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Wastes and biomass materials as sustainable-renewable energy resources for Jordan

Zayed Al-Hamamre [a,*], Motasem Saidan [a,d,*], Muhanned Hararah [b], Khaled Rawajfeh [a], Hussam E. Alkhasawneh [c], Mohammad Al-Shannag [a]

[a] Chemical Engineering Department, School of Engineering, The University of Jordan, Amman 11942, Jordan
[b] Environmental Engineering Department, Faculty of Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan
[c] College of Engineering, Alhosun College, Al Balqa Applied University, Irbid, Jordan
[d] Water, Energy and Environment Center - The University of Jordan, Amman, 11942, Jordan

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ABSTRACT

An assessment of biomass resources potential in Jordan for power/heat generation and biogas production is presented in this paper. The investigation is based on five crucial requirements toward process sustainability and production cost. These requirements include biomass analysis and availability, conversion technologies, optimizing efficiency, reduction of environmental impact, and political decisions. All of these requirements collectively work in synergy toward commercial implementation of bioconversion technologies of biomass into energy. The information obtained in this study is expected to be useful for both decentralized and centralized wastes based energy planning by policymakers and industry developers, which can increase the biomass based renewable energy share to the energy mix. Direct biomass resources including agricultural residues, animal manure and municipal solid waste are considered in the analysis. Jordan produces more than 5.83 MT of wastes and residues annually, where 42% of which are estimated as available sources for energy generation and biogas production. The corresponding annual biogas and power potential is 313.14 MCM and 847.39 GWh, respectively. The produced biogas could replace almost 23.64% of Jordan primary energy consumed in the year 2012 in the form of natural gas (656 toe). Amongst all wastes and residues, municipal solid waste generated in the middle region of Jordan has the highest potential for biogas and power generation at 24.26%. This is followed by poultry manure with 18.58% and olive residues with 15.1%. The potential of the other wastes and residues is estimated at 42.06%.

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* Corresponding authors.
E-mail addresses: z.hamamre@ju.edu.jo (Z. Al-Hamamre), m.saidan@ju.edu.jo (M. Saidan).

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1. Introduction

The global energy demands have been continuously growing due to the increase in population and industrialization. Fossil fuel resources including crude oil and its derivatives, coal and natural gas, represent important world energy resources. The energy security and declining of fossil fuel resources promoted the advancement of sustainable and renewable technologies that utilize cheap, or zero cost biomass. Subsequently, this will easily replace the many uses of fossil oil. For example, producing liquid or gas biofuels helps to reduce fossil oil demand with potential benefits that tackle problems associated with greenhouse gases, energy security, sustainability and production cost.

Biomass is available abundantly on earth and considered to be the most common component for renewable energy production [1,2]. Biomass can be converted into various types of biofuels or energy utilizing a number of processes including thermal, physical, and biological processes [3,4].

Biofuels and energy are derived from a wide variety of biomass materials varying in source and quality. The five basic categories of materials including: virgin wood, energy crops, agricultural residues, food wastes, and industrial wastes and co-products [5–8]. The presence of biomass varies in terms of quantity and type on the basis of climatic, morphological, economic and social factors.

Agricultural residues and municipal solid wastes (MSW) can viably provide cost-effective sources of energy with low sulfur content [9,10]. Biomass materials represent a sustainable energy source that can be used as replacement for fossil fuel. This will not only reduce negative impact of the waste into on the environment [11,12], but also forms a solution to environmental problems and depleting energy supplies. Hence, sustainable utilization of these resources is of great importance from economic and environmental perspectives [13]. However, in comparison with the fossil fuel, biomass has nonhomogeneous form, lower grindability index, high moisture content, high oxygen to carbon ratio (O/C) ratio [14,15]. Consequently, biomass has lower calorific value in comparison with the fossil fuel (about 10–40% of that of most of fossil fuels) [14]. The moisture content for animal manure varies depending on production conditions and manure clean-out procedure. For example, poultry litter ranged in moisture content from 7–49% [16], while analyses of cow dung have reported a moisture content of 41.2% [17]. On the other hand, the reported moisture contents of MSW ranged between 55–65% [18], respectively. The heating values vary between 12.3 [19] to 16.9 MJ/kg-dry wastes [20] for animal manure, while for MSW the heating values estimated at 11.49 MJ/kg [21].

For a newly cut tree wood, the moisture content can be as high as 60% of the total mass, while for air dried wood the moisture content is normally around 12–20 wt%. Accordingly, the heating value can vary between 5 MJ/kg for fresh biomass to 20 MJ/kg for dry wood briquettes. This is equivalent to approximately 44% of heating value of coal, whose low heating value varies from about 22 MJ/kg for lignite [22] to 34.9 MJ/kg for low volatile bituminous coal [23]. On the other hand, the water content in fermentation residues and raw sludge can be as high as 90% and works as heat sink upon burning.

The aforementioned negative characteristics of biomass materials result in technical constrains that limit the use of biomass materials alone in energy utilization systems and present challenges to some conversion methods [24]. Likewise, the high investments costs for biomass feed systems, uncertainty in the security of the feedstock supply due to seasonal variations and limited infrastructure for biomass supply in some countries are other significant obstacles. All of these hurdles and obstacles should be taken into account while investigating the feasibility of biomass for energy utilization.

The objectives of this study are: (1) to assess the availability of biomass residues in Jordan for agro-energy purposes in particular to be used for heating, biogas production and electricity generation; (2) to encourage and motivate public and private sectors to participate in the management and development of biomass energy sector; (3) to find better and sustainable utilization of biomass, MSW and other organic wastes with minimum environmental impacts the ecosystem.

1.1. Assessment of biomass energy potential

Energy assessments of biomass resources can be considered as a development strategy for the improvement of the quality of life and the environment. The yearly obtainable biomass residues are varied depending upon several local conditions; among which climatic factors, farm production, the type and variety of livestock and crops planted and their yields [25]. One of the key barriers to biomass development is the lack of knowledge on the resource potential [26,27]. Accurate estimates of biomass sources are significantly needed to support the policy and decision making processes.

Several studies have estimated the potential of different agricultural and forest residues available for energy purposes in different regions and territories worldwide including the Party of General Pueyrredón in Argentina [28], China [29–32], Sri Lanka [33], India [34–37], Sudan [38], Egypt [39], Bangladesh [40,41], Ghana [42], Colombia [43] Czech Republic [44], Europe [45,46], Portugal [26,47] and Italy [48,49]. Depending on the case, the different types of biomass include agricultural residues, from agriculture harvesting or processing; municipal and industrial wastes and co-products, from manufacturing and industrial processes.

Malico et al., [46] evaluated the net positive effect of utilizing forest and agricultural residues to produce bio-heat for heating local public schools located in rural area of Portugal, Estremoz. Assessment of biomass availability, techno-economic feasibility and environmental aspects were included. The results show that about 273.14 thousand tone of residues can be produced annually in Estremoz. This corresponds to energy potential of about 267.680 TJ.

In Kumar et al., [34], biomass energy resource, potential energy conversion and policy for promotion implemented by government of India were discussed. The research reveals that India has large potential for biomass feed stock as surplus agricultural and forest