Engineering Science and Technology, an International Journal 18 (2015) 178–184

HOSTED BY

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: http://www.elsevier.com/locate/jestch

Full length article

Potential evaluation of biomass-based energy sources for Turkey

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ARTICLE INFO

Article history:
Received 22 July 2014
Received in revised form
11 October 2014
Accepted 24 October 2014
Available online 23 December 2014

Keywords:
Biomass energy
Biogas
Municipal solid wastes
Animal manure
Turkey

ABSTRACT

Turkey has great potential with respect to renewable energy sources (RES) and, among such sources, "biomass energy" is of particular importance. The purpose of this study is to determine the primary electrical energy potential obtainable from the biomass potential, according to different biomass source types. In this study, the biomass sources of municipal solid wastes, energy crops, animal manure and urban wastewater treatment sludge are evaluated. For each source, individual biogas and biomass energy potential calculations are made. Methods for energy conversion from wastes applicable to the conditions of Turkey, and technical and economic parameters are used. As a result of the calculations made, the total primary energy value of biogas obtainable from the examined sources is 188.21 TWh/year. The total primary energy value related to the potential of the evaluated biomass sources is 278.40 TWh/year.

1. Introduction

The usage of domestic and renewable energy sources (RES) by countries is important for the development of energy policies that decrease dependency on foreign sources. Power plants using renewable energy decrease dependency on foreign sources and are less damaging to the environment when compared to other energy sources.

Turkey's geographical location makes it a strategic energy hub for Europe by providing oil and natural gas from the energy-rich Middle East and the Caspian Sea to Europe. The oil and natural gas pipe lines which provide the fuels, and the straits of the country play an important role in fuel supply. In Turkey, the greatest share of electricity is generated from thermal power plants consuming natural gas, oil and imported coal. Although considerable potential is present in the form of lignite and coal, oil and natural gas reserves are negligible when compared to world reserves [1].

Almost all the natural gas and oil of the country has been imported from neighboring countries, many of which have had unstable regimes for many years. Conflicts both between and internal to these countries have been intensifying and these events pose a threat to Turkey's heavy dependence on imported energy resources. Without good relations with the neighboring energy importing countries, Turkey will face problems in supplying predicted energy demands. More than half of the primary energy consumption in Turkey is met by imports and the share of imports has increased each year. Therefore, Turkey has to supply energy demands using domestic and renewable resources; diversification of resources and a shift from conventional to renewable energy must be realized. Renewable energy must be given first priority as a key way for reducing Turkey's heavy dependence on imported energy.

RES are commonly accepted as the key for future life, not only for Turkey but also for the whole world. This is primarily because RES have some advantages when compared to fossil fuels. Renewable energy power plants have far less environmental impacts than fossil-fuel fired power plants. Usage of these technologies reduces the amount of carbon dioxide produced. RES can contribute to reducing dependence on energy imports and permit diversification of the energy supply. This will not only reduce Turkey's dependence on imports of fuel for producing energy, but will also ensure a continued local source of energy. In the developing countries, RES are more important because many of these nations do not have scarce fossil energy sources such as crude oil and natural gas [2,3].

Biomass is one of the most promising RES. It is considered as an alternative to conventional energy and has significant potential in

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Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2014.10.003

Turkey. Biomass is generally regarded as a low status fuel, and it offers considerable flexibility of fuel supply due to the range and diversity of fuels that can be produced. Biomass can be burnt directly or it can be converted into solid, gaseous and liquid fuels using conversion technologies. Direct burning of dried animal manure, wood, or processed wood products, hold a significant share of the heating for people in Turkey. Biomass to energy conversion projects are currently widespread.

Various studies have given a value to the biomass potential of Turkey and the energy value it has. In such studies, it is seen that while a biomass potential energy value is given, the detailed data used to obtain such a value is not given. Kaygusuz [4], determined that the total recoverable bioenergy potential of Turkey is about 16.92 Mtoe (196.779 TWh). This estimate is based on the recoverable energy potential of the main agricultural residues, livestock farming wastes, forestry and wood processing residues, and municipal wastes that are given in the literature. In the same study, the municipal solid waste potential is determined as 1300 ktoe (15.119 TWh), animal waste potential as 2350 ktoe (27.330 TWh) and dry and moist agricultural residue potential as 4810 ktoe (55.940 TWh). In the study, the value of the animal manure potential was determined by using some statistical data. For the other sources; while the potential values were given, the data used were not stated.

Ediger and Kentel [5], have determined the overall biomass energy potential of Turkey as 17.2 Mtoe (200.036 TWh). In the study, the biogas potential from the source of cattle, sheep and poultry manure was determined as 3.30 billion m^3/year, and the landfill gas (LFG) potential as 600 million m^3/year. In the study, the animal manure potential value was determined by using some definite data. There were no calculations related to the other potentials.

Demirbaş [6,7], has determined the annual biomass energy potential of Turkey for crops, residues from the agro and wood industry, animal wastes and other as 32 Mtoe (372.160 TWh). In the study [6], the energy potential of animal manure was determined as 1.3 Mtoe (15.119 TWh) and total recoverable bio-energy potential of Turkey as approximately 17 Mtoe [7].

Özgür [8], determined the energy value of the agricultural waste potential of Turkey as 653–839 PJ/year (181.388–233.055 TWh/year), the animal manure potential as 49 PJ/year (13.611 TWh/year) and municipal solid waste (MSW) potential as 315 PJ/year (87.5 TWh/year). In the study, while potential values were given, the data used were not stated. Erdem [9], gives the economical and feasible biomass potential of Turkey as 196.7 TWh/year. The source types and data covered by this value were not stated.

With the cooperation of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the T.R Ministry of Environment and Urbanization, the "Turkish-German Biogas Project" commenced in 2010. The target of the project is to determine the biogas potential of Turkey obtainable from cattle, poultry (broiler and laying chickens), organic waste and food industry waste, and the share of energy this might generate for the energy consumption of Turkey. It is planned that this project will be finalized following the Green Economy principle in 2014. Within the scope of this project, studies related to the determination of the biogas potential of Turkey according to different source types were made. Accordingly, the theoretical biogas potential of cattle in Turkey is 115.9 PJ/year (32.194 TWh/year) and the technical biomass potential is 47.3 PJ/year (13.138 TW-h/year). The theoretical biogas potential of poultry in Turkey is 36.6 PJ/year (10.166 TWh/year) and the technical biogas potential is 36.2 PJ/year (10.055 TWh/year). The energy value of the total technical biogas potential is 83.5 PJ/year (23.194 TWh/year). In the same study, the theoretical biogas potential of energy crops is given as 300 PJ/year (83.333 TW-h/year) and the technical biogas potential as 75 PJ/year (20.833 TWh/year). The theoretical biogas potential of MSW is 22 PJ/year (6.111 TWh/year) and the technical biogas potential is 11 PJ/year (3.055 TWh/year). The total theoretical potential from the sources of cattle and poultry manure, agricultural residues, energy crops, agro-industrial residues and MSW is 796.4 PJ/year (221.222 TWh/year), and the total technical potential is 220.4 PJ/year (61.222 TWh/year) [10].

Karayılmazlar, Saracoglu, Cabuk and Kurt [11], state the economical biomass energy potential of Turkey as 25 Mtoe/year (290.750 TWh/year). The animal manure source biogas potential is stated as 2.8–3.9 billion m^3 and 1.4–2 Mtoe (16.282–23.260 TWh/year). In the study, while the potential values are given, the data used are not stated.

Calculation of the biomass potential owned by Turkey according to different biomass source types, and of the energy value related to that potential according to the data used is critical.

2. The situation for renewable energy in Turkey

Energy from non-fossil sources, namely wind, solar, aero thermal, geothermal, hydrothermal and non-fossil sources like ocean, hydropower, biomass, LFG, wastewater treatment plant gas and biogas are defined as RES [12]. Turkey's renewable energy supporting mechanism is based on the "feed-in tariff" policy. This mechanism has been regulated under the scope of the "Law of renewable energy sources for the generation of electrical energy". According to this law, power plants that have been generating since May 18, 2005 or that are included in the scope of the law to be enforced before the end of 2015, may make use of the fixed price application for a period of 10 years. Plants that are supported under the scope of this law are: wind, solar, geothermal, biomass, gas obtained from biomass (including LFG), stream, tidal and wave, and hydroelectric generation plants of which the river type or reservoir area is under 15 square kilometers. In the case of the generation of mechanical and/or electro mechanic equipment that belongs to power plants with RES inside the country, an additional tariff is applied in addition to fixed prices. The feed-in tariff under the new legislation for Biomass including LFG is 13.3 Dolar-cent/kWh. This tariff could be 18.90 Dolar-cent/kWh at max if all equipments in the supporting mechanism are used [13].

Power plants with a Renewable Energy Certificate (REC) under this law, and persons who generate under the scope of unlicensed electric generation with REC, may make use of the RES Supporting Mechanism [14]. The installed power capacities belonging to plants supported by the RES supporting mechanism are given in Table 1 according to the source and plant type [15].

It can be seen in Table 1 that there is not sufficient capacity despite the RES supporting mechanism. In Turkey, there are no aero thermal, oceans, stream, tidal and wave energy systems connected to the grid. As of the end of November 2013, Turkey has 21874.3 MW hydroelectric, 310.8 MW geothermal, 224.0 MW biomass/waste, 2694.6 MW wind installed powers. The total installed power value of Turkey is 62663.9 MW [16]. The ratio of the installed power value of natural gas power plants within the total installed power is about 32%. The ratio of installed power capacity for hydroelectric power plants within the total installed power is about 35%. While the ratio of all renewable energy sources within the installed power is about 40%, the ratio of hydroelectric plants within the RES is about 87%.

Licensing priority and grid connection priority are given for RES; the license fee is reduced to 1% for a RES plant and the plant in its first eight years of operation is exempted from annual license fee [17]. In Turkey, there are no plants that generate electrical energy with the incineration method by using dried wastewater treatment