural sustainable development encompassing economic (additional income over time for the forest owners), social (collaboration among different actors), and environmental current and potential benefits. Still, it is interesting to note some differences among groups of stakeholders: the *additional income over time for private forest owners* is considered as the most important strength factor by four groups out of five, while public administrations considered the *use of local wood for bioenergy purposes* as a key strength factor. As for the latter, it is not a surprising outcome: the increased use of biomass from forests in Sarentino valley and South Tyrol could provide an added value in the supply chain and could help the province in becoming more independent from foreign energy supply (PAB, 2005). Currently 32 000 m^3 of wood are harvested for both timber and bioenergy purposes (62% of the total annual

increment). Recent study on the biomass supply potential in Sarentino valley showed that a relatively sustainable wood harvesting could be obtained even in the case of extraction of 96% of the total annual increment (51 000 m^3): 4% could not be used due to the hydrogeological constraints. This means that additional 16 960 m^3 per year (or a substantial part of it) could be used as biomass feedstock in the Sarentino DHP (TIS innovation park, 2010). On the demand side, as of 2013, 890 buildings (53%) in the most populated hamlets use the 9×10^6 kWh of heat and this trend is expected to rise and reach an optimal heat distribution to the households in Sarentino municipality. Unfortunately due to economically and technical difficulties related to the position of the peripheral hamlets, full coverage of heating demand could not be feasible. In addition, a legitimate idea of upgrading the DHP into a CHP (Combined Heat and Power) plant would mean providing both heat and electricity from locally available renewable resource also to those households that currently use forest residues for their individual stoves and for all the inhabitants that use electricity from the national network.

The possibility for the forest owners to detain additional income was a key factor for the Academia members in this study and this finding is very similar to what was obtain as an outcome in the study of Catron *et al*. (2013). A study on the economic implications of using local wood for bioenergy purposes in Sarentino valley showed an added value of about 30 €/m^3 for the forest owners that collaborate with the Sarentino DHP (TIS innovation park, 2013).

NGOs and associations preferred the additional income for the farmers over the other proposed strengths, which differs significantly to what emerged in similar SWOT-AHP studies (Duchelle *et al*. 2012 and Dwivedi and Alavalapati 2009). This might be due to the fact that these organizations do not perceive the current forestry activities of a particular ecological or recreational threat, and relate more to the economic situation of the individual forest owners.

Significant differences were found in the opportunities category: while the public administrations, the Academia and the actors in the forest sector preferred the *continuity of the wood-bioenergy to maintain the active forest management in line with traditional practices*, the NGOs opted for the *major use of wood residues of the local timber industry to increase the efficiency of wood use along the FWB chain* and the farmers preferred the *development of shared forest management strategies among small forest owners*. The preference of the farmers is in line with their current status of the forest sector: many of them detain small forest areas and shared strategies could help them improve their forestry activities or benefit from shared forest strategies.

The NGOs and associations' sector preferred major use of sawmills' residues as biomass feedstock, which could represent viable solution to feed potentially increased bioenergy requirements of the DHP and to optimize the wood utilization across the supply chain. Currently, only one carpentry provides 30 m^3 to the DHP, while the rest of the carpentries and the sawmill export a fairly high amount of wood residues. The use of the sawmill by-products (30 000 m^3) could represent a game changer in the effort of closing the loop in the forest-wood-bioenergy chain in the valley. Careful proposal to include the sawmill as local provider of defined amount of wood by-products at fixed price (as it is done for the forest owners) could also create a premise for a regional circular economy related to the bioenergy sector. This option seems more grounded when we consider a potential threat of intensified wood harvesting on several categories of ecosystem services in addition to hydrogeological protection. Verkerk *et al*. (2014) investigated the relationship between the intensive extraction of roundwood and wood residues, and their impact to the forest ecosystem services across 3 different scenarios (baseline, bioenergy development, and biodiversity targets). They found a significant trade-offs between the increased wood harvesting on the one hand and carbon sequestration, habitat services (deadwood as a proxy), and recreation attractiveness, on the other hand. Several authors evidence that the use of forest residues for energy has a negative impact on wildlife and biodiversity (IEA, 2002), while Nijnik *et al*. (2014) identified three types of negative impacts of residue and deadwood extraction: logging residues attract species laying eggs in the piles, soil disturbance affects mosses, and species reproducing in the vegetation, and deadwood extraction leads to habitat fragmentation for dependent species. Higher energy supply for Sarentino valley with

potentially negative environmental impacts was also the major future concern among the members of the NGOs and associations in the SWOT-AHP survey.

Local and regional policies concerning the use of forest wood residues for energy purposes should incorporate in the decision making process (or revaluation process) the potential positive externalities in terms of enhancement of active forest management, which, in the case of the South Tyrol valleys, was once present in the traditional forestry activities. The outcomes of this study showed that the improved forest management is considered as important opportunity factor in Sarentino bioenergy chain by local forest owners, but also by Academia members and forest policy experts and regional public administrations.

Potential misperception of the economically sustainable wood extraction could be induced by the presence of regional and European funding according to three groups of stakeholders (public administrations, Academia members and farmers). In general, it is economically challenging for the local forestry in mountainous areas in South Tyrol to perform timber and residues harvesting (Mühlberg and Stauder, 2013). In fact, the results of this study showed that all of the stakeholders' groups unanimously perceive high extraction and transportation costs of wood residues as the most important weakness in the category. One possible way to address this weakness is through regional and European contributions and incentives. Still, this could often be perceived as the only solution for the forestry activities, and, as consequence, many forest management decisions and practices take into an account the presence of external contribution. Nevertheless, there are also other strategies that could lessen the economic burden of the wood harvesting. One of them could be a careful reconsideration and preliminary identification of the fixed costs and extended implementation of co-ownership of the more recent machinery technology or transportation scheme. Special efforts could be put in craving bottom-up project or strategy capable of providing common bases for shared forest management among owners of small parcels of forest. The establishment of FOC (forest owners cooperation) could be seen as an interesting opportunity that could include many of the small-scale forest owners. In his study, Rauch (2007) presented an FOC reality in Sweden where the cooperation could act as a broker between the forest owner and the buyer (DHP, sawmill), ensuring optimal prices for the former and reliable quantity and quality of wood and residues (moisture and size) for the latter. The forest owners are also members of the organization, can earn dividends and can have right to vote regardless of the size of the property. There are two strategies for wood supply of this FOC: the first one is to purchase the timber as a stumpage in cases where the forest owner does not harvest the timber. This could be the case for the forest owners that are overloaded with agricultural work and do not have human and machinery resources to ensure a stable timber supply. The other strategy of this FOC is to purchase the timber and residues at the forest road in cases the forest owners decide to harvest the wood themselves. In this case, several scenarios could be adopted to use the FOC's machinery for the forest owners, by applying small fee for the use. The choice of machinery should be based on its productivity (high-mechanized) and with the lowest environmental impacts (i.e., soil compaction). The initial purchase of the machinery by FOC could be sustained by the local or regional institution, but the FOC should be capable to deal with the operation costs through the years.

V. CONCLUSIONS

This case study aimed at analyzing current perceptions of an actual bioenergy supply chain by applying SWOT-AHP methodology to as many as possible actors along this chain and stakeholders indirectly involved in the biomass-based energy development in Sarentino valley.

The results showed that positive characteristics of the bioenergy supply chain, like use of local wood and additional income for the forest owners outweighed the current and future obstacles that, however, should not to be disregarded.

In fact—although the potential use of additional 17 000 m^3 of wood and residues would mean as twice as double provision to the DHP in the foreseen increase of energy supply—there are some structural changes that could be implemented to make sure that there would be a constant wood supply from local providers without high environmental and social negative

externalities. For instance, plausible scenarios would necessarily involve other existing and new actors in the wood market. Sawmills and carpentries could have important role in ensuring that the processed wood by-products do not flow out of the valley, but instead, through favorable contract terms, the same wood flow could be used in future heat and electricity production. Promoting cooperation among forest owners between various phases of the bioenergy supply chain (extraction, transport, wood processing, and heat production), would address the high extraction and transportation costs and the inclusion of small-scale forest owners.

The SWOT-AHP method is a useful tool to analyze in hierarchical manner stakeholders' preferences and priorities, to increase and improve the information available to political decision makers in order to define or readdress the local energy policy. Besides, this methodology can be used as an instrument of communication and information of social actors in the participatory decision-making process. The knowledge of the preferences and opinions of different stakeholder groups can predict and therefore prevent any conflicts between groups before the decision making process.

We believe that the SWOT-AHP methodology gets the most interesting application results when it is used at regional or local levels, because it enables to tailor the description of the strategic factors to the local context, and to include much more beneficiaries, including those that will have direct impact from the policy. Finally, we assert that the analysis of stakeholders' opinions and preferences of biomass-based energy development strategies should be an essential starting point every time that a regional energy policy with local impact is implemented.

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