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Renewable energy from woody biomass 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 11 %. Turkey's annual biomass potential is about 120 million tons and the total biomass energy potential is about 36 Mtoe. The amount of usable biomass potential of Turkey is approximately 18 Mtoe. Turkey has the potential to produce 4.0 million tons of wood pellet has approximately 780 million dollars of market value by the help of existing woody biomass. Producible wood pellet could account to 1.4% of total primary energy consumption in 2014 and 1.38% of imported energy. If Turkey utilized existing woody biomass as wood pellet, this would represent a saving of 340 million dollars from energy imported in 2014. The capacity for wood pellet production in Turkey is quite low, due to its high cost. Therefore, relevant institutions should launch more projects to promote the production and consumption of wood pellet. International pellet standards should be adopted, and private sector should be encouraged by government.

Keywords: Biomass; bioenergy; energy forestry; pellet production; Turkey.

1. Introduction

There is an increasing tendency all around the world to use the renewable energy sources instead of fossil fuels with a view to mitigate climate change, supply renewable energy, adapt to climate change and for other reasons [1]. However, certain criteria such as protection of the forest, enhancement of biodiversity, competitiveness for forest products, sustainability, development of appropriate policies should be met to use the forest based woody biomass for bioenergy as a renewable source. The woody bio mass is a main component of the forest biomass, a significant potential as a primary energy source in the world, that has been used in various forms ranging from industrial raw material to energy wood through modern and/or traditional ways. Woody biomass from forestry is defined as all of the aboveground and underground biomass of trees, including all by-products and residues [2-5].

Woody biomass can be generated directly from harvest operations related to the commercial and precommercial forest management, forest restoration and fuel reduction activities [3, 4]. The natural gross potential of biomass energy (including agricultural, forestry and other products) was calculated as 120–130 Million tons of oil equivalent (Mtoe)/year while it was assumed that the net potential was 70 Mtoe/year, the technical potential was 30 Mtoe/year, and the economical potential was 20 Mtoe/year in Turkey [4]. According to the data obtained from the Ministry of Energy and Natural Resources (MENR), the total available biomass potential was roughly 7.0 Mtoe per year. Furthermore, the total woody biomass was 1 660 million tons only in the productive forest area and 162 tons per hectare according to the statistical data of FAO [4]. The total recoverable bioenergy potential from agricultural residues, forestry wastes and wood processing residues was estimated to be 17 Mton in 2000. The total biomass production was anticipated to be 12.6 Mtoe in 2020 [6-8].

Energy need has been increasing day by day with population increase and developing technologies [9]. This situation leads the need for finding new energy sources. For the last decades, biomass energy has

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been considered as an alternative to available energy sources. Biomass energy has found great opportunities for being environmentally friendly sustainable energy source, providing safe environmental management and targeting development throughout the world. For this reason, utilization of biomass energy has gained importance as an energy source in Turkey [10-14]. The present study discussed the potential and utilization of the renewable energy from woody biomass in Turkey. The results show that woody biomass energy has the potential to be a key player among the renewable energy options in Turkey, aiming to a reduction in the short term and substitution in the long term of fossil fuels dependence [15-26].

2. Woody biomass for energy

2.1. Introduction

Wood is already the major source of renewable energy in Turkey which is used for heating purposes. People in rural areas are the biggest users of wood energy. But unfortunately industrial wood energy sector has not developed yet. There are only a few wood briquettes production factories. wood chips are only used in some processes for heat generation in big forestry factories. Although there is no commercial wood and co-firing power plants in Turkey, due to the promote legislation it is expected to be installed in next years. However, the growth of the biomass sector in Europe creates an opportunity for the development of wood energy markets in Turkey [10-16].

Wood fuel has several environmental advantages energy [2-4].

over fossil fuel. The main advantage is that wood is a renewable resource, offering a sustainable, dependable supply [3]. Other advantages include the fact that the amount of carbon dioxide (CO_2) emitted during the burning process is typically 90% less than when burning fossil fuel [3]. Wood fuel contains minimal amounts of sulfur and heavy metals. It is not a threat to acid rain pollution, and particulate emissions are controllable. The principle economic advantage of wood biomass energy is that wood is usually significantly less expensive than competing fossil fuels (see Table 1). Public institutions, such as schools, hospitals, prisons, and municipality-owned district heating projects, are prime targets for using wood biomass

Table 1. Cost and combustion efficiencies of the fuels

Fuel	Cost	Application Efficiency	Cost ($) perMillion kJ
Coal	250 US$/Ton	75%	11
Pellets	190 US$/Ton	80%	15
Fuel oil	3.60 US$/gallon	78%	33
Electricity	0.12 US$/kWh	100%	35
Natural gas	1.40 US$/Therm	78%	18
LP Gas/Propane	2.84 US$/Gallon	78%	40
Hardwood	200 US$/Cord	60%	17

Before building or remodeling a facility to utilize wood biomass for energy, potential users should evaluate the local market for the available supply of wood. Transportation costs may limit the benefits of burning wood fuel hauling wood biomass from outside of the 80 km radius is usually not economical. This should be followed by a rigorous life-cycle analysis for the energy system. Initial costs of a wood biomass energy system are generally 50% greater than that of a fossil fuel system due to the fuel handling and storage system requirements [3].

Today, the installed cost of a 0.3 to 1.5 MW wood fuel burner/boiler system is estimated at $150,000 to $225,000 per 1.0 MW of heat input. New and existing technology for using wood fuel effectively can be a combination of wood combustion, wood gasification, cogeneration, and cofiring, depending on the fuel application [5, 6].

2.2. Wood combustion

Instead of paying disposal costs, wood combustion for electricity and heat is one way in which forest products companies can utilize their wood residues. Typically, wood in a variety of forms, particularly green chips (45% to 50% moisture content on a wet basis), is shipped and maintained at a holding site by the energy plant. Augers or belt conveyors transport the wood chips to the combustor, where they are burned, and the heat of combustion is transferred to a steam or hot water boiler. Steam is converted to electrical power by steam turbines. Excess steam can be used in other plant processes—for example, in a dry kiln. Hot water boilers can provide heat to a building through a piping distribution network [3, 5, 6].

2.3. Wood gasification

Wood gasification is the process of heating wood in an oxygen-starved environment until volatile pyrolysis gases (CO and H_2) are released from the wood. Depending on the final use of the typically low-energy wood (producer) gas (~5.6 MJ/m³), the gases can be mixed with air or pure oxygen for complete combustion and the heat produced transferred to a boiler for energy distribution. Otherwise, the gases can be cooled, filtered, and purified to remove tars (a major concern for any wood gasification process) and particulates and used as fuel for internal combustion engines, micro turbines, and gas turbines [3, 5, 6].

2.4. Cogeneration

Cogeneration is the simultaneous production of heat and electricity, commonly called combined heat and power (CHP), from a single fuel. Traditionally, a steam turbine is used to produce electricity, although a wood gasification/ internal combustion unit can also be a cogeneration unit. Several factors affect the economic feasibility of a CHP unit including wood waste disposal problems, high electricity costs, and year-round steam use [3, 6].

Two common mistakes when installing a CHP system are buying a steam boiler that is designed for less than 690 kPa or oversizing the system [3]. Buying a steam boiler that is designed for less than 690 kPa results in a quality of steam that is not adequate for turbine operation. Oversizing the system results in additional capital costs and more electricity and heat are generated for a lesser amount of fuel by a CHP unit than by a separate heat and power (SHP) unit. Common challenges for all wood-fired systems are ensuring adequate fuel procurement and solving the complex fuel handling and storage issues [3, 5, 6].

2.5. Cofiring

Cofiring refers to the practice of introducing biomass as a supplementary energy source in coal plants. It is a near-term, low-cost option for using woody residue, costing approximately $0.02 per kWh while reducing pollutants [2]. Extensive demonstrations and trials have shown that effective substitutions of biomass energy can be made from 10% to 15% of the total energy input. Investments are expected to be $100 to $700 per kW of biomass capacity, with the average ranging from $180 to $200 per kW. Cofiring results in a net reduction in greenhouse gases and lower emissions of sulfur dioxide and nitrogen oxides [2, 3, 6].

3. Wood pellets: a good choice for heating

3.1. Introduction

Many building owners use fossil heating fuels, such as oil or propane, for space heating. These fuels are often expensive and unstable in pricing, and are threatening the global climate and sustainability of communities [7]. Proven alternatives to fossil heating fuels exist and are already in use across North America: Biomass fuels are a local, renewable resource for providing reliable heat [8]. Wood pellets are a common type of biomass. Biomass is any biological material that can be used as fuel—including grass, corn, wood, and biogas as well as other forestry and agricultural residues [3, 6, 7, 8].

One biomass fuel that has gained national attention with rising fossil fuel prices is wood pellets. Wood pellets are compressed by-products from the forest products industry, often woodchips and sawdust. They are a locally available and a cost-effective heating fuel with several advantages over other types of biomass [7].

Wood pellets are a condensed uniformly sized form of biomass energy, making them easier to store and use than many other biomass fuels. Pellet heating technology is also quite simple, minimizing operation and maintenance requirements. These heating systems can be easy to plan for and install and can save a building owner thousands of dollars in energy costs over time while providing significant local economic and environmental benefits [7].

Using biomass fuels helps mitigate such environmental issues as acid rain and global climate change. Perhaps the greatest advantage of biomass fuels, however, is that they cost on average 25-50% less than fossil heating fuels and are more stable in pricing. It is unlikely that any future carbon or energy taxes will increase the cost of biomass fuels and are more likely to raise the cost of heating with fossil fuels. The technology is becoming well established in the North American market and the choice to heat with biomass fuels can be as simple as choosing a traditional fossil fuel heating system. In addition [3, 7]:

- Wood pellets are convenient and easy to use, and can be bulk stored in less space than other biomass fuels;
- Wood pellets have a high energy content, and the technology is highly efficient compared to other biomass fuels;
- Wood pellets are a clean-burning renewable fuel source;
- Wood pellets are produced from such waste materials as forestry residues and sawdust
- Wood pellets are price stable compared to fossil fuels.

3.2. Characteristics, availability and cost

Wood pellets are a manufactured biomass fuel. They are made from wood waste materials that are condensed into pellets under heat and pressure. Natural plant lignin holds the pellets together without glues or additives. Wood pellets are of uniform size and shape (between 2-4 cm by approximately 0.5-1.0 cm in diameter), making them as easy to store and use as traditional fossil heating fuels. Wood pellets also take up much less space in storage than other biomass fuels because they have a higher energy content by weight (roughly 63 Kcal per Kg at 6.0% moisture content) due to their densified nature and low-moisture content (typically between 4-6% moisture by weight) [2, 3, 6, 7].

While wood pellets are typically not differentiated between soft and hardwood sources, there are three grades based on the amount of ash produced when they are burned:

- Premium (ash content less than one percent)
- Standard (ash content between one-two percent)
- Industrial (ash content three percent or greater)

Premium and standard grade pellets are suitable for any wood pellet boiler with automatic ash removal, including most institutional- or commercial-scale applications. Industrial grade pellets, or those with ash content greater than three percent, should be avoided due to the high volume of ash produced. For the residential market, wood pellets are sold in 40-pound bags at farm or building supply stores. Small commercial- or institutional-scale applications of the type being discussed here, however, require bulk delivery and storage. Several wood pellet manufacturers can deliver in bulk. The customer is charged per ton delivered, the price typically including a per-load fee scaled to the distance of the delivery [3, 6, 7].

When exploring the conversion from fossil fuels to wood pellet heat, an important consideration for building owners is the fuel-cost savings from using wood pellets. Because fossil fuels and wood pellets are sold in different units, a price comparison must be based on the amount of energy (in millions of kilo Joule, MkJ) delivered by each fuel. The basis for comparison then becomes the cost of producing one MkJ with each fuel being considered. Several other factors affecting the true cost of heating with any fuel include the energy and moisture content and the efficiency of the heating system used to burn each fuel. Figure 1 shows the cost competitiveness of different energy sources.

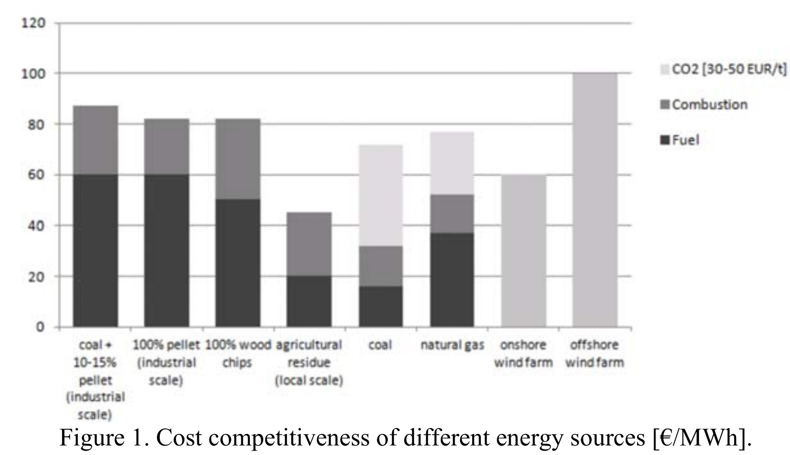


Figure 1. Cost competitiveness of different energy sources [€/MWh].

3.3. Global wood pellet market overview

Due to the global economy recovery, the demand for energy is increasing, and wood pellets as a new energy is also highly demanded internationally. In 2014, numerous companies invested in wood pellet plants which can covert biomass into pellets, which will be used for heat and electricity production. And the global pellet production reached 28 million tons in 2014, which is increased nearly 13% over 2014 volumes. As for 2014, the statistics are not yet fully available at present, however, according to related research study, the global production capacity of wood pellets is increased 8% and the global capacity of wood pellets has been reached to 25.5 million tons estimated [8]. Figure 2 also shows the global wood pellet production. As shown in Figure 2, the global wood pellet production is increased from 2.0 million tons in 2000 to 28 million tons in 2014.

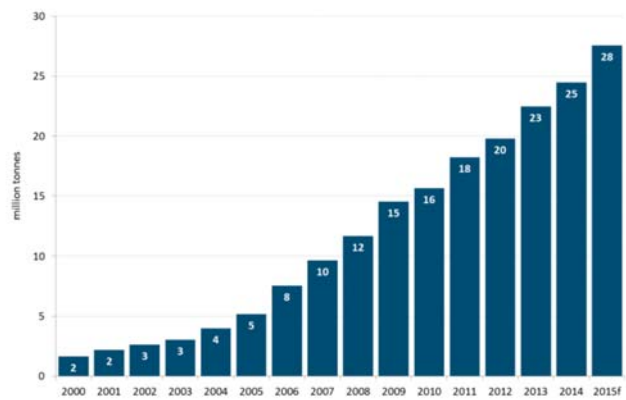
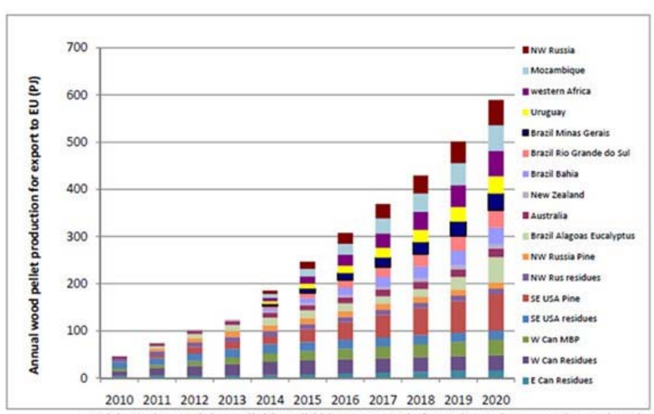


Figure 2. Global wood pellet production.

In terms of global perspective, in 2013 EU remains to be the largest wood pellet demander and producer, which produced 12.0 million tons pellets, with Germany, Sweden, Latvia, and Portugal as its top producers. Then it is Canada and US, Russia, and China, with pellet production capacity of 6.0 million tons, 2.0 million tons, and 2.0 million tons respectively. On the other hand, as for wood pellet consumption in 2013, Europe ranked top, which demanded 10.0 million tons of wood pellets for domestic heat production while 9.0 million tons of wood pellets for industrial uses, and it was followed by North America and Asia, with wood pellet consumption of 4.0 million tons and 1.0 million tons respectively [8]. Figure 3 shows annual global wood pellet production for export to EU as a Pega Joule (PJ).

In wood pellets global trade, Europe played a vital role in order to meet its growing demand for wood pellets. In 2013, the Europe imported about 6.4 million tons of wood pellets, with around 75% of total imports from North America, which is an 55% of increase comparing with 2012, and the rest was almost from Russia and Eastern Europe [8].



anticipated growth in available solid biomass supply from the various sourcing regions in the high import scenario from 2010 to 2020. For comparison: 1 million tonnes of wood pellets equals about 18 PJ.

Figure 3. Annual global wood pellet production.

4. Woody biomass in Turkey

Turkey's biomass energy is flourishing and amazing opportunities for the development and commercial implementation of energy crops. Energy imports in Turkey are 75% of its energy needs and energy demand in the country is forecast to double by 2020. Supporting sustainable energy investments is therefore a key element of several banks and investors in Turkey. The Republic of Turkey located in southeastern Europe and southwestern Asia, has an area of over 779,452 km^2 and a population of 82 million. Economic growth in recent years has been associated with the privatization of public enterprises. Macroeconomic performance was boosted by a growth in the energy sector [8-12].

Figure 4. Turkey's biomass amount (ton).

The demand for energy and particularly for electricity is growing rapidly as a result of social and economic development. Recently, the Turkish Central Bank has launched the Turkish Sustainable Energy Financing Facility worth up to US$ 250 million, for on-lending to businesses and households via local partner banks [9].

On the other hand, the proceeds of the facility are used to finance energy efficiency and small-scale renewable energy investments, including geothermal, solar, biomass and biogas, implemented by Turkish businesses and households, helping them to cut their carbon footprint by reducing energy wastage. Some local companies have developed enough an evaluation of resources and define the map we have included here below which shows a total national potential of 170 TWh/year [13-16].

Turkey has a great potential, but energy crops sometimes will be required to minimize biomass collection and supply chain risks to bio-based industries Turkey represents a stable investment environment in South-East Europe with clear rules and fair FIT rates [9]. Current cumulative installed biomass capacity in the country of 130 MWe is insignificant, but a number of fully permitted and ready to build projects will promptly increase in 2014. On the other hand, Turkish biomass market has a good chance of reaching several hundred MWe cumulative installed capacity in the next four years. The report provides a complete picture of the market situation, dynamics, current issues and future prospects [17-20].

The largest portion of this product is used in rural areas for heating and cooking in a primitive way. Turkey has about 21,7 million hectares of forest area (about 27,2% of country's land area) [10]. A similar share is occupied by pastures and grasslands. Turkey has about 21,7 million hectares of forest area (about 27,2% of country's land area).

A similar share is occupied by pastures and grasslands. The consumption of forest biomass compared to total energy has slightly decreased from 22 to 14% during the last decade because the consumption of liquefied petroleum gases (LPG) is increasing continuously. LPG is not expensive; it is easy to transport and ignite, and in addition it is a clean fuel. Domestic energy consumption accounts for 37% of the total energy consumption [21-26].

The annual biomass energy potential of Turkey has been estimated to be 32 Mtoe and the total biomass consumption in Turkey was 5.2 Mtoe/year (in 2014). The recoverable biomass energy potential come from [10-12]:

- Agricultural residues
- Forestry and wood processing residues

- Animal wastes
- Municipal wastes.

Electricity selling price regulations that are generated with the usage of the renewable energy sources such as hydropower, wind, geothermal, biomass and solar. In 2014, electrical production from biomass, primarily wood, had a net impact of $4.7, billion and biomass electrical-generating capacity will have grown to approximately 36 GW in 2014 [9, 10]. At this capacity level, the economic benefits are estimated to be $6.6 billion in personal and corporate income and 250,000 jobs [12, 13, 14].

One alternative for producing electricity from biomass in a gas turbine is direct combustion of biomass as a primary energy source. Biomass is burned directly to produce steam; the steam turns a turbine and the turbine drives a generator, producing electricity. Because of potential ash build-up, only certain types of biomass materials are used for direct combustion. Direct combustion usually involves reducing the biomass into fine pieces for fueling a close-coupled turbine system. In a close-coupled system, biomass is burned in a combustion chamber separated from the turbine by a filter.

Renewable electricity production is supported by feed-in rates. The feed-in rates for the different types of renewable electricity generation are (MENR, 2016):

- Wind and Hydraulic Power: 7.1 cents $/kWh
- Geothermal Power: 10.2 cents $/kWh
- Biomass/Biogas Power and solar: 12.6 cents $/kWh

This selling price is for both gasification and combustion applications. Legislation has been recently approved by Turkish Assembly at the end of 2016. With this attempt, Turkey is newly on the way of subsidizing renewable energy entrepreneurs and of increasing the usage of biomass as well [9, 10]. Table 2 shows the estimated energy amount from renewables.

Table 2. Estimated energy amount from renewables for heating and cooling in Turkey (ktoe)

Renewables	2014	2015	2016	2017	2018	2019	2020	2021	2022
Geothermal	360	380	390	405	420	430	452	460	474
Solar	660	682	691	710	718	734	746	760	778
Woody biomass	3 550	3 550	3 550	3 550	3 550	3 550	3 550	3 550	3 550
GHP	1 850	1 882	1 952	2 024	2 096	2 158	2 234	2 309	2 370
TOTAL									

GHP: Geothermal Heat Pump; ktoe: kilo tons of oil equivalent Data Source: Ref. [9]

Not many experiences with novel energy crops have been experienced and reported in Turkey in recent years. Some published reports with Miscanthus have shown low potential in semiarid lands (310mm rainfall per year) with yields as low as 7 dried tons per hectare [11]. The fact is that a semiarid land like Turkey needs to use the long record and experience we had in Spain, Italy and Greece. Alternatives like Cardoon, Tall wheatgrass and many other crops we suggested for marginal lands, has much more sense in marginal lands with extremely low lands lease costs. Irrigated and rain-fed crops are both possible in several regions now occupied with grasslands or in abandoned lands [11].

Biomass energy has the potential to be a key player among the renewable energy options in Turkey, aiming to a reduction in the short term and substitution in the long term of fossil fuels dependence (see Tables 2-4 and Figs. 4-6).

According to the energy need of the country it was identified that bioenergy options that supply heating and cooking as well as electricity would have a prime interest. Thus, the potential to convert biomass residues into more efficient fuels such as briquettes and pellets or alternatively directly produce heat and electricity using CHP was the main interest area of BEFS assessment. The results of this assessment indicate that there exists a high potential to supply the renewable energy targets based on the available biomass in Turkey, using efficient technologies and specific profitable production conditions [10].

Technical meetings and expert workshops were held in Turkey with the lead government counterparts, including country experts in the related fields. The discussions held throughout the various phases of the workshop and at the final presentation raised the following issues [10]:

Table 3.Turkey's annual biomass energy potential in 2013

Biomass	Annual potential (million tons)	Energy value (Mtoe)
Crops	60	20.0
Forest residues	20	5.4
Residues from agro-industry	10	3.0
Residues from wood industry	5	1.6
Animal wastes	6	1.4
Other	9	1.6
Total	110	33.0

Table 4. Present and planned biomass energy production in Turkey

Years	Modern biomass (ktoe)	Classic biomass (ktoe)	Total (ktoe)
2012	2121	5364	7485
2014	2543	5082	7625
2016	2854	4856	7710
2018	3284	4568	7852
2020	3598	4234	7832
2022	3860	3976	7836
2024	4086	3785	7871
2026	4472	3556	8028
2028	4732	3322	8054
2030	4940	3300	8240
Total	39840	53773	93613

- Lack of knowledge and awareness of biomass, biomass potential which limits the understanding of what potential for bioenergy may exist and where and how to exploit such potential;
- Lack of technology, although various stakeholder reported on a number of industries starting up in the country;
- Lack of policy coordination across sectors with related lack of inter-ministerial coordination across relevant bioenergy policy areas in the country, including agriculture, environment and energy policymakers. At times, this can result in bottlenecks in the mobilization and use of the identified net available resources. There is the need for the agriculture, environment and energy policymakers and industry players to agree and coordinate on defining which residues can be used and are available for use [10].

The measures discussed and pointed to were the following [10]:

- Feedstock collection points;
- Central management platforms for biomass;
- Need for policy coordination;
- Clarification of what may be agriculture waste or what may be agriculture residues that could therefore be used for bioenergy; and
- A system to coordinate feedstock supply to ensure stability of supply.

In the short-term, it is recommended that bioenergy production should focus on those residues that are either already collected in field or at the agro-processing plant. Residues that are already collected have low mobilization costs as well as high accessibility [9]. It is recommended to identify the most promising feedstock, in terms of quantity available and suitability to be used for CHP, biogas production and for the production of briquettes and pellets. The country can then identify and verify the province with highest availability and accessibility of that feedstock [10].

In the long to medium term, efforts should be made to develop appropriate policies and mechanisms, to put in place an agricultural residue value chain that ensures a uniform and dependable supply of residues. This should involve cooperatives, intermediaries and a mechanism to encourage information exchange between energy producers and biomass owners as well as policies to introduce mechanization equipment for the collection and pre-treatment of residues and storage facilities [10].

5. Conclusions

Today, biomass energy continues to be the main source of energy in many developing nations, particularly in its traditional forms, providing on average 35% of the energy needs of three-quarters of the world's population. This rises to between 60 and 90% in the poorest developing countries. However, modern biomass energy applications are increasing rapidly both in the industrial and developing countries, so that they now account for 20–25% of total biomass energy use. For example, the USA obtains about 5% and Finland and Sweden 25% their primary energy from biomass. Biomass energy is not a transition fuel as it has often been portrayed, but a fuel that will continue to be the prime source of energy for many people.

Turkey is a developing country with rich biomass potential. Because Turkey is an energy important 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, woody biomass seems to be the most interesting because its share of the total energy production of Turkey is high, at 10 % in 2008 and the techniques for converting it to useful energy are not necessarily sophisticated.

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