Cost-opportunity analysis of the use of *Posidonia oceanica* as a source of bio-energy in tourism-oriented territories. The case of Alghero

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**Abstract**

The use of seaweed biomass for energy production is under consideration in several countries of the world. This paper, after a review of other scientific papers on the subject, aims at evaluating the pros and cons of the use of *Posidonia oceanica* as biomass source for anaerobic digestion (AD) in territorial contexts where the presence of large quantities of beached seagrass is also a problem for the tourism economy. The case chosen is the Sardinian town of Alghero.

The presence of large *Posidonia* leaves deposits on the beaches is responsible for some inconveniences, such as the foul odour derived from the natural decomposition process. Other problems are the reduced usability and the untidy appearance of the beach, which lays within the town’s urban context. This condition reduces the competitiveness of the hotels, bars and restaurants that are located on the seaside promenade and the quality of life of nearby residents and tourists.

The methodology used to define and analyse the problem is based on the following steps: territorial analysis, evaluation of the available quantities, regulatory issues, economic and social impacts evaluation.

Although the overall quantity of fresh *Posidonia* evaluated by the municipal authorities is of approximately 200 tonnes per year, other calculation methods show that the potential quantity of raw biomass is far superior (up to 3,500 tons). It is possible then to determine the potential CH4 yield and the consequent thermal/electric output after an AD process.

Based on the quantitative data of our analysis we are able to determine a cost structure and to evaluate, from the economic point of view, the adequacy of the choice of installing an AD plant fuelled with *Posidonia oceanica* in the town’s industrial area. The study has a preliminary approach, as the data used for the biogas production estimation are derived from laboratory tests.

Furthermore, the effects of the removal of the seagrass from the beaches, provided that the operations are carried out in a sustainable and non-destructive way, could improve the quality of life of residents and tourists in the nearby areas.

Based on our findings we can suggest that the usage of *Posidonia oceanica* in the studied case is potentially interesting as a resource for biogas production although further research is needed to validate this solution.

The future research efforts will have to concentrate on several issues: definition of the available biomass quantities, evaluation of the biogas yield of *Posidonia* on an industrial scale, available codigestion solutions, treatment and possible use of the digestate sludge.

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1. Introduction

Research efforts on the use of biomass are the answer to the ever growing demand of sustainable and low cost energy from renewable sources.

The techniques used to obtain energy from biomass are very variable both in terms of yield and of type of technology, so that it is possible to classify in a synthetis way the available solutions in macro-categories based on the technology and on the final output. In this classification, the concept of output is to be intended not as a substitute for electric energy but more as the final result of the transformation process the biomasses undergo when used for energetic purposes.
The first category includes the thermal and thermo-chemical technologies as incineration, pyrolysis and gasification, hydrothermal carbonisation (HTC) (Kambo and Dutta, 2015) while anaerobic digestion (AD) and alcoholic fermentation fall within the category of biological technologies.

Thermal and thermo-chemical technologies, with the exception of incineration, are known to be more complex and expensive in terms of the level of technology, know-how and energy consumption to achieve the temperatures and conditions they require in order to produce their output. Table 1 displays the main processes and their outputs in terms of energy products (gas, oil) and by-products.

The use of *Posidonia oceanica* for the production of syngas through pyrolysis and gasification processes (Conesa and Domene, 2015; Plis et al., 2014) seem to provide with interesting results.

A second type of biochemical technologies are available at lower costs: Anaerobic Digestion (AD) and Alcoholic Fermentation (AF). Such processes are easier to monitor and operate and are suitable for implementation on different scales.

In particular the application of alcoholic fermentation are under evaluation for the use of municipal and agro food industry waste industry (Asquer et al., 2014; Scano et al., 2014a, 2014b) while Anaerobic Digestion is already widely used for energy production from biomasses.

Another characteristic of biological technologies, particularly AD, is to produce, together with the biogas, the so-called digestate, a sludge that accounts for about 80% in mass of the initial input. Such substance can be used as soil conditioner, provided its characteristics are compatible with the agronomic standards. Furthermore, large quantities of digestate might prove difficult to dispose of and could become a cost for the AD process. On the other hand, AD of residual biomasses produces additional environmental benefits because of its capability to reduce, compared with other energy production techniques, the emissions of greenhouse gases in the atmosphere (Mata-Alvarez et al., 2000).

*Posidonia oceanica*, commonly known as seagrass, is a phanerogamic plant adapted to underwater life. It is a key element preserving the Mediterranean ecosystems, protecting from coastal erosion, and regulating CO2 absorption in the sea and in the atmosphere. The function of the meadow is comparable to the mangrove. The chemical characterization of *Posidonia oceanica* leaves behind the eelgrass and invertebrates, especially larvae and young fish.

They also play an important role in the processes concerning beach and dunes systems. The *Posidonia oceanica* leaves left on the shores act as a natural dock reducing the energy of the waves and minimizing erosion.

This study aims to carry out a preliminary analysis, based on the available data from scientific literature, experimental projects and industrial applications, to check the feasibility and sustainability of the use of *Posidonia oceanica* (L.) Del as a biomass for AD processes.

The study is preceded by a theoretical review aimed at describing the research efforts implemented until now and to expose the gap in the literature regarding the use of *Posidonia* in AD processes.

### 2. Literature review

The study of biomasses for energetic purposes has produced a wide literature. This short review will briefly summarise the available studies on the following subjects:

- Papers on AD of residual biomass (waste and by-products) applications in Sardinia;
- Papers on AD of algal or maritime biomasses;
- Beached seaweed management and issues
- Chemical characteristics of *Posidonia oceanica*
- Experimental use of *Posidonia oceanica* for energy uses other than AD
- Alternative uses of *Posidonia oceanica*

The variability of the biomass resources has allowed scientists and technicians to explore several sources to fuel AD plants, such as the biomasses originated from agriculture (both by-products/waste and dedicated production), from the food industry, and from the organic fraction of municipal waste.

In Sardinia there have been studies on the use of forestry biomass (Melis et al., 2014; Murgia et al., 2014; Orrù et al., 2013; Tola et al., 2010) and the use of different kinds of organic waste originated from agriculture and food industry (Asquer et al., 2014; Scano et al., 2014a, 2014b).

Numerous papers are also available on the use of algal or maritime biomasses for AD but the available data concern mostly other species than *Posidonia oceanica* or other territorial contexts (Allen et al., 2013, 2014; Barbot et al., 2016; Bastianoni et al., 2008; Habig and Ryther, 1983; Hansson, 1983; Migliore et al., 2012; Nallathambi Gunaseelan, 1997; Toru et al., 2006; Vergara-Fernandez et al., 2008).

The chemical characterization of *Posidonia* and its possible uses have been studied by Lawrence (Lawrence et al., 1989), and, more recently by Cocozza and Parente (Cocozza, 2011a, 2011b) with the latter paper focusing on the comparison between agricultural vs. energy production usage.

Chiado, Zafarana et al. have studied the use of pyrolysis to *Posidonia* in comparison with other wood biomasses (Chiado et al., 2016), while Turkish researchers (Deniz et al., 2015) developed a study on application of hydro-thermal gasification of *Posidonia*.

Furthermore, the data obtained by Ntalos and Sideras, on the use of this variety of biomass as pellet fuel for heating are available (Ntalos, 2014).

The management of beach-cast biomasses is a very important topic for the Mediterranean coastal towns and cities. A survey conducted in March—May, 2008, on 11 sites along the Apulia coastline, estimated more than 28,000 m³ of beach-cast residues concentrated in only about 4 km of beaches, ports, and esplanades. The presence of high amounts of residues close to urban centres may represent a hardship because of the odours that develop from the accumulation or even a danger because of the possibility of fires, with consequent problems of public health and safety (Parente et al., 2014).

In all these cases, the coastal municipalities are forced to remove seaweed residues that, in the absence of alternative solutions, are disposed of in landfills. This practice results in both environmental charges, given the relevant amount of organic matter removed from the ecosystem, and economic costs due to disposal (Castaldi et al., 2004).

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**Table 1**

<table>
<thead>
<tr>
<th>Type of technology</th>
<th>Process</th>
<th>Output and by-products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo-chemical</td>
<td>Incineration</td>
<td>Heat, flue gas, ashes</td>
</tr>
<tr>
<td></td>
<td>Pyrolysis</td>
<td>Pyrolysis gas, Bio-oil, Char</td>
</tr>
<tr>
<td></td>
<td>Gasification</td>
<td>Syngas, ashes</td>
</tr>
<tr>
<td></td>
<td>HTC</td>
<td>Hydrochar, process liquid</td>
</tr>
<tr>
<td>Biological</td>
<td>Anaerobic digestion</td>
<td>Biogas, digestate</td>
</tr>
<tr>
<td></td>
<td>Alcoholic fermentation</td>
<td>Bio ethanol, CO₂</td>
</tr>
</tbody>
</table>

This table shows the main processes available to extract energy from biomass. Each process delivers one or more energy source and by-products.
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