Energy Production From Forest Residues in Turkey

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Abstract

Biomass is the major source of energy in rural Turkey. Biomass is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. Biomass potential includes wood, animal and plant wastes. Among the biomass energy sources, fuelwood seems to be the most interesting because its share of the total energy production of Turkey is high at 21 %. Turkey's annual biomass potential is about 117 million tons and the total biomass energy potential is about 32 Mtoe. The amount of usable biomass potential of Turkey is approximately 17 Mtoe. The electrical production from usable biomass has a net impact of 4,4 billion USD in personal and corporate income and represent more than 160,000 jobs.

Turkish forest area occupies about % 27,1 (21,7 million hectares) of entire land area. Of which % 53,3 is productive. Estimated total annual wood increment in Turkish forests is about 42,2 million m^3. Annual allowable cut is about 17 million m^3. Annual wood production including private is about 26 million m^3, of which % 46 is consumed as fire wood. There is a total 4 million ha of degraded coppice forests for energy forestry applications in Turkey. 640.000 hectares of energy forests were established in degraded oak coppice forest areas between 1978-2010. It is a very important activity which is as important as forestation in the improvement of degraded coppice forests and converting them into productive energy forests in order to meet the fuel requirements to prevent the destruction of productive high forests. Therefore to supply more wood raw material for the forest industry which at present operates with low capacity. The first biomass combined heat and power plant which is using wood and wood bark and producing 32 MW_{heat} and 10 $MW_{electricity}$ since 2008 at Caycuma Paper Factory in Turkey. Eight power plants are producing nearly 85 MW heat by using forest and agricultural wastes in a year. Pellet production plants are producing nearly 200.000 ton pellet in a year. Pellet production from wood- and agricultural wastes will play an important environmental role in Turkey too.

Keywords: biomass, bioenergy, energy forestry, pellet production, Turkey

1. Highlights of Turkish Forestry

Turkish forest area occupies about % 27,2 (21,7 million hectares) of entire land area. Of which % 53,3 is productive. Productive high forests cover about % 47,4 of total forest area and % 11,4 of total land area. Coniferous species make up about % 60 and broadleaved species % 40 of designated forest area. Amoung coniferous pine, fir, juniper, spruce and cedar and amoung hardwoods oak, beech, alder, chesnut, ash and hornbeam constitute the major tree species. By the figures 2013 of Turkish Forest Inventory, current growing stock in our forests is 1.494.454.538 m^3, annual increment 42.179.115 m^3 and total allowable cut is 16.995.201 m^3. Required raw material in 2008 was 28.150.000 m^3 and 16.640.000 m^3 of required raw material is obtained from state forest, from which 11.540.000 m^3 industrial wood and 5.100.000 m^3 fire wood, 4.800.000 m^3 from private sector, 4.050.000 m^3 from illegal consumption from state forests and 2.660.000 m^3 from abroad (Table 1,2,3,4,5) [1].

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Table 1: Distribution of forest land in Turkey

Forest Form	Productive		Degraded		Total	
	Hectare	%	Hectare	%	Hectare	%
High Forest	10 281 728	47,4	6 978 864	32,2	17 260 592	79,6
Coppice Forest	1 276 940	5,9	3 140 602	14,5	4 417 542	20,4
Total	11 558 668	53,3	10 119 466	46,7	21 678 134	100

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

Table 2: Distribution of growing stock of forests in Turkey

Forest Form	Productive		Degraded		Total	
	m^3	%	m^3	%	m^3	%
High Forest	1 365 186 239	91	53 319 695	4	1 424 505 934	95
Coppice Forest	52 296 445	4	17 652 159	1	69 948 604	5
Total	1 417 482 684	95	76 971 854	5	1 494 454 538	100

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

Table 3: Distribution of annual increments of forests in Turkey

Forest Form	Productive		Degraded		Total	
	m^3	%	m^3	%	m^3	%
High Forest	37 300 713	89	1 411 640	3	38 712 353	92
Coppice Forest	2 719 466	6	747 296	2	3 466 762	8
Total	40 020 179	95	2 158 936	5	42 179 115	100

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

Table 4: Total forest area by tree species in Turkey

(Hectare)

Species	Forest Form			Total Forest Area
	Total	Productive	Degraded	%
Turkish pine (Pinus brutia)	5 854 673	3 207 914	2 646 759	27.00
Oak (Quercus sp)	5 152 561	2 105 937	3 046 624	23,76
Crimaen pine (Pinus nigra)	1 961 660	1 621 257	340 403	9,05
Beech (Fagus orientalis)	1 479 648	751 060	728 588	6,83
Scots pine (Pinus silvestris)	670 389	406 989	263 400	3,09
Fir	670 389	406 989	263 400	3,09
Juniper	575 315	91 234	484 081	3,09
Cedar (Cedrus libani)	463 521	220 328	243 193	2,14
Spruce	334 472	230 212	104 260	1,54
Alder	141 118	99 984	41 134	0,65
Chesnut	111 044	75 249	35 795	0,51
Stone pine	89 028	60 889	28 139	0,41
Hornbeam	19 962	15 235	4 727	0,09
Lime tree	11 523	9 577	1 946	0,05
Ash tree	9 443	8 495	948	0,04
Poplar	6 547	1 871	4 676	0,03
Eucalyptus	2 528	2 398	130	0,01
Other species	101 642	69 846	31 796	0,47
Total	**21 678 134**	**11 558 668**	**10 119 466**	

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

Table 5: Wood raw material production in Turkey

(1000 m^3)

Year	Wood Category			
2008		Industrial Wood	Fire Wood	Grand Total
	Forestry General Directorate	11 540	5 100	16 640
	Private Sector	3 300	1 500	4 800
	Import	2 285	375	2 660
	Unplanned removals from state forests		4 050	4 050
	Total	17 125	11 025	28 150

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

In Turkey as a result of ignorant and unsystematic uses for hundreds of years, our forests suffered great losses and in places either completely disappeared or lost a significant portion of their productivity. As a result of this, the natural balance between soil, water and plants was upset and the productive soil in the country flowed away (346 million ton/year). % 79,43 of land area is under erosion pressure. To reestablish this natural balance that was upset, to protect farmland from floods and wind erosion and to meet the need for forests and forest products that increases every year. It is necessary to regenerate the present forests by natural and artifical means and to transform them to a productive condition by afforesting forested areas that are unproductive or have become completely barren.

The duties of the Afforestation and Silviculture Department Chairmanship that is responsible for the activities undertaken for this objective by the General Directorate of Forestry (GDF). % 45 of population living in rural areas near the forest land and their economic status is too low. Higher life standards they get, the better chances we can get to prevent their negative effects on forest land. In order to increase the rate of required raw material, the policies of production of raw material must be reorganised. Because, it is an important step to prevent erosion. Natural forest land in Turkey is not satisfactory to solve this problem. Plantation is vital to provide required raw material. Energy forestry plantations can be the best solution to prevent deforestation and erosion and give job possibilities to thousands of people. Energy forestry biomass has an importance to supply wood and energy demand too. The most important thing is to be more economical.

2. Forest residues potential of Turkey

Forest residues may include logging residues, rough rotten salvageable dead wood, and excess small diameter trees. At the initial harvest, up to 50 % of the tree (leaves, tops, branches, stump) may not be useful to a particular industry. There is potential here for recovering some of the harvesting residue for energy, while still leaving a suitable amount of material to assist in soil recovery and nutrient flows. In fire dependent ecosystems forest harvesting residues can create increased fire hazard and this is reduced if the material is removed. Current strategies to lower fire danger focus on reducing these fuel levels through thinning. Most forest residues are suitable for energy conversion, but they may have high moisture content and may require some energy intensive drying depending on the conversion system to be used. The annual sustainable forest residue potential for bioenergy was calculated approximately 5 to 7 Mton by GDF. The maximum production potentials of fire wood, forest residues and shurbs vegetation are in the Mediterranean Region of Turkey. For example Mugla Forest Regional Directorate has approximately 750.000 ton woody biomass potential for bioenergy. Adana Regional Directorate has about 550.000 tonnes, Antalya and also Izmir Regional Directorates have significant forest residues production capacity.

Mediterranean Region is suffered from forest fires and forest fire combating is essential in this region. The General Directorate of Forestry spends great effort to effectively fight against forest fires in the Mediterranean Region. Forests in the Black Sea Region constitute the second largest forest residue potential. Forestry activities are very intensive in Kastamonu and Amasya Forest Regional Directorates. Furthermore, it is estimated that annual about 2 Mt. woody residues potential used in forestry industry for heating purposes in some production processes in Turkey.

The first biomass combined heat and power plant constructed by Mimsan Heating Technology - Turkey, which is using annual 60.000 ton wood residues and wood bark and producing 32 MW_{heat} and 10 $MW_{electricity}$ since 2008 at Caycuma Paper Factory in Turkey. Electricity production from wood is made only in this paper factory, OYKA, for its 70 % own heat and electricity need in Turkey. Eight heat plants which were constructed also by Mimsan Heating Technology - Turkey, are using cotton waste, sunflower shell, tea waste, sawdust, wood waste, paper waste, hazelnut shell and producing 82 MW heat energy (Table 6).

Table 6: Biomass plants regarding use of forestry and agricultural biomass in Turkey

Name of operator	Location	Technology suppliers	Type of feedstock	Heat capacity MW	Electricity capacity MW	Net calorific value Kcal/cal	Feedstock consumption Kg/h
Paymar Oil Factory	Hatay	Mimsan Heating Technology	Cotton waste, acidic oil, coal	8.3		2.500	3.800
Trakya Oil Factory	Bursa	Mimsan Heating Technology	Sunflower shell, coal	5.5		2.800	2.140
Çaykur Tea Factory	Rize	Mimsan Heating Technology	Tea waste, coal	10.4		2.000	5.650
Akfa Tea Factory	Giresun	Mimsan Heating Technology	Tea waste, coal	10.4		2.000	5.650
Meray Oil Factory	Merzifon	Mimsan Heating Technology	Sunflower shell, coal	6.9		2.800	2.650
Vezirköprü Forest Product F.	Samsun	Mimsan Heating Technology	Wood bark, sawdust, wood waste, coal	2 x 12,5		3.200	2 x 4.100
Oyka Paper Factory	Caycuma	Mimsan Heating Technology	Wood bark, sawdust, wood waste, coal	32	10	3.200	8.850
Gitas Oil Factory	Konya	Mimsan Heating Technology	Sunflower shell, coal	6.6		2.800	2.550
Marmara Oil Factory	Bandırma	Mimsan Heating Technology	Sunflower shell, coal	8.4		2.800	3.200
Bat Oil Factory	Georgia	Mimsan Heating Technology	Sunflower shell	8.4		2.800	3.200

Natron Paper Factory	Bosnia and Herzegovina	Mimsan Heating Technology	Wood bark, sawdust, wood waste	35	8	3.200	9.250

3. The advantages of wood as a energy feedstock

Wood fuel has several environmental advantages over fossil fuels. The main advantage is that wood is a renewable resource, offering a sustainable, dependable supply. Other advantages include the fact that the amount of carbon dioxide (CO_2) emitted during the burning process is typically 75 % less than that of fossil fuel. Wood fuel contains minimal amounts of sulfur and heavy metals. It is not a threat to acid rain pollution, and particulate emissions from wood are controllable through standard emission control devices such as bag houses, cyclone separators, fly-ash injectors, and electronic precipitators. Bottom ash is minimal. Usually, wood ash is less than 1 % of the weight of the wood, and sometimes wood's ash may be used as a fertilizer. Wood is a rich fuel in terms of volatile substances and hydrogen. It is burned in short time compared to coal and provides quick heat. Less air is needed for wood combustion. Wood energy can be managed as a carbon neutral feedstock: replanting trees neutralizes CO_2 emitted from wood fuels. However, fossil-derived oil, coal, and natural gas are net carbon producers, which increase greenhouse gases without any possible regenerative offset.

Wood pellets are an economic, sustainable, and environmentally friendly alternative to the fossil fuels available. Both new and residual wood is used to supply the pellet production, and new raw material resources are constantly being developed. As well as residual wood, scrap wood such as tree tops and thinner trunks are readily used in pellet production. In the near future, the growing of energy-rich woods on follow agricultural areas could provide even more resources for pellet production in many countries and in Turkey. 15 million tons of wood pellet has been produced in 2009. It will be estimated to produced 270 million tons of wood pellets in 2030 in the world [2].

4. The Importance of forestry for Turkey

In the most of third World countries heating, cooking and other needs of people are supplied by 80-90 % wood energy consumption. However, firewood quantum is not enough in these countries. Also in our country, firewood consumption is more than developed countries. But, wood production capacity is not sufficed and so this situation makes negative effect on forest areas. If oak, poplar, willow, eucalyptus, alder, acacia energy plantations, that will be able to profit to economy of country, supply and demand balance in wood production may be maintained. Thus, coppice forests that exploited by short rotation periods may be maintained, and increasing and continuous wood production may be supplied. In addition, varied energy sources and chemical matters may be produced by new transformation of energy systems.

Although natural forests in our country have decreased rapidly for the last 100-150 years, our population and the necessity of wood have increased. Deforestation and erosion are big problems of our country and erosion will cause the lack of natural forests in the first part of the 21st century. 45 % of population are living in rural areas near the forest land and their economic status is too low. Higher life standards they get, the better chances we can get to prevent their negative effects on forest land. In order to increase the rate of required raw material, the policies of production of raw material must be reorganized, because, it is an

important step to prevent erosion. Natural forest land in our country is not satisfactory to solve this problem.

Not long ago combustion of biomass was a principal method of providing heat for the home in Turkey. Wood was the fuel of choice for cooking and heating water. In effect bioenergy is one of the oldest energy resources. A key difference that distinguishes this source of energy from other natural resources such as petroleum, coal and nuclear is that wood energy is a renewable energy.

Bioenergy is defined as all energy derived from biofuels, that is fuels derived from biomass (matter of biological origin). Conversion of biomass into solid, liquid or gaseous energy sources, leads to a wide range of applications. It can be:

- burned directly to produce heat and/or electricity,
- converted biochemically to produce liquid fuel;
- digested or gasified to produce gaseous fuel; and finally,
- pyrolized to produce oils and high value chemicals.

Typical biomass supply is derived from: woody forest residues, fire wood, mill residues, short rotation crops; non-woody agricultural crops, crop residues, processing residues; and animal waste such as manure from feed lots and municipal sewage and waste [3].

Sustainably managed forests have multiple environmental and socio economic functions important at the global, national and local levels, and play a vital part in sustainable development. Reliable and up to date information on the state of forest resources is crucial not only on area and area change, but also on such variables as growing stock, wood and non wood products, carbon, protected areas, use of forests for recreation and other services, biological diversity and forests contribution to national economies to support decision making for policies and programmes in forestry and sustainable development at all levels.

The two largest sources of biomass supply in Turkey come from forestry and agricultural operations. Another important function of forests is that they are major renewable energy sources. In most of Turkey, forest growth exceeds harvest and mortality and some of this growth is potentially available for biomass energy. Forest derived woody biomass includes small diameter trees, tops, and branches that are not included in a conventional timber harvest registry. With proper management and harvesting techniques, this traditionally unmerchantable woody material can be removed without compromising the health of the forest ecosystem, wildlife habitat, or soil nutrient cycles. Thanks to new markets for low grade forest products, foresters will be able to use a greater array of management techniques to produce higher quality timber, improve forest health, create early successional habitat, and design management plans [4].

Forests that are insufficient for supplying the fuel wood demand of forests villages have been heavily utilized. Thus their sustainability has been under a serious threat in Turkey. For these reasons, measures should be taken not only in the form of protection, but also in the way in which alternative energy sources such as fuel briquettes and energy forests are introduced to the needy while searching for alternative energy sources. Heavy utilization on high forests should be lifted through establishing energy forests near the forest villages[5].

The interesting and promising results obtained from experimental cultivations and from laboratory tests emphasize the importance of continued research into energy forestry. In order to achieve cultivation areas of importance from the national economic perspective up to year 2010, introduction of practical energy forestry should be immediately started in areas where

conditions are promising. Domestic species of trees, when cultivated as energy forests, have all possibilities of becoming very important renewable and environmentally-adjusted sources of energy.

In Turkey of the future there will be keen interest in cultivating broadleaved species (oak, poplar, willow, eucalyptus, alder, acacia) on suitable forest land and on former agricultural land. The wood produced will be used primarily as a source energy and a source of short fibres. As a result of developments in the paper industry, more and more short fibres will be needed in future industrial processes. Biomass production for energy purposes through the cultivation of fast-growing, broadleaved trees will result in an ecologically sound and economically viable crop. It is still possible to solve some of our environmental problems in an efficient and perhaps even a cost-effective way by utilising suitably located forest land and former agricultural land for energy, fibre and timber production [6,7].

In Turkey, to meet principally the need for firewood and with the objective of decreasing the unfavourable effects upon forests from grazing and use of leaves and branches, starting in the South-eastern as well as the Eastern and Central Anatolian regions, emphasis is placed on energy forest facilities. By generating the unproductive or very unproductive coppice areas by vegetative means " energy forest regeneration " activities are undertaken for " Energy Forest Facilities " and the protection of productive coppice areas and filling in of empty areas. The amount of land suitable for energy forestry in Turkey has been calculated to about 4 million hectares forest land. Agricultural land and other types of land can be added to this amount. The most interesing areas for introduction of energy forestry are the unproductive or low productive oak coppice areas of southern, south-eastern and middle of Turkey. Oak species with 6.426.277 hectares (2.005.401. ha productive forests, 4.420.877 ha degraded forests) has 30.32 % ratio of total forest area, the biggest percentage in these and other areas of Turkey. As table 6 shows, 623.247 hectares energy forest has been established in the degraded oak coppice forests between the period of 1978 - 2005 in Turkey (Table 7).

Table 7: Energy forest plantations between the period of 1978-2005 in Turkey

Year	1878-1980	1981-1990	1991-2000	2001	2002	2003	2004	2005	1978-2005
Hectare	12531	383664	153129	13194	13100	14812	14032	18785	623247

Source: Republic of Turkey, Ministry of Environment and Forestry, Forestry Statistics, 2013

Fuelwood from energy forests is used for heating and cooking. For many years, some unproductive and productive coppice forests were assumed to be allocated for potential areas by the Turkish Forest Service. A General Directorate of Forestry project made available the locations of coppices, natural forests and potential areas for energy forest establishment. Goals are to protect biological diversity in coppice and natural forests especially near settlements, increase productivity and use of wood and wood residues for energy by establishing combined heat and power plants, reduce soil erosion, reduce the volume of environmentally harmful emissions, create new job opportunities for local people and challenge them in rural participation on sustainable forest management. Turkey's annual biomass potential is about 117 million tons and the total biomass energy potential is about 32 Mtoe. The amount of usable biomass potential of Turkey is approximately 17 Mtoe. The electrical production from usable biomass has a net impact of 4,4 billion USD in personal and corporate income and represent more than 160,000 jobs [8].

The potential in very degraded forest areas should be utilized to support the national economy by the establishment of energy forests. With respect to the selection of areas to be utilized for

energy forests, degraded forests and degraded coppice forest areas should have priority. Energy forests are also important for making fuel wood and forage available and for erosion control. In Turkey there are about 4 million ha of degraded coppice forest that are suitable for the establishment of energy forests [9].

The first wood pellet plant in Turkey produced wood pellet in 2005. Pellet plants are producing nearly 200.000 ton pellet in Turkey in a year. Pellet production from wood- and agricultural wastes are playing an important environmental role in Turkey too. 20 million tons of wood pellet has been produced in 2014 in the world. It will be estimated to produced 350-400 million tons of wood pellets in 2030 in the world [10].

5. Conclusion

Turkey is a developing country with rich biomass potential. Because Turkey is an energy-importer country, indigenous energy sources of Turkey are of strategic importance. Limited sources of petroleum-based fuel made the subject of producing quality energy and productive usage of it an important point for Turkey. Among the renewable energy sources, fuelwood seems to be the most interesting because its share of the total energy production of Turkey is high, at 21 % in 1995 and the techniques for converting it to useful energy are not necessarily sophisticated. Biomass can be used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers high-energy conversion efficiencies. The electricity produced by direct combustion of biomass, advanced gasification and pyrolysis technologies are almost ready for commercial scale use. A supplementary firing of biomass in steam-electric power plants may, under certain circumstances, prove to be economically feasible.

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