Assessment of Crop Residues Energy Potential and Efficient Usage in the South-western Zone of Afghanistan

Abdul Ghani Noori

Abstract—In the south-western zone of Afghanistan (Kandahar, Helmand, Urozgan and Zabol) about 807,890 tons of wheat, 945 tons of rice, 46,164 tons of barley and 105,276 tons of maize were produced in 2016-17. Based on the residues to product ratio (RPR) of the crops (1.8 for wheat straw, 1.5 for rice stalks, 0.2 for rice husk, 1.3 for barely straw and 2 for maize stsalks) about 1,454,202 tons of wheat straw, 1,418 tons of rice stalks, 189 tons of rice husk, 60,013 tons of barely straw and 210,552 tons of maize stalks were generated in the south-western zone of the country. By considering the lower heating values (LHV) of the crop residues (13.76 MJ/kg for wheat straw, 12.81 MJ/kg for rice stalks, 16.33 MJ/kg for rice husk, 13.97 MJ/kg for barely straw and 13.22 MJ/kg for maize stalks), it was resulted that 20,010 TJ energy can be generated from wheat straw, 18 TJ from rice stalks, 3 TJ from rice husk, 838 TJ from barely straw and 2,783 TJ from maize stalks. Cumulatively, around 23,653 TJ of energy can be generated from the selected crop residues in the south-western zone of Afghanistan in 2016-17. These crop residues are mainly used for cooking by using the very inefficient stone three cook stoves (η = 12.6%) and two support cook stoves (η = 13%). To use these crop residues more efficiently, it is advised to replace the mentioned inefficient cook stoves with improved Chulha and Anagi II cook stoves, which have an efficiency of 21% and 22% and can save off to 43% and 40% fuel wood, respectively compared to the traditionally used cook stoves.

Index Terms—Crop Residues, Energy Potential, Efficient Usage, South-Western Zone, Afghanistan.

I. INTRODUCTION

Due to war and instabilities in Afghanistan, access to electricity is very limited in the country. Until 2009, the households electricity access was 15% in urban and 6% in rural. Afghanistan has enough energy resources, but they are not properly tapped to fulfill the energy requirements of the country [1]. About 57% of the total primary energy supplied is from biomass. While petroleum has 32% share in total primary energy supply which is imported from the neighboring countries, such as Pakistan, Uzbekistan, Turkmenistan and Iran [2]. The solid biomass like, fuel wood, charcoal, animal dung, and crop residues are the major source of energy in Afghanistan. The residential sector is completely dependent on these biomass resources compared to petroleum for obtaining energy. Biomass is used almost in 90% of households for cooking and heating purposes and 65% of this biomass is fuelwood. For heating the spaces, a locale made heater which is called “Bukhari” is used [3].

As of now the utilization of biomass resources is very inefficient. Mostly, open burning and inefficient cook stoves are used in the households and as a result the degradation of resources and health problems are occurred. The energy potential of these biomass resources is unknown and their efficient usage is not suggested in the country. The efficiencies of presently used cook stoves are very less (about 12%) [4], and suitable efficient biomass energy technologies are not identified to overcome these problems. Therefore, it is needed to determine the energy potential of the available crop residues and identify suitable improved biomass energy technologies.

II. LITERATURE REVIEW

In Afghanistan, the crop cultivation is mainly concentrated in the irrigated lands along the rivers, while some crops are cultivated in the rain fed lands. In the agriculture GDP, 50% share goes to the livestock products [5]. The country has both high elevation and low elevation lands.

The high elevation (above 2,000 meters) lands are cultivated once a year, because of short growing season, while the lands at lower elevation give two crops a year. The main crop is wheat, contributing about 80% of the total crop consumption in Afghanistan. Both irrigated and rain fed lands are cultivated for the crops production, but the yield of irrigated land (2.95 t/ha) to the rain fed land (1.18 t/ha) is almost three times higher. Winter wheat is the primary crop and the spring wheat is the secondary crop. In addition to wheat, rice, barley and maize are also cultivated. Generally, barley is cultivated for grain in the rain fed higher altitude lands and for the green fodder at lower altitude lands. As the crop production depends on water, which originates from snow melting and rainfall, therefore the crop harvesting dramatically varies year to year [6]. During 2003, 2005 and 2007, the yield of crop production was good, because of advantageous weather. While, a low crop yield was recorded during 2000-2002 and 2004, because of drought. Other crops like pulses and fodder are also grown. The pulses include chickpea and lentil. The fodder like clover and alfalfa are grown for animal feeding. Beside these, vegetables and fruits like potatoes, onions, tomatoes, okra, cauliflower, melons, watermelons, apricots, peaches, pomegranates, apples, sugar beet and sugar cane are also included in Afghan cultivation. Almond, walnut and pistachio are also produce in these areas.

In the northern and eastern provinces (Baghlan, Kunduz and Nangarhar), oilseed crops mainly, cotton, mustard, sesame seeds and flax are grown. In 2008–9, about 6.5 Mt of crop residues were produced...
in Afghanistan. Based on the energy content of these crop residues (10-17 GJ/t), 68 PJ to 115 PJ energy could be produced. The country is also rich of pruning. The biomass production from this source was estimated to be about 285,000 tons per year, which equals to 5.7 PJ/year, energy. In addition, the processing residues of almond and walnut shells can be used for charcoal production by the pyrolysis process or can be used for cooking. Around 1,338 TJ, energy can be produced from these processing residues. In 2012-13, the total primary energy consumption of Afghanistan was 140,966 TJ [7].

In Afghanistan, 80% of the crop residues are utilized for the household consumption and others are supplied to the local market, where in the other countries the crops are produced commercially and generate large amount of residues. The lack of a large scale crop residues production and high transport costs are caused to restrain the use of these residues for electricity generation in a centralized system [1]. Beside cultivation, the people keep some kind of animal like cattle, oxen, horses, donkeys, camels, goats, sheep, and poultry not only for meat, dairy products, and eggs, but also for providing the cooking fuel and fertilizer [8].

The central province of the south-western zone, Kandahar has almost 157,400 ha cultivatable land, about 118,000 ha (75%) is irrigated land. The main sources for irrigation are canals, kareze, springs and wells. About 81.5% of the irrigated land was irrigated by canals. In 1983-84, about 78,000 ha land was grown by wheat with a yield of 1.82 ton per hectare. The common crops are wheat, barley and maize, produced throughout the province. The wheat was cultivated mainly in the irrigated land, while some amount was cultivated in the rain fed land. Fodder crops like, alfalfa, clover and some industrial crops like, sunflower, cotton, sesame, olives, cumin and groundnuts were also grown. In addition to it, different types of vegetables like okra, tomatoes, onions, eggplant and cucumber are also cultivated throughout the province [9]. Beside these activities, the people keep cattle, sheep, goats, donkeys and camels in their forms [10].

The cultivatable land ownership in this province was around 4.2 hectare per owner and the total land ownership was 13.66 ha per owner, where 65% of this land was not cultivated. Nearly 30.8% of the total cultivable land of the province was cultivated and 8.5% was counted as unplanted. 83.1% of the cultivated land was the grain crops, 9.6% fruits, 3.1% vegetables, 1.7% industrial crops and 2.5% some other crops [9].

III. METHODOLOGY

A. Determining crop residues energy potential

The energy potential of crop residues (EPresidue) is estimated based on the annual harvesting (AH), residue to product ratio (RPR), annual residue generation (ARG), surplus availability factor (SAF), its energy use factor (EUF) and lower heating value (LHVresidue) [11].

\[
EP_{\text{residue}} = \text{ARG} \times \text{LHV}_{\text{residue}} \quad (1)
\]

Where,

\[
\text{ARG} = \Sigma (\text{AH} \times \text{RPR}) \quad (2)
\]

In the above equations,

\[
\begin{align*}
\text{EP} & = \text{Annual energy potential (TJ/y)} \\
\text{ARG} & = \text{Annual residue generation (t/y)} \\
\text{LHV} & = \text{Lower heating value (TJ/t)} \\
\text{AH} & = \text{Annual harvesting (t/y)} \\
\text{RPR} & = \text{Residue to product ratio}
\end{align*}
\]

B. Determining cook stove efficiency

The efficiency of the cook stove is defined as the ratio of energy utilized in the water boiling to the energy content of the fuel used for water boiling. Efficiency is determined from the quantity of fuel used and the quantity of water evaporated after complete burning of the fuel. This test is called the standard water boiling test (WBT).

The following equation is used to calculate the efficiency of the stove (The equation is based on the lab manual).

\[
\eta = \frac{m_{\text{w, evap}}(T_{\text{e}} - T_{\text{i}}) + m_{\text{w, pw}} H_{\text{i}}}{m_{\text{f}} H_{\text{f}}} \quad (3)
\]

Where, 

\[
\begin{align*}
m_{\text{w,1}} & = \text{Initially mass of water in the cooking vessel (kg)} \\
C_{\text{pw}} & = \text{Specific heat of water (4.189 kJ/kg C°)} \\
m_{\text{w, evap}} & = \text{Mass of evaporated water (kg)} \\
m_{\text{f}} & = \text{Mass of fuel burned (kg)} \\
T_{\text{e}} & = \text{Temperature of boiling water (C°)} \\
T_{\text{i}} & = \text{Initial temperature of water in the pot (C°)} \\
H_{\text{i}} & = \text{Latent heat of evaporation at 100 C°, and 1 bar (2,270 kJ/kg)} \\
H_{\text{f}} & = \text{Calorific value of fuel (kJ/kg)}
\end{align*}
\]

IV. CROP RESIDUE ENERGY POTENTIAL

This section presents the crop production, crop residue generation and crop residue energy potential in the south-western zone of Afghanistan.

A. Annual crop production

The annual crop production or annual harvesting in the south-western zone of Afghanistan is the very essential and key data for determining crop residues and then the energy potential of crop residues (as shown in the methodology). This data was taken from the Central Statistics Organization (CSO) of Afghanistan for the year 2016-17.

Table I shows that wheat is the dominant crop among barely, maize and rice. It has the highest production in each province, but the most wheat productive province is Helmand. Around 487,500 tons of wheat was cultivated in the mentioned province in 2016-17. It is shown in the Table I that cumulatively, maize is the second and barely is the third highly cultivated crop in this zone. The cultivation of rice is very rare in the region. It is only cultivated in the Urozgan province in a very little amount.
B. Annual crop residues generation

The crop residues generation is estimated based on the annual crop production and residue to product ratios (1.8 for wheat straw, 0.2 for rice husk, 1.3 for barely straw and 2 for maize stalks) of the selected crop residues.

Among all crop residues shown in Table II, wheat straw is the highly generated residues followed by maize stalks and barely straw. Rice stalks and husk have very little share among all generated crop residues because, rice production is done only in the Urozgan province of the south western zone. Mostly, barely straw, maize stalks and part of wheat straw are used as the cooking and heating fuel while most of the wheat straw is used for feeding the animals. In the recent years, a part of the generated wheat straw is also used for making boards. This activity has caused to bring up the price of wheat straw in the market.

C. HHV and LHV of crop residues

The heating value of biomass is recognized in two terms, one is the higher heating value (HHV) of biomass and the other is lower heating value (LHV) of biomass.

For the south western zone crop residues, Noori (2015) has found the higher heating value and lower heating value by testing the collected samples from the mentioned zone [4]. It was shown that the higher heating value (HHV) is 15.08 MJ per kg for wheat straw, 13.90 MJ per kg for rice straw, 15.36 MJ per kg for barley straw and 14.57 MJ per kg for maize stalks. The lower heating value for the crop residue was determined from the higher heating value (HHV) and the weight percentage of hydrogen (H) in the sample. The calculation result of the lower heating value (LHV) was 13.76 MJ per kg for wheat straw, 12.81 MJ per kg for rice straw, 13.97 MJ per kg for the barley straw and 13.22 MJ per kg for maize stalks, summarized in the Table III.

In this study, the lower heating values (LHVs) are used for the energy estimation of biomass, which are also called net calorific values of biomass.

D. Annual crop residues energy potential

The energy potential of crop residues is estimated based on the annual crop residue generation and lower heating value of crop residues.

Though rice husk has very high lower heating value, their energy potential is very little (3 TJ) among wheat straw, barely straw, maize stalks and rice stalks. Again it is shown that the most share of energy potential goes to wheat straw. It is around 20,010 TJ. In the second stage, maize stalks come. It has about 2,783 TJ and most of the maize stalks are generated in the Helmand province. Barely straw energy potential takes third place and its energy potential is 833 TJ. Rice stalks have only 18 TJ energy potential per year (2016-17). As a total, around 23,652 TJ energy can be generated from wheat straw, barely straw, maize stalks, rice stalks and rice husk.

V. Efficient usage of crop residues

Currently, almost all households use three stone and two support cook stoves (shown in Fig. 1 and 2) for their daily cooking requirements. Both these stoves were examined for their cooking efficiency during this research. It was shown that the three stone cook stove efficiency is 12.6% and the two support cook stove efficiency is 13%. It is clear that both of the cook stove have very low efficiencies and as a result have high crop residues consumption. To reduce the crop residues consumption in the daily used cook stove in the south-western zone of Afghanistan, three stone and two support cook stoves can be replaced by more energy efficient cook stoves such as Anagi II (shown in Fig. 3) and improved Chulha (shown in Fig. 4) with 21% and 22% efficiencies, respectively.
The fuel saving potential of the improved cook stoves (Anagi II and Improved Chulha) is based on the efficiencies of the currently used three stone cook stove, Anagi II cook stove and improved chulha. The currently used three stone cook stove efficiency and fuelwood consumption are kept as reference for estimating the fuelwood saving potential of the improved cook stoves. Kandahar province is home for about 158,892 households and the average fuel wood consumption for cooking with three stone cook stove is around 1,100 kg per household per year [2]. Based on these, around 174,781 ton of fuel wood is used by three stone cook stove annually. By involving the cooking efficiencies in preforming the same amount of work, Anagi II and improved chulha will consume 104,869 ton per year and 100,102 ton per year, respectively. The annual fuel wood saving potential of these improved cook stoves will be around 40% and 43%, respectively. This is nearly half of the annual fuelwood consumption by three stone cook stove for cooking.

Table V shows the fuel wood saving potential of the identified improved cook stoves compared to the currently used three stone cook stove in south western zone of Afghanistan.

<table>
<thead>
<tr>
<th>Cook stove type</th>
<th>Fuelwood Consumption (ton/year)</th>
<th>Cooking Efficiency (%)</th>
<th>Fuel wood saving potential (ton/year)</th>
<th>Fuel wood saving potential (%)</th>
<th>Energy Saving potential (ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three stone</td>
<td>174,781</td>
<td>12.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anagi II</td>
<td>104,869</td>
<td>21</td>
<td>69,912</td>
<td>40</td>
<td>866</td>
</tr>
<tr>
<td>Improved chulha</td>
<td>100,102</td>
<td>22</td>
<td>74,679</td>
<td>43</td>
<td>925</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

By completion of this research, the two main objectives were achieved. The first objective was to determine the crop residues energy potential in the south western zone of Afghanistan and the second objective was to suggest the efficient usage of crop residues in the mentioned zone.

The main cultivated crops in the southwestern zone of Afghanistan (Kandahar, Helmand, Urozgan and Zabul are wheat, barley and maize. Rice is also cultivated by a very little amount in the Urozgan province of the zone. In the mentioned zone of the country, about 807,890 tons of wheat, 945 tons of rice, 46,164 tons of barley and 105,276 tons of maize were produced in 2016-17. Based on the residues to product ratio (RPR) of the crops (1.8 for wheat straw, 1.5 rice stalks, 0.2 for rice husk, 1.3 for barely straw and 2 for maize stalks) about 1,454,202 tons of wheat straw, 1,418 tons of rice stalks, 189 tons of rice husk, 60,013 tons of barely straw and 210,552 tons of maize stalks were generated in the south western zone of the country in 2016-17. By considering the lower heating values (LHV) of the crop residues (13.76 MJ/kg for wheat straw, 12.81 MJ/kg for rice stalks, 16.33 MJ/kg for rice husk, 13.97 MJ/kg for barely straw and 13.22 MJ/kg for maize stalks), it was resulted that 20,010 TJ energy can be generated from wheat straw, 18 TJ from rice stalks, 3 TJ from rice husk, 838 TJ from barely straw and 2,783 TJ from maize stalks. Cumulatively, around 23,653 TJ of energy can be generated from wheat straw, rice stalks, rice husk, barely straw and maize stalks in the south western zone of Afghanistan in 2016-17.

In the second objective, it was found that three stone cook stoves and two support cook stoves are the main stoves used in the south western zone of Afghanistan. Their efficiencies were tested in the field. The efficiency is 12.6% for three stone cook stove and 13% for two support cook stove which are very less compared to the improved cook stoves efficiencies (21% for Anagi II and 22% for improved chulha). It was suggested that improved chulha can be a very appropriate candidate for replacing the three stone cook stove currently used in the zone. It was shown that 43% energy can be saved by using improved chulha and 40% energy can be saved by Anagi II, if used instead of three stone cook stove. Due to people culture and cook stove construction analogies, it was suggested that improved chulha is the best suitable cook stove for burning crop residues in the south western zone of Afghanistan.

REFERENCES

Abdul Ghani Noori a citizen of Kandahar, Afghanistan was born on 01-April-1989 in Kandahar. He obtained his bachelor of engineering degree in civil engineering from Kandahar University, Afghanistan in 2013 and his master of engineering degree in energy technology from Asian Institute of Technology (AIT), Thailand in 2015.

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Mr. Noori is a member of technical, research and curriculum committees of Kandahar University. Besides that, he also has membership in the Afghanistan Renewable Energy Union (AREU). He has been awarded several prizes for being as a best teacher, best leader and best researcher from Kandahar University and other organization.

https://www.engineeringforchange.org/static/content/Energy/S00030/how_to_make_sri_lankas_anagi_stove.pdf