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Global utilization of wood pellet for residential heating

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Abstract
Renewable sources particularly biomass account for an increasing proportion of energy generation. This change is due to increasing price of fossil fuels, supply problems, development of alternative sources and efforts to limit the use of fossil fuels in order to address climate change. Typical energy sources in rural areas include fuel oil, residual oil, propane, electricity, wood and other renewable resources. 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. 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. 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. Wood pellet is a biomass alternative to fossil fuels. All over the world, approximately over 26 million tons production of wood pellet have been made and consumed. The major producers and traders in wood pellet are Russia, Canada, the USA and EU countries.

Keywords: Renewable energy sources; fossil fuels; biomass; wood pellet.

1. Introduction

Rapid increase of the effects of energy sources on social life and the need for these sources from the basic reasons like increase in population, economic developments, and the changes in social relationships and increase in energy-based life styles [1, 2]. The relationship between people and sources of energy has been developing throughout history, accelerated following the industrial revolution. Within the last two centuries, primary energy consumption increased by 3666% and CO_2 emissions increased by 2133% [3, 4]. In the last two centuries, fossil fuels have been widely used due to low constant developments in production technologies [5]. Fossil fuels have therefore predominated over renewable sources of energy [6]. The energy era of cheap petrol and coal faced a price-shock during the oil crisis of 1973 [7]. As a result of this feeling of insecurity, deep interest in new and renewable sources of energy occurred all over the world [8, 9].

The use of fossil fuels has important effects on environmental pollution and the emission of greenhouse gases, especially CO_2 cause global climate change [4]. The amount of CO_2 emitted to the atmosphere was 15.7 billion tons in 1973 and reached 37.2 billion tons in 2013 [5]. Biomass energy is therefore regarded as playing a crucial role in global decarbonization [8]. Biomass energy reduces dependence on fossil fuels and is more easily stored and transported than other renewable energy sources. Biomass energy is widely used all over the world. Figure 1 shows global woody biomass trade for energy [8]. Many countries began to use biomass, especially woody material to reach the target they determined [10-12].

Wood pellet is more popular than other biomass fuels, predominantly due to its physical and combustion characteristics [13]. Wood pellet is obtained by smashing and compressing the wood residuals such as wood chips and tree bark [14]. Sawdust or wood chips that are compressed under high temperature and pressure bind together, due to their lignin content, to form wood pellet [8]. Wood pellet, which is a subsidiary product obtained from sawdust as a result of wood processing, can now also be obtained from round chocks and battens [13]. Wood pellet is highly preferable to other solid

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biomass fuels due to its low humidity (less than 10%) and high energy density. Figure 2 shows the global wood pellet consumption by region and country.

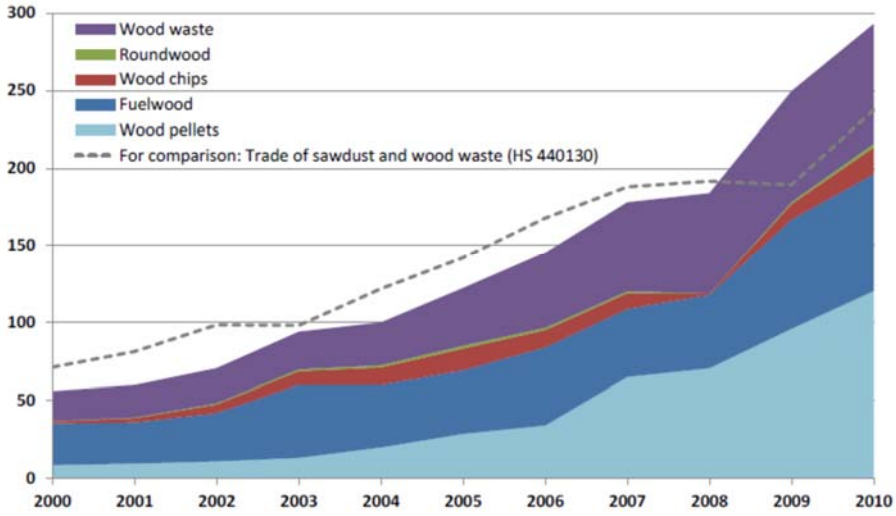

Figure 1. Global woody biomass trade for energy (PJ).

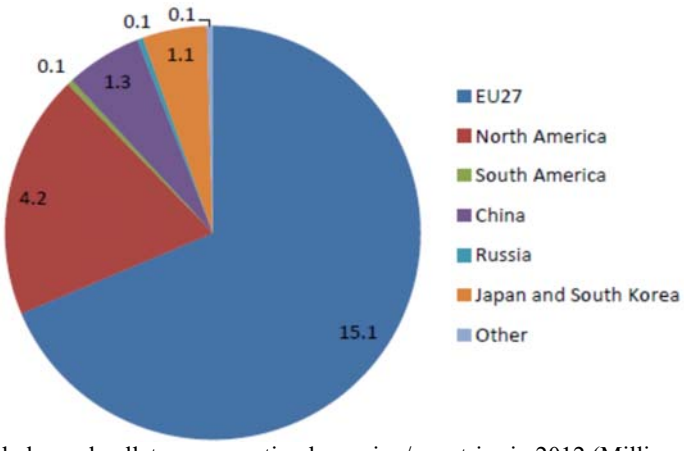

Figure 2. Global wood pellets consumption by region/countries in 2012 (Million ton).

Recently, wood pellet has become increasingly popular as a sustainable domestic heating source in countries with large forests [8, 13]. In addition, wood pellet plays a crucial role in neutralization of atmospheric carbon due to its positive effect on nature [2, 5]. Wood pellet produces atmospheric CO_2 emissions of 68 kg/MW, compared with natural gas 228 kg/MW, fuel-oil 342 kg/MW and electric heating 681 kg/MW. Compared with wood pellet, in order to produce1 MWh energy, natural gas gives off three times more, fuel-oil gives off five times more and electric heating gives of ten times more CO_2. We can conclude from these values that energy production with pellet and pellet usage will contribute especially to meeting Turkey's carbon quota [11]. The objective of this work is to discuss the production and consumption of wood pellets globally and calculate the cost of pellet production in Turkey.

2. Global energy demand

Global energy demand is set to grow by 37% by 2040 (Table 1) according to the International Energy Agency (IEA) scenarios, but the development path equal parts: oil, gas, coal and low-carbon sources. for a growing world population and economy is less Consumption increased for all fuels, reaching record energy-intensive than it used to be [4]. By 2040, the levels for every fuel type except nuclear power; world's energy supply mix divides into four almost- production increased for all fuels except coal [2]. For

oil and natural gas, global consumption growth was weaker than production. The data suggest that global CO_2 emissions from energy grew at their slowest rate since 1998, other than in the immediate aftermath of the financial crisis [3]. Emerging economies accounted for all of the net growth in energy consumption, as they have on average over the past decade, although growth in these countries was well below its ten year average [4]. Chinese consumption growth was the slowest since 1998, yet China still recorded the world's largest increment in primary energy consumption. OECD consumption experienced a larger than average decline, with weakness in the EU and Japan offsetting above average growth in the US [2, 5].

Table 1. World total final consumption in [1]

Energy source	2012	2020	2040
Coal	3 879	4 346	5 346
Oil	4 194	4 492	5 274
Gas	2 844	3 186	4 326
Nuclear	642	842	1 384
Hydropower	316	386	546
Biomass and bioenergy	1 344	1 554	2 264
Other renewables	142	302	1 286
Total energy demand	13 361	15 108	20 426

Global energy consumption increased by just 0.9% in 2014, a marked deceleration over 2013 and well below the ten year average of 2.1%. Growth in 2014 slowed for every fuel other than nuclear power, which was also the only fuel to grow at an above-average rate. Growth was significantly below the ten year average for Asia Pacific, Europe & Eurasia, and South & Central America. Oil remained the world's leading fuel, with 32.6% of global energy consumption, but lost market share for the fifteenth consecutive year [5, 8].

Global oil consumption grew by 0.8 million barrels per day in 2013. Countries outside the OECD once again accounted for all of the net growth in global consumption. OECD consumption declined by 1.2%, the eighth decrease in the past nine years [5]. Chinese consumption growth was below average but still recorded the largest increment to global oil consumption; Japan recorded the largest decline, with Japanese oil consumption falling to its lowest level since 1971. Light distillates were the fastest growing refined product category for a second consecutive year.

World natural gas consumption grew by just 0.4%, well below the ten year average of 2.4%. Growth was below average in both the OECD and emerging economies, with consumption in the EU experiencing its largest volumetric and percentage declines on record. The Europe & Eurasia region had the five largest volumetric declines in the world in Germany, Italy, the Ukraine, France and the UK. The US, China and Iran recorded the largest growth increments. Globally, natural gas accounted for 23.7% of primary energy consumption [5, 8].

Global coal consumption grew by 0.4% in 2014, well below the ten years average annual growth of 2.9%. Coal's share of global primary energy consumption fell to 30.0%. Consumption outside the OECD grew by 1.1%, the weakest growth since 1998, driven by a flattening of Chinese consumption. India experienced its largest volumetric increase on record, and the world's largest volumetric increase. OECD consumption fell by 1.5%, led by a 6.5% decline in the EU. Global coal production fell by 0.7%, with large declines in China and Ukraine more than offsetting large increases in India and Australia [8].

Global nuclear output grew by an above-average 1.8%, and the first time nuclear power has gained global market share since 2009. Increases in South Korea, China and France outpaced declines in Japan, Belgium and the UK. Japanese nuclear power output ceased in 2014 as the country's last operating reactor was taken off line. Global hydroelectric output grew by a below average 2.0%. Growth in the Asia Pacific region offset drought-driven declines in the Western Hemisphere and Europe & Eurasia. Chinese hydroelectric output grew by 15.7% and accounted for all of the net increase in global output. Drought conditions reduced output in Brazil by 5.5% and in Turkey by 32%. Hydroelectric output accounted for a record 6.8% of global primary energy consumption [1-5].

Renewables continued to increase in 2014, reaching a record 3.0% of global energy consumption. Renewables used in power generation grew by 12.0%. It meant that renewables accounted for a record 6.0% of global power generation [2]. China recorded the largest increment in renewables in

power generation. Globally, wind energy grew by less than half of its ten year average, with below average growth in all regions. Solar power generation grew by 38.2%. Global biofuels production grew by a below-average 7.4%, driven by increases in the US, Brazil, Indonesia and Argentina [4].

3. Global wood pellet market

Wood pellet is a biomass fuel and a renewable energy source [7]. Wood pellet has advantages over all other renewable energy sources due to being environmentally friendly, and the simplicity of its production technology [14]. Wood pellets are fuel chunks of 6–10 mm diameter that are obtained by drying wood waste that is ground to make sawdust and compressed under high pressure [15]. Densification consists of three stages: drying, grinding and pelleting [16]. Sawdust, which initially has 50–60% moisture content is oven-dried to reduce the moisture content to 10% [17]. In the second stage, this sawdust is screened through a grid of approximately 6.4 or 3.2 mm diameter, pressed and transformed into pellets. Pellets are pressed at approximately 70–90 ^{o}C, then cooled to 25 ^{o}C and then packed [18-26]. Table 2 shows the global wood pellet trade in 2013 and Table 3 also shows the main pellet producers in the European Union region [8].

Table 2. Global wood pellet trade in 2013

Exporter	Importer	Volume (Kilotons)
Australia	EU-27	31
Belarus	EU-27	134
Bosnia Hersek	EU-27	187
Canada	EU-27	2,093
Canada	Japan	50
Canada	South Korea	50
Canada	United states	30
Croatia	EU-27	165
Egypt	EU-27	16
EU-27	Switzerland	39
EU-27	Norway	18
Norway	EU-27	60
Russia	EU-27	642
Serbia	EU-27	55
Southeast Asia	Japan	100
Southeast Asia	South Korea	100
Ukraine	EU-27	159
United States	EU-27	2,828
Other	EU-27	19

Table 3. Main pellet producers in European Union (1,000 MT)

Country	2009	2010	2011	2012	2013	2014*
Germany	1 600	1 750	1 880	2 200	2 260	2 450
Sweden	1 580	1 650	1 340	1 340	1 340	1 450
France	345	465	530	680	910	1 300
Latvia	525	615	713	979	1 000	1 020
Austria	695	850	940	894	940	960
Portugal	287	627	675	700	730	740
Poland	410	510	600	600	620	680
Total	7 940	9 186	9 470	10 650	11 940	13 260

MT: Million Tons ; *: estimated

For wood pellet, The European Union CEN/TC 335 study group has attempted to standardize all solid bio fuels that are defined within biomass [21]. European Union wood pellet standards have been proposed, designated CEN/TS 14961 [27]. In addition, many European countries have developed their own quality standards. For example, Austria uses Önorm M7137 standards, Germany uses DIN51731 and Italy uses Pellet Gold standards [28-31]. The characteristics of wood pellet in the general framework are given in Table 4.

Table 4. Pellet properties

Size	6-10 mm diameter and 10-30 cm length
Energy content	4.5-5.5 kWh/kg (17-19 MJ/kg)
Moisture content	7-12%
Ash content	Approximate 0.5%
Bulk density	650-700 kg/m^3
Space demand	Approximate 1.5 m^3/ton

Wood pellets used for energy constitute one of the largest international markets of solid biomass fuels [23]. Wood pellet can now be compared with biodiesel and bioethanol in terms of trading volume [24]. In 2007, global pellet production was 9.7 million tons (Mt), increasing to 23.6 Mt in 2013 as shown Figure 3 [8, 25]. Russia, Canada, the USA and EU-27 lead the global wood pellet market. Many countries have conducted studies on alternative energy sources and especially the production, technology and use of wood pellet [8, 25, 29].

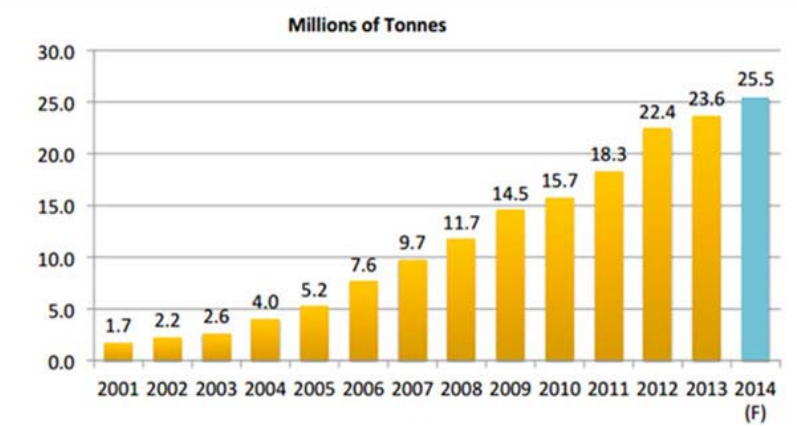

Figure 3. Global wood pellet production.

Among countries leading the wood pellet market, Russia has the best developed wood pellet market includes exports to Europe [32, 33]. In addition, European demand for Russian wood biomass is expected to rise. For Instance, Finland intended to increase its use of renewable energy from 25% to 38% by 2020 [8, 30]. Because energy production from wood has increased six times since 2008, domestic Finnish production is insufficient and woodchips have been imported from Russia [31]. In 2010, Finland conducted wood import with Russian Federation at 61% rate and mostly imported woodchips. While Finnish imports of fuel wood from Russia increased in 2009, the greatest increase occurred in was experienced in 2010 [32-35].

The EU aims to produce 20% of energy production from renewable sources by 2020. The EU therefore increased its financial support for renewables from 6% to 12% in 2010, and established the European Pellet Council (EPC). The council has been studying the standardization of wood pellet products and markets. Recently, biomass fuels and especially wood chips and wood pellet have increasingly been used in the EU [33]. The increase in prices of traditional fuels, high taxes on fossil fuels, incentives for biomass fuels and Europe's aim of decreasing greenhouse gas emissions has increased the demand for wood pellet in the EU. In addition to domestic use, wood pellet is regarded as an important alternative fuel that can substitute fossil fuels such as coal and oil derivatives that are used in combined heat and power facilities, and also can be used in electricity production similarly to coal and gas [33]. In 2008, nearly 630 pellet facilities in Europe produced 8 Mt of pellets while in 2009 nearly 650 facilities produced pellets over 10 Mt [36]. The use of wood pellet in 2010 increased by7% compared with 2009 to more than11 million tons [8, 25, 33].

The consumption of wood pellets in the EU was 13 Mt in 2013, 16 Mt in 2015, 20 Mt in 2017 and 25 Mt in 2019. Sikkema et al. [34] examined wood pellet production, consumption, import and export among EU countries. The major European producers were Germany and Sweden with nearly 1.6 Mt, and Italy with 770 000 tons. In 2009, the three major European producers were Sweden, Germany and Italy. These

countries use 64%, 56% and 87% of the capacities of their pellet facilities, respectively, compared with 54% for Europe overall. It is thought that if the three major European producers used all of their capacities, production could increase by nearly 2 Mt [8, 25, 33].

The Sweden bioenergy institution reported that 2010 production of 2.2 Mt will increase by 100% to 4.4 Mt in 2016. Portugal experienced major development in wood pellet production in 2005. In 2008, high-capacity facilities were established and annual production was 400.000 tons. Portugal exported approximately 90% of this production to Europe. On the other hand, wood pellet production also increased in Western Balkan countries. The national market in Serbia has shown limited development. Wood pellet is retailed only in some supermarkets in the cities of Novi Sad and Belgrade. In 2008, five pellet facilities produced 10.000–35.000 tons of wood pellets in total. There is only one facility in Montenegro, with a production capacity of 25 000 tons. The total production capacity of Bosnia-Herzegovina is 120 000 tons and there are five pellet production facilities with capacities between 3.000 and 45.000 tons. Approximately10–15% of production is consumed in the national market [8, 25, 33].

Most wood pellet exports are to Italy and Slovenia. Slovenia has three pellet production facilities with 89 000 tons capacity in total [8]. Slovenia started major production in 2005 and exports 90% of production to Italy. Slovenia uses pine and fir species in wood pellet production. Croatia is the biggest producer in the Western Balkan Region, with annual capacity of 194 500 tons and seven pellet production facilities with capacities between 7 500 and 40 000 tons. Croatia has potential for approximately one million cubic meters of biomass fuel production. Despite being the biggest wood pellet producer in the Western Balkans, the wood pellet market in Croatia remains in the first stages of development [25]. In the EU, the price of wood pellet was 115 € in July 2007, at the beginning of 2009 it was 140 € and at the end of 2010 it was 125 € [6-8].

The US wood pellet market has shown rapid development from 600 000 tons in 2003 to 4 million tons in 2009 and export was 50 000 tons in 2006 and reached to 250 000 tons in 2008 with five times increase [8]. Another indication of this rapid development is the export numbers between USA and EU. USA had not much wood pellet export to EU till 2008. The first commercial activity of USA with the EU was in 2008 with 85.000 wood pellet exports to Holland. This number reached to 60.000 tons in 2010. It is expected that in a couple of years Canada and USA will double their number of exports and their production capacities also will increase depending on the demands of international market [8, 25, 34].

Wood pellet production continues to rise in Canada. As of June, 2011 wood pellet production capacity of Canada is 2.931.000 tons [31]. Nearly 70% of the pellet production is made in West Canada and especially in British Columbia. However, the production capacity also develops in the east of Canada with the recently established facilities in Ontario and Quebec. Some of the European countries including Sweden, Holland, Belgium, Italy and England started to import from especially North America; because, they cannot meet the demand of wood pellet from domestic production. Canada has become the biggest supplier of wood pellet in Europe with 1.5 Mt export in total in the last 10 years. According to the estimations of 2011, 1.7 Mt to Europe, 90 000 tons to North America, 60 000 tons to Japan and 50 000 tons to Korea and 1.9 Mt in total are expected [8, 25, 34].

3.1. Heating with wood pellets

There are currently two main types of pellet appliance available, these are smaller-scale space heaters and larger scale water heaters suitable for a range of uses form top-up space heating to complete space and water heating. As can be seen pellet stoves are far more efficient than open fires or wood burning stoves [6]. Small-scale pellet stoves are suitable for top-up space heating in houses or large rooms and provide an elegant feature for any room, typically providing 2-12 Kw of heating energy. They can take the place of an open fire; wood burning, coal, gas or electric stove and use an attractive genuine flame for heating. They are more efficient, easier to use and require far less maintenance than coal stoves. Most pellet stoves include a convection fan - this means that heat is more evenly distributed around a room then other types of space heating. Pellet stoves can be controlled by thermostats and usually have a variable output, allowing for easy heat output adjustment [6]. Figure 4 shows a pellet stove and its operation principle [6].

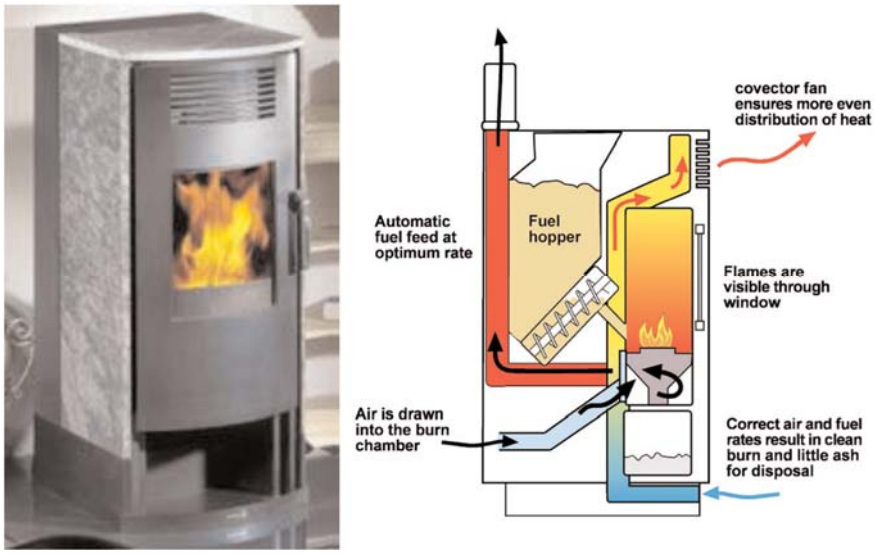

Figure 4. The pellet stove and its operation principle.

A pellet stove consists of a hopper, screw feed, heating element, electronic control, suction & convection fans and a combustion chamber. Heat output is controlled by a thermostat, which regulates how much fuels are fed into the heating chamber. Unlike a wood burning stove, heat output can be adjusted according to requirement. The hopper typically takes 25 Kg of pellets and, depending on heat demand will last 2-5 days [6]. When the stove is fired up some fuel is released from the hopper into the combustion chamber via a worm screw, and ignited by way of an electric heating element. The worm screw delivers the correct amount of fuel to the combustion chamber according to the temperature set on the control panel [6].

Cold air is drawn from outside, through the fire chamber by a fan and then directed back outside through a low temperature flue. A separate convection fan draws in cooler air from the room at the bottom of the appliance past the firebox, warming it as it goes and blowing it out at the top of the appliance. The convection fan distributes the warmed air throughout the room, rather like an electric fan heater. Ash drops down into an ash pan, which, thanks to the high efficiency and combustion temperatures, only requires occasional emptying (less than 5 times a year). Ash deposits are normally <2% of the total fuel volume of fuel burnt [6].

4. Future of biomass energy

4.1. Biomass energy

Global changes in the energy market, particularly decentralization and privatization, have created new opportunities and challenges for both renewables in general and bioenergy in particular [8]. Experiments in market-based support are changing the way we look at energy production and utilization. It is notoriously difficult to forecast long-term energy demand [3]. However, it seems clear that demand will continue to grow (Table 5). Globally there is a growing confidence that renewable energy in general is maturing rapidly in many areas of the world and not just in niche markets. It is important to recognize that the development of biomass energy will largely be dependent on the development of the renewable energy industry as a whole, as it is driven by similar energy, environmental, political, social and technological considerations [18].

The 1970s were pioneering years providing a wealth of innovative ideas on renewable energy which were further advanced in the 1980s when the computer revolution played a key enabling role. In the 1990s, improvements in renewables allowed the technology to meet emerging market opportunities, such as gasification [19]. This opportunity was very much linked to the growing concern about climate change and the environment [20].

Table 5. Overview of the global potential of bioenergy supply

Biomass category	Technical potential in 2050 (EJ/yr)
Energy crop production on surplus agricultural land	0-700
Energy crop production on marginal land	<60-110
Agricultural residues	15-70
Forest residues	30-150
Dung	5-55
Organic wastes	5-50
Total	<60 - >1100

The early part of the 21st century may be dominated by a global policy drive to mitigate climate change. It is essential that biomass energy is integrated with existing energy sources and thereby able to meet the challenges of integration with other renewable energy and fossil fuels. In case of bioenergy to have a long-term future, it must be produced and used sustainably to demonstrate its environmental and social benefits in comparison to fossil fuels. The development of modern biomass energy systems is still at a relatively early stage, with most of the R&D focusing on the development of fuel supply and conversion routes that minimize environmental impacts. Although the technologies are evolving quite rapidly, the R&D devoted to bioenergy is insignificant compared to that on fossil fuels, and needs to be substantially increased. In addition, the development of biomass energy should be more closely integrated with other renewable energy technologies and with local capacity building, financing and the like [19].

In the future, biomass has the potential to provide a cost-effective and sustainable supply of energy provided that the private and public sectors ensure that harvesting biomass residues and growing bioenergy crops are sustainable, and the production of bioenergy and biofuels are environmentally benign, while at the same time aiding countries in meeting their GHG reduction targets. In the short to medium term, biomass is expected to dominate energy supply. For the generation of electricity and heat, while using advanced combustion technology, organic wastes can be used as modern biomass [3, 6, 7, 19].

4.2. Wood pellet

Historically dry sawdust and chips have been the main raw materials for wood pellets plants due mainly to nonexcessive prices, already dried and its homogenous composition. Declining activity in the traditional forest industry has reduced the availability of dry raw materials for many wood pellets plants. In Europe, the economic sustainability for wood pellets producers depends mainly on their domestic markets as the international pellet prices are lower than European productions cost, with exception for the Portuguese case still devoted to exportation instead of internal consumption.

In these countries, no direct support for wood pellets occurs, implying that wood pellets must be competitive due to price, quality and logistical operations. In a near future wood pellets production will be based on wet raw materials, competing directly with other industries like pulp and paper or fibreboard industries. In this scenario must be expected an increase in raw materials prices once wood pellets production will grow continuously [6-8]. Transition from small wood pellets plants using dry raw materials to larger plants using wet feedstock in future pellet production can be expected to follow comparative advantages, especially regarding feedstock and energy costs, but also with respect to economies of scale (see Table 6). Increased production in the medium term will probably take place in larger mills based on pulpwood which offers more secure biomass supply compared to dry residues. Increased biomass costs and hence pellet prices must be expected over time, but do not necessarily imply that wood pellets will lose competitiveness compared to other technologies or prevailing energy prices. Long term development of biomass costs and wood pellet production costs depends on the development for biofuels, bio-refineries and other technologies for renewable power production as well as the development in the forest industries [30-35].

Table 6. Compare of energy sources.

Energy sources	Energy (kcal)	Amount (kg)	Unit price ($)*	Total ($)
Coal	6 000	2 000	0.28	560
Fuel oil	10 500	1 142	0.77	880
Natural gas	8 250	1 454*	0.30	437
Wood pellet	4 500	2 660	0.13	346

* amount of consumption calculated m^3 for natural gas

5. Conclusions

Due to the posed threat of climate change, the volatile fossil fuel market and the need for an independent energy supply to sustain economic development all necessitate the need for sustainable and renewable energy resources. Biomass is the most common form of renewable energy and represents the greatest opportunity as a feedstock for biofuels. All types of woody biomass, agricultural residues and energy crops are suitable raw materials for pellet production. Pellets are a key technology for increasing biomass use in both electricity and heat production. On the other hand, experimental studies show that co-firing energy crop biomass for electricity and heat production can demonstrate substantial greenhouse gas (GHG) emission savings.

The shares of renewable energy sources in energy generation is increasing due to the increasing cost of fossil fuels, problems with power supply, development of alternative sources of energy and efforts to limit the use of fossil fuels in order to limit climate change. This situation led to the emergence of alternative, non-fossil fuels as a means of energy production and new markets for these products. Wood pellet has the advantage among biomass fuels of being easy to produce and of having high raw material potential. Several regulations have been introduced to increase the use of renewable energy sources. However, the demand for wood pellet has failed to meet expectations due to high production cost. As a result of increased wood pellet production and consumption, wood pellet can be used as alternative to fossil fuels, notably coal, thereby reducing dependence on petroleum products.

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 2013, 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 23.6 million tons in 2013, which is increased nearly 13% over 2013 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.

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