IWEC 2024

4. International World Energy Conference

FULL TEXT BOOK

EDITORS
Mustafa Serdar GENÇ
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Şükrü Taner AZGIN
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December 06-08, 2024 / Kayseri, Türkiye

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İlgili makama;

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08.12.2024 / Hall-2 / Online Session-3 / TSI Time - 15^{00}:17^{00}

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HEAD OF SESSION: Prof. Dr. Cengiz KARACA

Authors	Affiliation	Presentation title
Cemre YILMAZ **Prof. Dr. Dilek ERDİRENÇELEBİ**	Konya Technical University, Türkiye	A Physical Separation Methodology and its Effects on the Waste Animal Fat Content Prior to Biodiesel Production Process
Cemre YILMAZ **Prof. Dr. Dilek ERDİRENÇELEBİ**	Konya Technical University, Türkiye	The Effect of Reaction Time on Biodiesel Quality from Waste Animal Fat Using Ethanol
Assoc. Prof. Dr. Sedat BOYACI **Prof. Dr. Atılgan ATILGAN**	Kırşehir Ahi Evran University, Türkiye Alanya Alaaddin Keykubat University, Türkiye	Determination of Energy Potential of Plant Residues from Greenhouse Courgette Cultivation
Assoc. Prof. Dr. Sedat BOYACI **Prof. Dr. Atılgan ATILGAN**	Kırşehir Ahi Evran University, Türkiye Alanya Alaaddin Keykubat University, Türkiye	Investigation of the Effect of Energy Saving Measures on Heat Energy Requirement in Greenhouses
Mehmet Can ÖZTÜRK	Osmaniye Korkut Ata University, Türkiye	Effects of Wooden Structures on Energy Performance and Carbon Emissions
Yasir Tümay DOST **Assist. Prof. Dr. Cemil KOYUNOĞLU**	Yalova University, Türkiye	Biomass-Based Energy Production Plant Feasibility Study
Prof. Dr. Cengiz KARACA	Hatay Mustafa Kemal University, Türkiye	Energy Production Potential from Agricultural Residues in Kayseri Province
Prof. Dr. Cengiz KARACA	Hatay Mustafa Kemal University, Türkiye	The Potential of Biogas Production from Livestock Manure and Effects on Greenhouse Gas Reduction in Kayseri Province

ENERGY PRODUCTION POTENTIAL FROM AGRICULTURAL RESIDUES IN KAYSERİ PROVINCE

Cengiz KARACA

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Abstract

The aim of this study is to determine the amount of agricultural residues in Kayseri province and the amount of energy that can be produced from these residues. Kayseri province is a province in the Central Anatolia Region of Turkey with a total of 16 districts, of which five are central districts. The amount of residues obtained from some agricultural products commonly grown in Kayseri province was calculated using production data and tree presence data for the year 2023. The annual potential of agricultural residues was calculated using the residue rate and the amount of crops or number of trees. The energy potential of residues for each district was calculated by multiplying the calorific value of agricultural residues by the amount of usable residues. The total amount of agricultural residues based on the products commonly cultivated in the province was determined as approximately 297.52 kt per year. The total calorific value of these agricultural residues was calculated as 5,074.24 TJ. When the districts are ranked according to the amount of agricultural residues, the first three districts are Kocasinan (47.99 kt), Pınarbaşı (47.58 kt) and Yeşilhisar (43.61 kt). According to the total heating values, the main crop residues were wheat straw (32.4%), barley straw (22.9%), sunflower stalks (16.9%) and vineyard pruning waste (7.2%).

Keywords: Biomass Energy, Agricultural Residues, Kayseri

KAYSERİ İLİNDE TARIMSAL ARTIKLARDAN ENERJİ ÜRETİM POTANSİYELİ

Özet

Bu çalışmanın amacı Kayseri ilinde tarımsal artıkların miktarını ve bu atıklardan üretilebilecek enerji miktarının belirlemektir. Kayseri ili, Türkiye'nin İç Anadolu Bölgesi'nde beş adet merkez ilçe olmak üzere toplam 16 ilçesi bulunan bir ilidir. Kayseri ilinde yoğun olarak yetiştirilen bazı tarım ürünlerinden elde edilen artık miktarları, 2023 yıllarına ait üretim verileri ve ağaç varlığı verileri kullanılarak hesaplanmıştır. Tarımsal artıkların yıllık potansiyeli, artık ürün oranı ve ürün miktarı veya ağaç sayıları kullanılarak hesaplanmıştır. Her ilçe için artıkların enerji potansiyeli, tarımsal artıkların ısıl değerlerinin kullanılabilir artık miktarı ile çarpılmasıyla hesaplanmıştır. İlde yoğun olarak yetiştiriciliği yapılan ürünlerin baz alındığı toplam tarımsal artık miktarı yıllık yaklaşık 297.52 kt olarak belirlenmiştir. Bu tarımsal artıkların toplam ısıl değeri 5,074.24 TJ olarak hesaplanmıştır. İlçeler tarımsal artık miktarına göre sıralandığında, ilk üç ilçe Kocasinan (47.99 kt), Pınarbaşı (47.58 kt) ve Yeşilhisar (43.61 kt) olarak belirlenmiştir. Toplam ısıl değerlere göre başlıca ürün artıkları buğday samanı (% 32.4), arpa samanı (% 22.9), ayçiçeği sapı (% 16.9) ve bağ budama atıkları (% 7.2) şeklinde sıralanmıştır.

Anahtar Kelimeler: Biyokütle Enerjisi, Tarımsal Artıklar, Kayseri

INTRODUCTION

Energy is central to economic development, and there is a clear correlation between energy consumption and living standards. Energy sources are split into three categories: fossil fuels, renewable sources and nuclear sources (Karaca, 2015). Fossil fuels are limited resources, collected in few regional areas of the world.

Turkey is an agricultural country, with special emphasis on the Central Anatolia, Çukurova and Southern Anatolia regions, and has significant forestry potential. Agricultural waste is a major source of biomass due to its high potential (Karaca and Başçetinçelik, 2014). Biomass energy includes agricultural residues, domestic

waste, fuelwood, animal waste and other fuel derived from biological sources (Başçetinçelik et. al. 2006). Agricultural residues are defined as a biomass by-product from the agricultural system and include straws, husks, shells, and stalks. These residues can be divided into two groups: crop residues, which remain in the field after harvest including cotton stalk, and agricultural residues, which are the by-products of the industrial processing of crops such as rice husk (Karaca, 2015).

This study aimed to determine the biomass potential and the energy value, being produced from agricultural residues in Kayseri province. The major benefits are environmental and relate to the reduction of GHG emissions, conservation of natural resources, and avoidance of fossil fuel consumption. They are complemented by economic benefits (reduction of imported fuel consumption), regional development and investment increase.

MATERIALS AND METHODS

Kayseri is a province of Turkey on the Central Anatolia Region. Kayseri province is divided into 16 districts, five of which are included in the municipality of central district. The districts of Kayseri province are Hacılar, İncesu, Kocasinan, Melikgazi, Talas, Akkışla, Bünyan, Develi, Felahiye, Özvatan, Pınarbaşı, Sarıoğlan, Sarız, Tomarza, Yahyalı and Yeşilhisar.

Grains crops have the most important place regarding production area and amount of product in the production of agricultural products of Kayseri. The province has 602,495 hectares of agricultural land. Field crops constitute 75% of the agricultural land, while fallow areas constitute 15.8 % and the remaining part consists of vegetable and orchards. Wheat, barley, sunflower, rye, chickpea, apple, apricot and vineyard are the prominent products in the province. (TURKSTAT, 2024a)

The amounts of residues from the crops cultivated in Kayseri province were calculated using production data of crops with Turkish Statistical Institute for the 2023 seasonal years (TURKSTAT, 2024b). The annual gross potential of agricultural residues was determined by using residue to product ratio (RPR) (Table1).

The net potential of residues was determined by using the availability of residues. The availability of residues is unused and completely wastes part of residues (Table1). The available potential of the agricultural residues in each district of Kayseri was calculated using the Eq.1. (Karaca, 2015)

$$(AAR)_I = (AAP)_I \, x \, (RPR)_I \, x \, (A)_I \qquad (1)$$

where $(AAR)_I$ is the available amount of agricultural residues of Ith crop in ton, $(AAP)_I$ the amount of agricultural product in tons or number of tree for pruning wastes, $(RPR)_I$ residue-to product ratio of the Ith crop and $(A)_I$ the availability of residues.

The residues are materials left over the field after agricultural production. Some agricultural residues have already been used for domestic purposes, heating, animal fodder, bedding. Mainly residues from the production of industrial, agricultural products are left over the field. The species are maize stalk, sunflower stalk, cereal straw, pruning, etc.

The energy potential of residues for each district was calculated by multiplication of the heating values of a selection of agricultural residues which was taken heating value per each residue (Table 1) with the available residue amount (Eq. 2). (Karaca, 2015)

$$(THV)_i = (AAR)_i \, x \, (LHV)_i \qquad (2)$$

where $(THV)_i$ the total heating value of agricultural residues of ith crop in GJ, $(AAR)_i$ is the available amount of agricultural residues of ith crop in tons and $(LHV)_i$ lower heating value of air-dry residues of ith crop in MJ kg^{-1}.

The energy content of the selected products for each district was calculated using the above equations. For each district, the calculated values that the total amount and the total energy potential of agricultural crop residues were mapped using the GIS software. The produced maps were provided to see more clearly in the differences of data among the districts. The mapping can provide the rise of public awareness and policy-makers reference about these subjects.

Table 1. The ratio of product to residue, availability and heating values of a selection of agricultural crop residues (Başçetinçelik et. al., 2006; Bilandzija et. al., 2012; Karaca, 2015)

Field Crops	Residues	Ratio of Product to Residue (*RPR*)	Availability (*A*) (%)	Heating Value (*LHV*) (MJ kg^{-1})
Wheat	Straw	1.06	15	17.9
Barley	Straw	1.14	15	17.5
Rye	Straw	1.20	15	17.5
Oats	Straw	1.18	15	17.4
Triticale	Straw	1.20	15	17.2
Chickpea	Straw	1.10	60	18.1
Maize	Stalk	1.30	60	18.5
	Cob	0.30	60	18.4
Sunflower	Stalk	2.00	60	14.2
Fruits Crops				
Apple	Pruning	2.50*	80	17.0
Pear	Pruning	2.50*	80	16.7
Apricots	Pruning	5.80*	80	19.3
Sweet cherry	Pruning	5.90*	80	16.7
Sour cherry	Pruning	5.00*	80	18.0
Plum	Pruning	7.00*	80	17.3
Walnuts	Pruning	3.50*	50	19.0
Almonds	Pruning	5.80*	80	18.4
Peach	Pruning	7.00*	80	19.4
Vineyard	Pruning	4,250**	80	18.0

* RPR kg/tree

** RPR kg/ha

FINDINGS AND DISCUSSION

The total amount of agricultural residues, including field crop residues (grains, sunflower, chickpea) and orchard residues (tree pruning) were calculated to be about 297.52 thousand tons in Kayseri (Table 2). Its distribution by the source is field crops (88.21%) and fruit crops (11.79%). Major crops that included in the ratio of the total residue amount are wheat (30.8%), barley (22.3%), sunflower (20.3%), vineyard pruning (6.8), maize (5.2%) and chickpea (5.0%).

Table2. The amount of agricultural product and available residues of Kayseri

Field Crops	Amount of Agricultural Product (*AAP*) (tons)	Residues	Available Residues (*AAR*) (tons)
Wheat	577,070	Straw	91,754
Barley	388,561	Straw	66,444
Rye	45,755	Straw	8,236
Oats	17,521	Straw	3,101
Triticale	13,047	Straw	2,348
Chickpea	22,392	Straw	14,779
Maize	15,965	Stalk	12,453
		Cob	2,874
Sunflower	50,370	Stalk	60,444
Fruits Crops	**Number of trees / Planting area**		
Apple	5,901,446*	Pruning	11,803
Pear	67,267*	Pruning	135
Apricots	343,272*	Pruning	1,593
Sweet cherry	75,575*	Pruning	357
Sour cherry	18,200*	Pruning	73
Plum	35,388*	Pruning	198
Walnuts	80,976*	Pruning	142
Almonds	92,186*	Pruning	428
Peach	20,639*	Pruning	116
Vineyard	5,954**	Pruning	20,244
TOTAL		**Residues**	**297,520**

* Number of trees

** Planting Area (ha)

When all districts of Kayseri are aligned according to the amounts of residue, an alignment is as in Table 3. Also, the distribution of these calculated residue amounts on the map and the pie charts showing the shares of the crops that constitute the residue in each district are given in Figure 1.

Table 3. The alignment of districts according to amount of agricultural residues

Districts	Field Crops Residues (tons)	Fruit Crops Residues (tons)	Total Residues (tons)	Share in Total Residues (%)
Hacılar (Merkez)	465	1,159	1,624	0.55
İncesu (Merkez)	7,771	11,463	19,234	6.46
Kocasinan (Merkez)	46,303	1,682	47,985	16.13
Melikgazi (Merkez)	7,779	1,176	8,955	3.01
Talas (Merkez)	4,812	2,374	7,186	2.42
Akkışla	2,352	62	2,414	0.81
Bünyan	25,569	345	25,914	8.71
Develi	17,208	1,203	18,412	6.19
Felahiye	8,954	1,211	10,165	3.42
Özvatan	3,238	716	3,954	1.33
Pınarbaşı	47,469	113	47,582	15.99
Sarıoğlan	15,857	195	16,051	5.40
Sarız	3,096	23	3,119	1.05
Tomarza	25,288	13	25,301	8.50
Yahyalı	9,570	6,443	16,013	5.38
Yeşilhisar	36,703	6,908	43,611	14.66
TOTAL	**262,433**	**35,087**	**297,520**	**100.00**

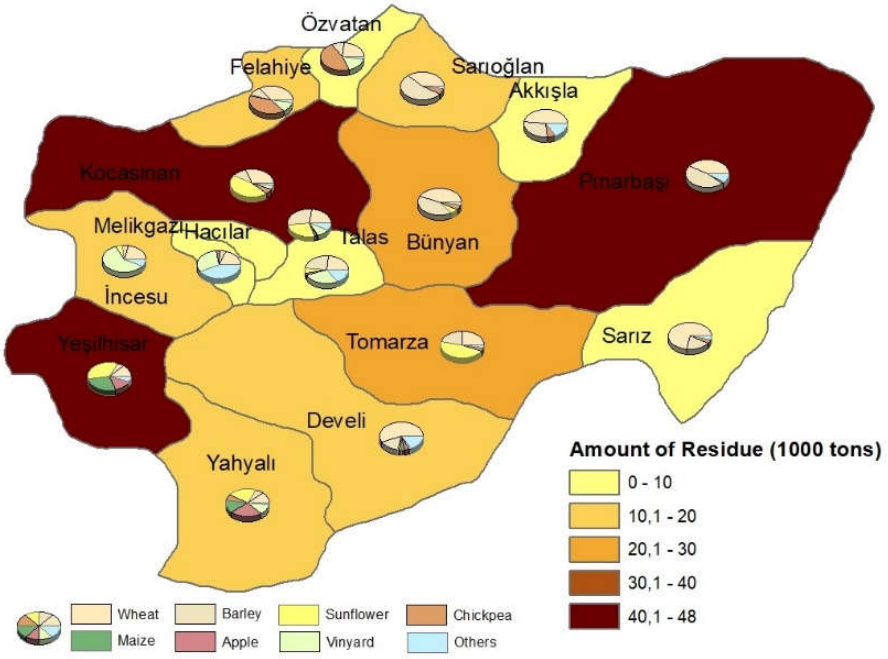


Figure 1. The distribution map of agricultural residues in Kayseri

According to the results, Kocasinan (47.99 kt) is the district with the highest agricultural residue potential in Kayseri province. Apart from this, it has been determined that there is a significant amount of agricultural residue potential in Pınarbaşı (47.58 kt) and Yeşilhisar (43.61 kt) districts. In these three districts, it is seen that there will not be a shortage of raw materials for investments and facilities to be constructed for obtaining energy from agricultural residues.

The potential of biomass from agricultural residues was determined in Samsun province. The total biomass potential was determined as 366.6 kt in the province. (Karaca et. al., 2017).

A study carried out by Karaca and Öztürk (2017) in Osmaniye province indicated that the total biomass potential from agricultural residues was 491 kt.

Karaca (2022) reported the amount of biomass from agricultural residues was about 124.54 kt, equivalent to about 2,182 TJ of heating value in Sivas.

Similarly, in another study conducted by Karaca (2023), the total agricultural residue potential of Gaziantep province was determined as 373.42 kt.

It was calculated that the total heating value of the agricultural residues was about 5,074.24 TJ (121.2 ktoe) for agro-production period of 2023in Kayseri. The heating value of agricultural residues that calculated separately for each product is given in Table 4. The distribution map was given Figure 2.

Table 4. Total heating value of agricultural residues of Kayseri

Field Crops	Residues	Total Heating Value (THV) (GJ)
Wheat	Straw	1,642,399
Barley	Straw	1,162,769
Rye	Straw	144,128
Oats	Straw	53,961
Triticale	Straw	40,394
Chickpea	Straw	267,495
Maize	Stalk	230,375
	Cob	52,876
Sunflower	Stalk	858,305
Fruits Crops		
Apple	Pruning	200,649
Pear	Pruning	2,247
Apricots	Pruning	30,741
Sweet cherry	Pruning	5,957
Sour cherry	Pruning	1,310
Plum	Pruning	3,428
Walnuts	Pruning	2,692
Almonds	Pruning	7,870
Peach	Pruning	2,242
Vineyard	Pruning	364,397
TOTAL		**5,074,236**

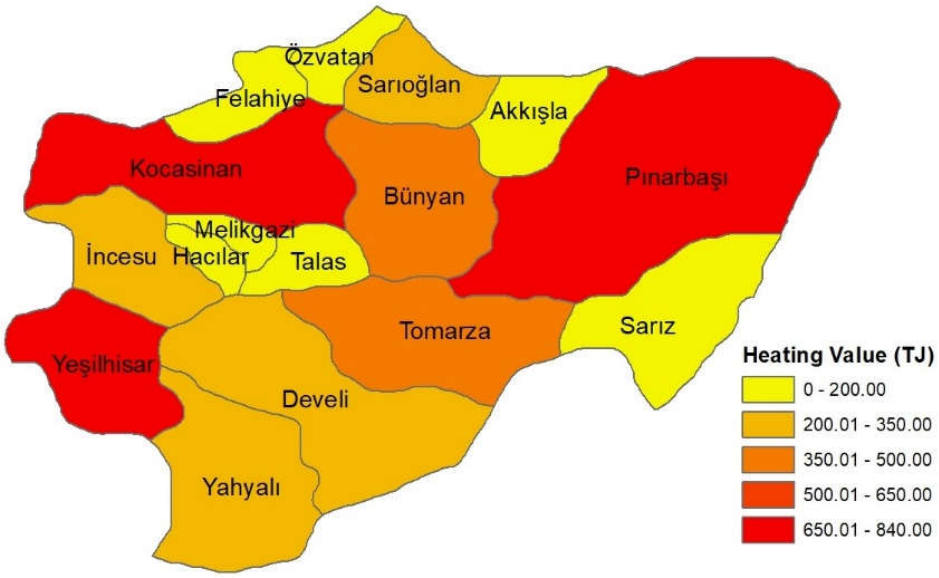


Figure 2. The distribution map of heating value based on agricultural residues in Kayseri

These maps (Figure1 and 2) showed that the potential of agricultural residues concentrated in Kocasinan, Pınarbaşı and Yeşilhisar districts. Especially, it is observed that the type and distribution of residues in Kocasinan district, the distribution of agricultural residues according to heating value is ranked as sunflower (320 TJ) and wheat (263.52 TJ) respectively. In Pınarbaşı district, this ranking consists of barley (380.91 TJ) and wheat (363.60 TJ) respectively. However different crop residues are remarkable in a certain district. Heating values of vineyard residues are 201.35 TJ in İncesu, and 30.6 TJ in Yahyalı. Furthermore, sunflower stalks constitute an important potential (217.77 TJ) in Yeşilhisar and (167.5 TJ) Tomarza. Moreover, chickpea residues also create a significant energy potential in Felahiye district (77.34 TJ) and Özvatan district (32.89 TJ). Finally, it was observed that maize residues (203.86 TJ) constitute a remarkable energy potential in Yesilhisar district.

CONCLUSION AND RECOMMENDATIONS

The aim of this study is to show the potential of agricultural residues in the districts of Kayseri and its distribution by mapping them. The importance of this study is increasing because Turkey is an energy importing country.

The total amount of agricultural residues was approximately 297.52 kt. It was found that the total heating value of the agricultural residues was around 5,074.24 TJ for the agricultural production period of 2023. It was determined that this potential concentrate in the Kocasinan, Pınarbaşı and Yeşilhisar districts. It was seen that the majority of agricultural residues originate from field crops. According to the amount of residues of agricultural products, it is listed as, wheat straw (30.8%), barley straw (22.3%), sunflower stalk (20.3%), vineyard pruning (6.8), maize (5.2%) and chickpea (5.0%).

Although Kayseri province has a medium level biomass energy potential, this potential is not adequately utilized. However, the results of this study show that such a significant potential should be utilized by establishing modern facilities.

In conclusion, agricultural residues are an attractive choice for Kayseri as an economical, sustainable and environmentally friendly energy source.

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