Renewable and Sustainable Energy Reviews 51 (2015) 634–647

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Analysis of the environmental impact of a biomass plant for the production of bioenergy

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ARTICLE INFO

Article history:
Received 6 November 2014
Received in revised form
4 May 2015
Accepted 28 June 2015
Available online 15 July 2015

Keywords:
Biomass plant
Energy recovery
Environmental impact
Environmental balance
Externalities evaluation
Implementation of a pollutant dispersion model

ABSTRACT

This work analyzed the environmental compatibility of a biomass plant to be constructed to produce both electricity and heat (bioenergy) in a small town in Piedmont (northern Italy). In order to study both the critical local impacts (with specific reference to air quality) and the overall environmental benefit (decrease of GHG generation), we evaluated the emissive flow modifications for the hypothesis of activating the biomass plant in the municipal area, by considering introduced and eliminated pollutant loads. This analysis included a consideration of the non-energy-related emissions ("ground value") currently operating in the area.

After carefully analyzing the major operational characteristics of the proposed plant and the principal characteristics of the surrounding territory and its energy needs, the evaluation was conducted using the tools of mass and energy balances, and an external costs methodology was also applied in order to define the social cost of the plant. In addition, the plant′s potential modification to local air quality was evaluated by considering the meteorological and physical characteristics of the considered area, using a pollutant dispersion model. Several different configurations for the flue gas purification line were also considered, so that the evaluation of the costs and benefits was based on the analysis of both industrial and external costs.

The conclusions, while based only on the specific studied case, can be considered to be fairly representative in general as a methodological approach for studying the effects of the implementation of biomass energy plants.

Contents

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http://dx.doi.org/10.1016/j.rser.2015.06.048

1. Introduction

The main objective specified in European Union Directive 2009/28/EC [1] is to obtain 20% of all energy from renewable sources by 2020. Of all such energy sources, bioenergy generated by renewable energy plants is strongly encouraged under the European legislation, because it is convenient and there is a large quantity of cellulosic material that could be employed for the purpose. On the other hand, the effects on the environment—particularly air quality—raise serious concerns.

The aim of this paper is chiefly to define the acceptability of a biomass plant, focusing particularly on its local impact, since there is often disagreement about the advantages of decreased CO_2 emissions versus the disadvantages of other combustion pollutants at the local level.

In the present work the proposed construction of a biomass plant for electricity generation in a small city in Piedmont (northern Italy) was considered. The objective of the plant is to co-generate electricity—to be added to the general local energy network—and heat—to be sent to a local district heating network, thereby utilizing both the generated electricity and thermal energy. The area of interest for the evaluation is the small municipal area where the plant is to be located.

In order to verify the environmental compatibility of the plant, an evaluation of the modification of emissive fluxes was first performed. To this aim, the new emissive flux that would result from the biomass plant activation was considered. For comparison, the avoided emission flux resulting from shutting down currently operating domestic boilers was determined, as was the additional electricity that would be generated and introduced into the local electricity network. Since it was our intention to evaluate the load introduced at the stack by the new plant, we also needed to take into account potential solutions for containment. This aspect was studied by considering the best technological solutions for maintaining air quality.

After this balance calculation an externalities definition was calculated, in order to establish the overall advantage or disadvantage of the proposed biomass plant. By using a dispersion model for the principal pollutants that would be introduced into the atmosphere, it was possible to determine the real differences in air quality after the plant activation.

Considering not only the initial advantage of technological reliability but also the subsequent environmental impacts and the production that would be transferred to the new plant, a very important definition of local acceptability could be established. The tools used in this analysis (environmental balance, evaluation of externalities, implementation of a pollutant dispersion model) are common in impact assessment, but their combined use for this specific technological process must be considered as a new methodology, and a very important one for evaluating this type of plant.

In fact biomass energy plants are very often evaluated from an energy point of view, with reference only to the need to limit GHG emissions, not addressing concerns about local compatibility. In this study, however, these aspects were defined using a numerical air quality approach, providing a useful and innovative tool for evaluating the overall impacts of these plants.

2. State of the art

Because of its ability to limit climate change from energy production, biomass is widely considered to be a major potential fuel and renewable resource for the future [2–9]. Bioenergy production plants, however, must be evaluated on the basis of their capacity to satisfy both local and regional needs for thermal and electrical energy, and while this evaluation leads to the consideration of the plants′ contribution to reducing GHG emissions and climate change, at the same time, its effects on local environmental quality must be considered [10].

In order to study the ability of different forms of biomass to satisfy the general energy requirements [11], a number of scenarios have been constructed, to cover large spans of both time and land area [12]. Two key inputs for these analyses are the amount of woody biomass that is available for large-scale energy production, and its price. At the same time the compatibility aspects must be considered; in fact a practical goal of bioenergy production is to lead to sustainable and economically viable methods for satisfying energy production requirements. One study with this aim was the European Environmental Agency (EEA) report [13], which discussed the different aspects of sustainability: the utilization of natural resources (land, water, and fertilizers), the effect on climate change, the potential introduction of local air pollutants, and the necessity of disposal, or if possible, re-use, of residual wastes from the biomass production.

By using a general approach, Dincer [14] discussed all the aspects of energy utilization and its major environmental impacts from the standpoint of sustainable development, including anticipated patterns of future energy use and subsequent environmental issues; renewable energy technologies and efficient energy utilization were identified as the most effective potential solutions to current environmental impacts. Generally, the LCA (Life Cycle Assessment) method seems to be the most useful tool for defining the different aspects of the total impact of a particular form of energy production, from resource consumption, to technological energy production systems, to residual and waste re-immission into the environment. An example of the application of LCA to this bioenergy chain can be found in Blengini et al. [15]. In the literature many references concerning bioenergy production [16] and related environmental sustainability [17] appear; in particular the individuation and utilization of indicators or methodologies corresponding to LCA [18] have made important contributions [19].

In addition, beyond LCA analysis, other important tools are used, in order to evaluate biomass plant compatibility. In particular, environmental balance, external costs (social costs) and the implementation of a pollutant dispersion model (in order to determine the anticipated modifications to the local air quality) must be considered. The literature contains many studies relating to this field, concerning the utilization of biomass [20], the local environmental impact [21] and the methodological approach to its use [22]. From these indicated references it is possible to establish that the environmental balances for energy-crop exploitation are well defined, and many examples are at our disposal for useful comparison [20]. Yet a specific definition of the local context and the existing operating conditions must be carefully examined, in order to arrive at valid conclusions for any particular proposed application [8].

The various tools (previously reported) used in this study in order to evaluate the compatibility of the biomass plant can also be used for analyzing various other aspects, such as the planning of biomass utilization [23] or the possible general air-quality changes [24].