Energy Exploitation of Agricultural Biomass Potential in Turkey

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ABSTRACT

The objective of this study is to determine the agricultural biomass potential in terms of types, quantities, regional distribution in Turkey and to review and assess efficient technologies for energy exploitation of agricultural biomass potential in Turkey. The calorific values of a selection of agricultural residues were determined by stoichiometric analyses. It was found that the total calorific value of the field crop residues was around 228 PJ for the production period of 2002–2003 in Turkey. The major crops that take place in the ratio of the total calorific value are maize (33.4%), wheat (27.6%), and cotton (18.1%). The total calorific value of the fruit residue was 75 PJ. The major fruits are hazelnut (55.8%) and olive (25.9%) for the agricultural biomass. The total calorific values for cow, sheep and poultry wastes in Turkey were found to be approximately 47.8, 3.6 and 8.7 PJ/year, respectively. Thus, the total agricultural biomass potential was found to be approximately 363.1 PJ/year for the production period of 2002–2003 in Turkey. The available agricultural and animal residues in Turkey have been estimated to be roughly equal to 22–27 % of energy consumption in Turkey. However, the actual role of bio-fuels in energy production is minimal. The most efficient way to utilize bio-fuels in energy production is combined heat and power (CHP) production. The most potential applications to utilize agro-bio-fuels in energy production in Turkey seem to be relatively small-scale applications. The most interesting size of the plant is below 10–20 MW.

Keywords: biomass, renewable energy, agricultural residue, combustion technology, gasification, biogas

I. INTRODUCTION

Turkey is an energy importing country. More than about 60% of energy consumption in the country is met by imports and the share of imports continues to grow each year. Therefore, it is critical to supply its energy demand by using domestic non-renewable resources (such as lignite, hard coal, oil and natural gas) and renewable resources. (Kaygusuz, 2002). Several authors have investigated demand, production, planning

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and utilization of energy sources in Turkey (Balat and Ayar, 2004; Balat et al., 2004; Balat, 2005a; Demirbas et al., 2004; Kaygusuz, 2004). Turkey's geographic location has several advantages for extensive use of most of the renewable energy sources. It is on the humid and warm climatic belt which includes most of Europe, the near east and western Asia. A typical Mediterranean climate is predominant at most of its coastal areas, whereas the climate at the interior part between the mountains that are a part of the Alpine Himalayan mountain belt is dry with typical steppe vegetation (Kaya et al., 2002). Comprehensive studies have been carried out concerning the present status, the technical potentials, and the regional distribution of renewable energy resources in Turkey by many researchers (Demirbas and Bakıs, 2003; 2005; Balat, 2004; Balat, 2005b; 2005c; 2005d; Balat et al., 2005; Kaygusuz, 2001a; 2001b) and concluded that Turkey has extensive renewable energy resources that can be developed as a significant source of energy.

The energy requirement in Turkey is steadily increasing due to the rapid growth in population and industrialization and is being met by both commercial and renewable energy sources. Among the different forms of renewable energy, biomass energy is one of the major resources in Turkey. Biomass energy includes agricultural residues, municipal wastes, fuel wood, animal wastes and other fuel derived from biological sources. The estimate is based on the recoverable energy potential from main agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes as given in the literature. The total recoverable bio-energy potential is estimated to be about 16.92 Mtoe. The biomass energy production for the year 2001 is 6.98 Mtoe. Comprising mostly wood and dung for heating and cooking, it is mainly used in rural areas (Bascetinçelik et al., 2005). In Turkey, biomass has great potential to provide improved rural energy services based on forest and agricultural residues. The potential of important biomass energy sources and animal solid wastes of Turkey have been determined and the potential of these as a source of fuel in thermal generating systems to produce electricity and thermal energy has been studied. A number of investigations which aimed at improving the utilization efficiency of biomass systems have been done by some researchers (Balat, 2005e; Acaroğlu et al., 1999; Karaosmanoglu, 1999; Türker et al., 1999; Sahin et al., 2000; Demirbay, 2001; Kaygusuz, 2001c; Akdeniz et al., 2002; Demirbas, 2000; 2002a; 2002b; 2002c; 2003; 2004a; 2004b; 2004c; Demirbas and Demirbas, 2004; Kaygusuz and Turker, 2002; Surmen and Demirbas, 2002; Yılmaz et al., 2002; Hepbaslı et al., 2003; Surmen, 2003; Akdeniz et al., 2004; Bilgen et al., 2004; Demirbas and Meydan, 2004).

Various agricultural residues such as grain dust, wheat straw, and hazelnut shell are available in Turkey as the sources of biomass energy. The main objective of the present study is to determine the exploitable potential and regional distribution of agricultural residues in Turkey. The present study has been carried out to address this need, in other words strengthen the capacity of the Turkish administration to deal with the sustainable exploitation of agricultural waste. The main driver will be the development of a strategy to coordinate actions towards the alleviation of existing barriers, be they administrative, legislative or technological. Other significant dimensions of the study are the comprehensive mapping of the exploitable potential in Turkey, the training and support of trainers in order to build the necessary capacity at regional level, the setup

of a supporting framework for investors and a rich dissemination campaign targeting a wide range of stakeholders. The potential benefits of the study are significant since the exploitation of agricultural waste is actually a win-win case. The major benefits are environmental and relate to the reduction of greenhouse gas 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.

II. EXPLOITABLE AGRICULTURAL BIOMASS POTENTIAL IN TURKEY

The agricultural total land of Turkey is about 26.350 million ha, from which: 38.4% sown area, 44.1% forest, 10.4% fallow land, 7.1% cultivated with fruit and vegetable areas (SIS, 2001). Cereals, oily seeds and tuber crops are among the most widespread in Turkey. Cereals are extensively grown in the central, eastern and southern parts of Turkey, whereas sunflower is prevalent in the region of Thrace (N–W Turkey). Cotton with maize are the dominant crops in the south (the Cukurova and SE Anatolian regions), and the west (the Aegean region). Tubers are widely produced in the Marmara (potatoes) and Central Anatolia (potatoes and sugar beet) regions. The highest estimated amounts of residues are of wheat and barley followed by maize and cotton. The total annual amount of agricultural residues in the country is about 50–65 Mtons.

Agricultural residues have been considered in three categories:

1. Annual crop residues that remain in the field after the crops are harvested. The main annual crops in Turkey are cereals, maize, cotton, rice, tobacco, sunflower, groundnuts, soybeans,
2. Perennial residues in Turkey that remain in the field after pruning of trees, shells, kernels etc.
3. Agro-industrial residues such as; cotton-ginning, seed oil industries, olive oil industries, rice industries, corn industries, wine and kernel factories.

The quantities of residues from the annual and perennial crops cultivated in Turkey, in tons of dry matter per year, were calculated and estimated using data from local authorities of Ministry of Agriculture and Rural Affairs, on the cultivated areas and the quantities of main product produced for each crop and for production period of 2002–2003. Although the main sources of information were gathered from the Ministry of Environment, the Ministry of Agriculture, State Institute of Statistics, Universities and other Institutions, a variety of sources such as previous relevant projects, Internet websites, publications, and commercial enterprises of the sector were used for the mapping of residues potential.

Residues left over the field after agricultural production. Cereal straw is used for various purposes such as animal feeding and animal bedding. Mainly residues from the production of industrial agricultural products are left over the field. The species are cotton stalk, corn stalk, sunflower stalk, straw and tobacco stalk etc. The total amount of crop residues that indicated in the tables was divided into theoretic and actual values. Theoretic values calculated by multiplication of the coefficient number which is taken from some references with the total production amount (Demirbas, 1997; CIGR, 1999). Calculation of actual values is the multiplication of the coefficient

number which is taken from Agricultural Departments of Province with the total production amount of the crops. Moreover available residue values were calculated by the multiplication of the crop availability percentage which is taken from references with actual residue.

The calorific values of a selection of agricultural residues were determined by stoichiometric analyses and given in Table 1. Total calorific values calculated by multiplication of the calorific values of a selection of agricultural residues which is taken stoichiometric analyses results (Table 1) with the available residues amount.

The total annual field crops production and residues in Turkey is given in Table 2. It was calculated that the total calorific value of the field crop residues was around 228 PJ for the production period of 2002–2003 in Turkey. The major crops that take place in the ratio of the total calorific value are maize (33.4%), wheat (27.6%), and cotton (18.1%). Table 3 shows the total annual fruit production and residue in Turkey. The total calorific value of the fruit residue was calculated as 75 PJ. The major fruits for the agricultural biomass are hazelnut (55.8%) and olive (25.9%). Thus, the total calorific value of the agricultural biomass was 303 PJ for the production period of 2002–2003 in Turkey.

In the present study, regional distribution of agricultural residues in Turkey was also determined. Turkey consists of seven regions: the Mediterranean region, the Aegean region, the Marmara region, the central Anatolian region, the Eastern Anatolian region, the Southeastern Anatolian region, and the Black Sea region. The share of regions in the regional distribution of the total calorific value of field crops and fruit residues is given in Figure 1. The share of regions in distribution of the total calorific value of field crops residues were 24.8% (the Mediterranean), 18% (the Marmara), 16.3% (the Southern East Anatolia), 13.7% (the Central Anatolia), 13% (the Black Sea), 10.6% (the Aegean) and 3.6% (the Eastern Anatolia), respectively (Figure 1a). However, it was found that the share of regional distribution in the total calorific values of the fruit residues were 48.2% (the Black Sea), 20.4% (the Aegean), 12.7% (the Marmara), 10.8% (the Mediterranean), 5.3% (the Southern East Anatolia), 1.34% (the Central Anatolia) and 1.25% (the Eastern Anatolia), respectively (Figure 1b).

Table 4 illustrates the number of animals, waste quantity and calorific values of animal wastes in Turkey. The number of cows, sheep and poultry in Turkey per year is approximately 13, 30 and 265 million, respectively. With these amounts, the capacities of waste quantities are 128, 25 and 8 million tons per year. Considering dry manure ratio (as percentage) for cows, sheep and poultry to be 12.7, 25 and 25%, respectively, the amounts of total dry manure were determined as 16.2, 6.1 and 1.9 tons per year. Total amount of available dry manure was determined by taking the availability of the manures on the site as 65, 13 and 99% respectively. Thus, the total available dry manure was determined by multiplying total dry manure with availability. Ratio of dry manure to biogas is 200 m^3 per tons for cow, sheep and poultry manure. And, calorific values are 22.7 MJ/m^3. Therefore, the total calorific values for cow, sheep and poultry wastes in Turkey were found to be approximately 47.8, 3.6 and 8.7 PJ/year, respectively. The share of the Black Sea, Mediterranean Aegean, Marmara, South Eastern Anatolian, Central Anatolian and Eastern Anatolian in distribution of the calorific value of the animal waste was 23.8%, 19.1%, 15.6%, 12.4%, 12.2%, 11.4% and 5.5%, respectively.

Table 1. The calorific values of a selection of agricultural residues

Material	Humidity[1] (%)	Volatiles[2] (%)	Loosing weight[1] at 770°C (%)	Bulk density[1] (g/L)	C[3] %	H[3] %	N[3] %	Calorific Value[4] (MJ/kg)	P[5] %
Cotton gin waste -1	17.27	78.7	81.5	86.40	41.19	5.10	1.72	15.65	0
Cotton gin waste -2	5.87	69.7	74.9	150.33	36.34	4.65	2.01	12.59	0.012
Cotton gin waste -3	9	83.6	86.3	110.79	39.19	5.09	2.47	N/A	0.025
Rice husks	7	77.3	77.9	129.33	36.80	4.41	0.73	12.98	0
Olive Cake	6.47	88.6	97.4	429.74	51.15	6.72	1.06	20.69	0
Pressed Olive Cake	10.3	92.2	96.4	508.39	48.84	6.25	1.13	19.68	0
Pressed Olive Cake	9.78	87.8	95.9	543.70	47.40	5.69	1.46	18.92	0.022
Olive Cake	10.33	89.6	91.3	698.27	44.41	5.38	1.35	17.89	0.015
Ground peanut shell	16.22	95.1	95.6	327.65	44.71	5.63	2.11	17.91	0.028
Ground peanut shell	9.21	95.8	96.3	319.22	47.48	6.27	1.76	20.74	0.025
Pulp residue of grape	17.21	90.3	96.8	299.16	40.38	6.39	1.09	13.34	0.018
Carob residue	8.6	96.8	97.4	439.62	46.58	5.80	0.97	17.18	0.010
Inorganic matter	9.6	95.1	95.4	365.36	50.96	7.01	4.56	21.13	0.056
Cotton seed	8	95.5	95.9	227.28	51.26	7.30	3.41	21.32	0.058

Stoichiometric analyses:

[1]SM- 2540 SM: Standard Methods For The Examination Of Water and Wastewater 20th Edition

[2]SM- 2540 E National Environmental Legislation

[3]Elemental Analysis Equipment (Carlo ERBA 1106)

[4]ASTM D 5865 Standard Test Method for Coal and Coke 2002

[5]SM- 4500 P, D

Table 2. The total field crop production and residues in Turkey

Crops	Residues	Production (tons)	Area (ha)	Yield (kg/ha)	Total Residues (tons)		Available Residues (tons)	Availability (%)	Calorific Value (MJ/kg)	Total Calorific Value (GJ)
					Theoretic	Actual				
Wheat	**Straw**	22,439,042	9,424,785	2,381	29,170,755	23,429,907	3,514,486	15	17.9	62,909,300
Barley	**Straw**	8,327,457	3,732,992	2,231	9,992,948	8,963,012	1,344,452	15	17.5	23,527,908
Rye	**Straw**	253,243	145,907	1,736	405,188	358,040	53,706	15	17.5	939,855
Oats	**Straw**	322,830	150,459	2,146	419,678	321,236	48,185	15	17.4	838,425
Maize	**Stalks**	2,209,601	565,109	3,910	5,911,902	4,970,259	2,982,155	60	18.5	55,169,873
	Cop				596,592	1,907,307	1,144,384	60	18.4	21,056,667
Rice	**Straw**	331,563	59,879	5,537	582,555	209,532	125,719	60	16.7	2,099,510
	Husk				88,527	77,747	62,198	80	12.98	807,327
Tobacco	**Stalks**	181,382	222,691	814	362,763	410,778	246,467	60	16.1	3,968,113
Cotton	**Stalks**	2,292,988	680,177	3,371	6,317,181	2,520,281	1,512,169	60	18.2	27,521,470
	Ginning				481,527	732,220	585,776	80	15.65	9,167,391
Sunflower	**Stalks**	836,269	545,963	1,532	2,341,554	2,259,121	1,355,472	60	14.2	19,247,709
Groundnuts	**Straw**	55,241	25,167	2,195	127,054					
	Shell				27,621	28,638	22,910	80	20.74	475,155
Soybeans	**Straw**	28,795	15,064	1,912	60,468	21,872	13,123	60	19.4	254,595

Table 3. The total fruit production and residues in Turkey

Cops	Residues	Production (tons)	Number of trees	Total residues (tons)		Available residues (tons)	Availability (%)	Calorific value (MJ/kg)	Total calorific value (GJ)
				Theoretic	Actual				
Apricots	**Shells**	467,903	11,288,357		154,573				
	Tree pruning			1,328,846	86,964	69,571	80	19.3	1,342,719
Sour cherries	**Shells**	114,466	4,446,680		39,916			21.75	
	Tree pruning			137,359	21,400	17,120	80	19	325,279
Olive	**Cake**	1,496,630	90,208,994	673,484	829,816	746,834	90	20.69	15,451,997
	Tree pruning				441,254	220,627	50	18.1	3,993,345
Pistachios	**Shells**	42,926	29,600,005		14,007	4,202	30	19.26	80,932
	Tree pruning				209,611	167,688	80	19	3,186,080
Walnuts	**Shells**	115,698	3,737,868	173,546	75,792	60,633	80	20.18	1,223,584
	Tree pruning				50,480	25,240	50	19	479,563
Almonds	**Shells**	46,701	3,631,622	44,366	25,784	23,205	90	19.38	449,716
	Tree pruning			13,076	28,500	22,800	80	18.4	419,521
Hazelnuts	**Shells**	652,803	286,697,887	698,499	566,437	453,150	80	19.3	8,745,790
	Tree pruning				2,177,986	1,742,389	80	19	33,105,388
	Tree pruning			236,852	88,465	70,772	80	17.6	1,245,582
Oranges	**Peel**	1,180,851	11,884,275						
	Tree pruning			3,424,439	237,686	190,148	80	17.6	3,346,612
Mandarins	**Peel**	592,884	8,619,163						
	Tree pruning			918,970	103,430	82,744	80	17.6	1,456,294
Grapefruits	**Peel**	126,285	894,293						
	Tree pruning				14,309	11,447	80	17.6	201,466

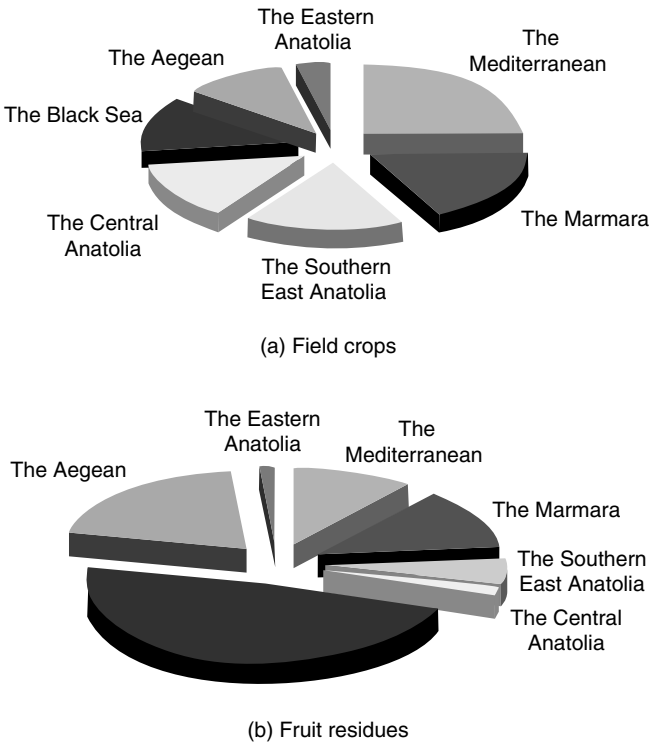


Figure 1. The share of regions in the regional distribution of the total calorific value of field crops and fruit residues

III. TECHNOLOGY REVIEW AND ASSESSMENT

a. Combustion technologies

The most significant and commonly used thermal conversion method of biomass is combustion. Bio-fuels are utilized as a single fuel but they are also co-combusted with other fuels (coal, waste fractions, etc.). Co-firing is favored especially in large scale when supply of large volumes of fuels is needed. Most of the biomass combustion technologies applied are different grate firing or fluidized bed boilers.

Stoker burners are well suitable for combustion of wood chips, pellets, and briquettes. Stoker burners are used in output range from 10 kW up to 0.5–1.0 MW. Stoker is additional equipment attached to the boiler. A stoker consists of a screw feeder or a piston working in connection between a fuel storage and combustion chamber. The incoming fuel pushes fuel forward on the grate. Burning gases and combustion air are efficiently mixed by blowing combustion air into the fuel layer and into the gas combustion space. The output of a stoker burner can be easily varied from 0 to 100%. Reduced output does not affect too much on total efficiency. This is a clear advantage compared to other technologies. Most stoker burners cannot use fuels with a moisture content of more than 30–40%. Stoker burners are suitable for "fossil to biomass" conversion: It can be installed to existing oil or gas fired boilers.

Table 4. The total number of animals, amount of animal wastes and calorific values of the wastes for Turkey

Animal waste	Animal number	Waste quantity (tons/year)	Total dry manure (tons/year)	Availability (%)	Available dry manure (tons/year)	Available biogas (m^3/year)	Calorific value (MJ/m^3)	Total calorific value (GJ/year)
Cow	12,838,285	127,645,932	16,211,033	65	10,537,172	2,107,434,345	22.7	47,838,760
Sheep	29,903,590	24,558,323	6,139,581	13	798,146	159,629,101	22.7	3,623,581
Poultry	264,784,050	7,731,694	1,932,924	99	1,913,594	382,718,866	22.7	8,687,718

The power of grate boilers change from 1 MW up to 10–20 MW the prevailing technology in Europe is grate firing. The size range is broad: technology is available up to 150 MW. Grate boilers are is suitable also for wet fuels. Fuel preparation costs are low as the combustion process does not set very strict limitations for fuel particle size. On the other hand grate boilers are sensible to fuel quality changes and they are not as easy to control as the fluidized bed boilers. There are various different grate boiler types. The most common are fixed sloping grate, moving horizontal grate, moving slope grate and multistage grate. One of the problems related to grate firing is the ash melting. Temperatures in the combustion chamber may reach 1300–1400°C. Ash melting problems may be reduced by using mechanical and water-cooled grates and by avoiding the use of preheated combustion air in the final burning area. Grate boiler with moving grate is common technical solution for wood combustion. Through the movement of the grate, the fuel gets carried from the feeding point until the end of the grate. First the fuel dries, then pyrolysis and finally burns as it moves on the grate. Grate can be water-cooled if the fuel used has low ash melting point. Flue gas circulation is also used for temperature control in grate boilers. In grate firing systems, it is also possible to combust straw as the sole fuel. The deposition rate and corrosion inside a grate boiler are highly temperature-dependent. Ash deposition and corrosion may constitute a significant problem in these boilers, particularly if the metal temperature is raised above 520°C. (Bascetincelik et al., 2005).

There are several examples of coal fired pulverized-fuel boilers converted to co-firing of coal and biomass. The pulverized-fuel boilers are typically very large-scale boilers, even hundreds of megawatts thermal. In the pulverized-fuel boilers converted to co-firing, the share of biomass is not very high. In pulverized fuel combustion it is always important to bear in mind that the fuel preparation is very energy consuming.

Previously grate firing was the dominant technology but during last decades fluidized bed combustion has became more significant technology especially in larger scale. Fluidized bed technology is applied especially in modern large-scale applications while small-scale applications are primarily based on grate firing. Fluidized bed technology is the most flexible for burning different types of fuels. Fluidized bed boilers can be designed to combust almost any solid, semi-solid, or liquid fuel as long as the calorific value is sufficient to heat the fuel, drive off the moisture and preheat the combustion air. Fluidized bed boilers are used mainly for capacities larger than 10 MW. They are suitable for many types of fuels, even for quite wet ones. The combustion temperature in a fluidized bed boiler is typically around 850°C, so this may limit the use of many gramineous biomasses, as their ash softening may start in temperatures as low as 800°C. In bubbling fluidized bed boiler the fluidization air velocity is low enough to keep the bed in desired level. In circulating fluidized bed the fluidizing air velocity is considerably higher so that the gases leaving the bed area carry part of the bed material to the upper part of the furnace. The solid material is then separated in a cyclone and recycled to the lower section of the bed. Bubbling fluidized bed boilers suit especially for wet fuels with low calorific heating value. They also tolerate wider variation in fuel particle size distribution.

Flue-gas condensation can increase boiler output by 10–30%. Since the increase in output is accomplished without an increase in fuel consumption, the boiler efficiency

increases in same ratio as the output. A condensation unit usually includes a scrubber. The scrubber together with a multi-cyclone decreases particle emissions almost as well as an electrical precipitator but it reduces other emissions as well. The cost of the scrubber-condensation unit increases the total costs of the boiler plant usually in proportion to the increase in output, but the investment outlay per capacity does not grow.

b. Gasification

Gasification is another thermal conversion technology, which can be used to recover energy from biomass. The primary product of gasification process is fuel gas, which can be used as a fuel in different power production processes or in industrial applications. Typical applications are combustion in a boiler or in industrial kiln and in small-scale use as a fuel of engine. The most simple and usual applications are wood fuelled gasifiers connected directly to kilns but there are also very advanced high efficiency power production technologies based on gasification. Integrated Gasification Combined Cycle (IGCC) process is very efficient power production process based on pressurized gasification.

During last 10 years gasification process has been applied for producing fuel gas for co-combustion applications. Relatively large-scale atmospheric pressure gasification is used for replacing part of the coal input of large-scale PC boiler by biomass-derived gas. This co-firing enables efficient utilization of solid and poor quality biomass even in pulverized coal fired boilers without pulverizing biomass. Risks related to corrosion and deposit formation by contaminants of biomass can be eliminated by cleaning the product gas prior co-combustion. Power production efficiency (from biomass to power) is high when large-scale steam cycle can be applied. In addition, when the gasifier is equipped with gas filtration biomass ash can be separated from coal ash. In addition, fluidized bed gasifiers are very flexible to fuel selection enabling wide variety of bio-fuels separately or as a mixture. Need of product gas cleaning prior co-firing with coal depends on the quality of the used biomass. Clean bio-fuels do not require any gas cleaning but demolition wood waste, straw and other bio-fuels containing harmful contaminants need. This technology is already in use in Finland, Netherlands and Austria and new plants are under design and commissioning phase.

Fluidized-bed gasifiers can be divided into circulating fluidized-bed (CFB) and bubbling fluidized-bed (BFB) gasifiers. Principles of these techniques are equal to fluidized-bed (CFB and BFB) combustion. The BFB gasification technology seems to be economically more suitable to medium size applications (15–60 MW) while the CFB technology is most feasible on larger scale (40–100 MW). Similar dry gas cleaning technology can be applied for BFB gasification as for CFB gasifiers. The principle of air blown atmospheric pressure CFB gasifier is simple. The system consists of a refractory-lined reactor where the gasification takes place, of a cyclone to separate the circulating material from the gas and of a return leg for returning the circulating material to the bottom part of the gasifier. The operating temperature in the reactor is typically 800–1000°C, depending on the fuel and the application. The fuel is fed into the lower part of the gasifier, above certain distance from the air distribution grid. When entering the reactor, the bio-fuel particles start to dry rapidly and the pyrolysis also occurs. The gaseous products of drying and pyrolysis flow upwards in the reactor. Most of the solids are separated from the gas in the cyclone and returned

to the bottom of the bed, where the charcoal is combusted with the air that is introduced through the grid nozzles to fluidize the bed (Bascetincelik et al., 2005).

The CFB gasification concept without gas cleaning can be utilized only for woody biomass fuels and clean waste-derived feedstock. Many potential biomass feedstock, such as straw and many fast-growing energy crops as well as industrial and municipal waste-derived fuels often contain high amounts of impurities like chlorine, alkali metals, and aluminum, which have a tendency to cause severe corrosion and fouling problems in boilers. Demolition wood waste is also locally important renewable feedstock, which is difficult to be introduced into ordinary coal-based combustion plants due to the relatively high content of heavy metals (Zn, Pb, Cd, As) and chlorine. The impurities may also effect on the usability of coal boiler ash for cement industry and construction purposes. Thus, in many cases, gas cleaning is required to avoid operation problems in the main boiler, to achieve the emission limits or to avoid the contamination of the coal ash by biomass alkalis or heavy metals from waste fuels. Most of the harmful impurities can be removed by filtering the gas at 350–450°C.

The most economical gasification technology that can be realized in small scale is fixed bed gasification. However, most of the available biomass residues do not meet the requirements of commercial fixed bed gasifiers. Usually the bulk density is low, the fuel is fibrous and also contains fines, which creates problems with the gas flow in gasifiers relying on gravity for fuel feed in the reactor. While there exist gasification technologies (e.g. fluidized bed) that are able to gasify these fuels, they are not suitable for small scale plants due to high costs. Conversely, the fuels that commercial fixed bed gasifiers are able to use as feedstock are normally not sufficiently cheap to make small gasifier driven combined heat and power plants competitive. The largest and most important markets for the small-scale, fuel-flexible gasifier concept are in small-scale combined heat and electricity production. At present, conventional steam turbines are not economically attractive in small-scale (<3 MW_e) applications, and units smaller than 1 MW_e are difficult to find. However, the gasifier engine concept can be realized also at this scale. Consequently, rapid development has been achieved in the development in small and also in large-scale CHP processes. Currently there are several gasification-engine power plants in demonstration phase.

The traditional fixed-bed gasifiers are suitable only for sized feedstock, which have high enough bulk density to guarantee stable fuel flow. In an updraft gasifier the fuel is fed to the top of the gasifier, wherefrom the fuel flows down slowly through drying, pyrolysis and gasification and combustion zones. Ash is removed from the bottom, where the gasification air and steam are introduced. As the products of drying and pyrolysis zones are directly drawn into the product gas without secondary decomposition reactions, the product gas of an updraft gasifier contains an abundance of oils and tars. In addition, the product gas temperature is low (with biomass fuels 80–300°C and with coal 300–600°C). Bottom ash is usually completely oxidised and does not contain significant amounts of unburned carbon. Usually, the dust content of the product gas is rather low due to low gas velocities and due to "filtering effects" of the drying and pyrolysis zones. The advantage of downdraft gasifier is the fact that the pyrolysis products have to flow co-currently through the hot combustion and gasification zones, were most of tars are decomposed and oxidized. Thus, the product

gas of an ideal downdraft gasifier after simple filtration and cooling can be used in an internal combustion (IC) engine. There have been several trials to develop a simple power production system based on downdraft gasifiers and IC engines.

One of the latest developments related to small-scale biomass fuelled CHP plants is new NOVEL gasification CHP plant. The plant is based on advanced fixed bed gasification, which is equipped by forced feeding. Forced feeding enables use of loose and even fluffy fuel when typically fixed bed gasifiers need much better quality fuels. For example typical downdraft gasifiers fuel has to have sized feedstock, which has high enough bulk density to guarantee stable fuel flow. The other advanced features of NOVEL gasifier are related to internal construction of the gasifier to reduce tar content of the gas. The first commercial NOVEL CHP plant is under construction and commissioning phase will start in April 2005. Plant is located in Kokemäki, Finland. This plant is equipped with a complete gas cleaning train consisting of a gas reformer, filter and acid/base scrubber for residual nitrogen compounds removal (Bascetincelik et al., 2005).

c. Biogas

One specific fraction of agricultural residues is animal manure. Traditionally manure has been utilized on the fields as a fertilizer but in many areas in Europe production of manure is locally larger than available surface area of the fields. This has led to situation that volume of manure to be used as a fertilizer has to be reduced. Thermal conversion (combustion and gasification) has been developed but heating value of wet manure is poor. In addition, ash behavior is very problematic and risk for serious deposit formation is high.

The alternative treatment and utilization method is anaerobic digestion (AD), which produces methane for energy purposes and residue is used for soil conditioning and as a fertilizer. Anaerobic digestion is widely used for treatment of sewage sludge but more and more plants have been constructed for treatment of animal manure, too. Anaerobic digestion of animal waste is utilized all over the world. For example in China it is estimated that more than 6 million farm scale biogas generators are in use. In developing countries biogas plants are primarily small; farm-scale plants when in more developed countries plants are usually larger and co-operated by several farms. In developing countries gas is primarily utilized for cooking and lightning but in more developed countries gas is usually used to generate heat and electricity to run the farm and export. Modern technology in agricultural waste digestion is based on the concept of centralized anaerobic digestion where many farms co-operate to feed a single larger digestion plant. The agricultural residues provided to these plants are mainly agricultural manures and they are often controlled by environmental legislation. AD treatment of these residues allow additional value to be gained through providing products and reducing the cost of disposal.

The produced biogas is very similar than natural gas. The primary product is methane, which makes it excellent fuel for many uses. In practice, cleaned biogas can be used for most of those applications where natural gas is used. One of the most common ways to utilize natural gas for power production is internal combustion engine. In smaller scale (< 200 kW) electrical conversion efficiency can be up to 25%

and in larger scale even 30–35%. In addition to electricity the IC engine produces heat, which can be utilized for district heating or hot water production. The residues from AD process are solid material and liquid. Liquid phase contains most of the valuable nutrients and so this fraction can be utilized as a fertilizer. The solid fraction can be used on farmland or on gardens to provide bulky organic matter to improve soil quality and fertility.

IV. CONCLUSION

In Turkey energy consumption had been growing much faster than its production, making Turkey a rapidly growing energy importer. Simultaneously agriculture is one of the main activities in Turkey and it represents large share of national income. Agricultural activities are concentrated on the production of industrial plants used for example for production of industrial products, like edible oils from olives, cotton seeds, sunflower, etc. These food-processing industries produce large quantities of residues, which could be utilized for energy production. In addition to these food industrial biomass volumes, a large volume of biomass is left on the fields during harvesting seasons. The available agricultural and animal residues in Turkey have been estimated to be roughly equal to 22–27% of energy consumption in Turkey. However, the actual role of bio-fuels in energy production is minimal. The most efficient way to utilize bio-fuels in energy production is combined heat and power (CHP) production. In North Europe almost all cities have constructed district-heating network, which enables efficient utilization of heat energy. Climate conditions in Turkey differ significantly from North Europe and especially in most southern parts of Turkey climate is so mild that district heating is not needed. In northern parts of Turkey climate is much colder but district networks have not been constructed disabling efficient utilization of CHP production.

CHP production could also be utilized for production of process heat and steam for industry. Industry needs heat for drying and many kind of processing, which enables efficient CHP production even without district heating network. In addition, heat production of smaller CHP plants can be used for heating of public or industrial sites. In large scale the highest interest seems to be focused on power production, i.e. production of electricity. The most favorable conditions for power production based on thermal conversion are in medium or large scale, which enables utilization of an efficient steam cycle. However, most of agro-biomass is distributed to large areas and missing logistics limits size of potential power plants. Industrial agro-biomass, like residues from olive oil or cottonseed oil production, is an exception because residue is usually available in relatively large volumes on one site. These industrial sites offer very attractive locations for biomass fuelled energy plants. The most potential applications to utilize agro-bio-fuels in energy production in Turkey seem to be relatively small-scale applications. The most interesting size of the plant is below 10–20 MW. Technically size of CHP or power plant is not limited but investment and operation cost of very small power plant is usually very high compared to large-scale power production. In most cases this results directly in conclusion that in small scales the most feasible way to utilize agro-biomass is heat production replacing some more valuable fossil fuels. However, this expects that there has to be a local need for heat.

Need for power is more or less similar around Turkey because national grid can be used for distribution of electricity but need for heat is always local. Heat cannot be transported long distances but it has to be utilized in the neighborhood of the plant. In practice, this means that actual need for heat has to be specified case by case.

Although there are sufficient quantities of agricultural biomass potential in the country, certain parameters should be taken into account before making a strategy for their energy exploitation.

- Small farming size depends on the region (increases harvesting and transportation costs).
- Environmental risks caused by the removal of the residues from the field (erosion in sloping and low fertility areas, etc.).
- Opportunity cost of the residue (e.g. cereals straw has already a market price as it is sold for animal feeding purposes and paper industry).
- Lack of commercial harvesting machinery for certain residue types (e.g. higher cutting stalks of maize and cereals, cotton residues).
- The future works to exploit the agricultural wastes in Turkey should be comprise the following tasks:
- Identification and assessment of legislative, institutional and administrative barriers to agricultural waste exploitation by identifying the chain of responsibility, the involved organizations and the principles of cooperation between all parties involved.
- Technology review and assessment, in order to assess the different technological solutions available in the EU and propose the most suitable ones for Turkey, taking into account local characteristics and market conditions.
- Preparation of an Action Plan, addressed to the Ministry of Environment, which will consolidate the findings of the project and prioritize recommendations for future work, aiming at promoting agricultural waste exploitation in Turkey by alleviating existing barriers and improving business environment.
- Create an effective training infrastructure at the Ministry of Environment, by training Ministry staff as trainers, equip them with appropriate training material and carry out pilot training courses at regions with specific interest. Training courses are planned to continue after the project conclusion by the Ministry trainers.
- Setup investment support infrastructure, by carrying out feasibility studies, preparing a software based assessment tool and setting up a help desk.
- Disseminate the results to a wide range of stakeholders using a variety of dissemination media.

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