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FEASIBILITY STUDY
ON WOOD WASTE UTILIZATION IN SERBIA

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1. SUMMARY

With the price of oil having reached previously unthinkable heights, more and more attention is being directed to renewable sources of energy. High oil prices simply make renewable energy sources more financially viable, as consumers seek the most economical source of electricity from among various fossil fuels and renewable sources. One of those renewables is wood waste biomass, which is burned to produce energy.

As recently as a few years ago, there was no pellet production at all in Serbia. According to the most current information on pellet plants in operation and those now under construction, by next year there will be six wood pellet producers in the country, with a projected production up to 250,000 tons. There is, however, plenty of room for further growth in the industry, as the estimated volume of wood waste from forests and sawmills could potentially be doubled. This study analyzed the location of the six existing plants, along with areas rich in forests, and recommended seven regions for new pellet plant installation.

Wood biomass residues have remarkable energy potential in Serbia, where forests cover about two million hectares, or more than one-fourth of the country's total land area. In fact, twenty-eight different municipalities have more than 40% of their entire area covered in forest. Municipalities with the highest share of forest area are in two main regions. In the southwestern region, Prijepolje is over 80% forested, and Priboj and Kuršumlija range between 61-80%. The eastern region includes Majdanpek, with over 80% in forest, and Kučevo, Žagubica, Bor, Baljevac, all between 41-60%. Serbia has two forms of forest ownership: private and state-owned, with private forests covering 48.5% of the total forest area. A slight majority is state-owned.[1]

Wood processing companies in Serbia are mainly privatized or in the process of privatization. Large privatized companies have had problems meeting former production rates. There is only one chipboard factory in the country, and there is no production of medium density fiberboard (MDF). A high volume of boards is imported in order to meet the demand for boards from other than the predominant domestic beech, oak, poplar, spruce and black pine.

Total wood volume in the forests is 204.6 million cubic meters. In short, there is a lot of wood in Serbia, but the rate of forest wood utilization - the ratio of cutting to regrowth - is a little less than 50%. The total annual wood cut in Serbia is 2.58 million cubic meters, while the estimated natural regrowth is 5.23 million cubic meters. Serbia's utilization rate is low as compared to the 75% benchmark rate of sustainable forest utilization in developed countries with better forest management and infrastructure (a well-developed network of forest roads). Much more wood could be harvested than is actually being cut.

Even so, total wood residues in the forests after cutting are estimated at 1.1 million cubic meters. Forest wood residues consist of bark stripped off round logs, thin branches with bark and stumps with large roots. Some residues are already being used for other purposes, and most stumps are left in the ground, so the real available volume of forest wood residues is about 600,000 cubic meters.

[1]Statistics in the study were based on information available from the Serbia Ministry of Agriculture, Forestry and Water Management

The potential is under-utilized, with just a fraction of wood waste used in inadequate, outdated boilers and furnaces. While the main wood pellet production raw materials are forest and sawmill residues, wood waste from other wood processing industries which produce pulp and paper could also be used for pellet production, but most of those companies tend to efficiently utilize the resource, so sawmills are the most appropriate source of the raw material used in pellet production.

In a well organized company, practically all wood waste is used in either board production or as fuel to produce heat and electricity. However, some wood processing companies in Serbia have available wood biomass, but aren't making good use of it. Instead, they either spread the waste around their property, or simply push it into rivers, discarding a potentially valuable energy producing resource.

So, much more wood could be cut, generating more of the wood waste resource, and a greater percentage of that waste could be converted into energy. One important condition for better forest (and waste) utilization in Serbia is improving the forest roads and general road infrastructure in less developed regions that are rich in forests, thus ensuring access to a steady supply of wood biomass resources. Improving forestation and reforestation of state-owned and private forests is also key. Most responsibility for creating these favorable conditions belongs to the Serbian government. Only roads of lesser importance, (excluding state-owned forest roads), are the responsibility of local (municipality) government.

Assuming more favorable conditions become the norm, the next question is, "Where is the market for biomass pellets?" A market for pellets in Serbia effectively does not exist today, since biomass use is thus far not supported by the state. Also, there is only one domestic producer of small boilers (up to 300 KW) with the auxiliary equipment required to feed pellets and automatically regulate combustion. Public buildings are not strongly motivated to use cheaper fuel such as biomass.

The main driving force actually is the European Union, where the price of pellets can exceed 150 € per ton, depending on the location. This makes pellet production very attractive to Serbian producers. Low salaries, the low cost of electricity and the availability of wood wastes provide financially attractive conditions for wood pellet production in Serbia. The high price of pellets in Europe would probably drive up the price of pellets in Serbia. That, combined with the previously described conditions, is probably obstructing the utilization of wood pellets in Serbia.

Assuming construction of a pellet plant with a capacity of 20,000 tons per year, financial analysis shows that the break-even price for the sale of wood pellets in Serbia would be 51 € per ton, compared to 81 € per ton in the EU. The investment cost for pellet plants is relatively low, as are annual operating costs. The main operating costs are raw material and energy, while Serbian worker salaries have a smaller portion. Transport costs are also very important. To manage its energy input costs more efficiently, a pellet plant would probably need to operate at least two shifts per day.

Financial justification of wood pellets production is based on relatively high pellet prices in the EU and low investment costs compared to operating costs. The most important issues for potential investors are transport and raw material costs. It is important that prospective wood pellet producers investigate methods to keep these costs as low as possible. As ways to reduce these two costs are found, revenue and other financial parameters are increased.

The market for biomass pellets could easily become more viable on the domestic front. In a price comparison of different fuels in Serbia, firewood in small towns was the cheapest solution for space heating, but in cities, where people generally have more money at their disposal, firewood is more expensive, so wood pellets priced at 80 € per ton would be the cheapest fuel. Further, the different types of coal usually used in Serbia are priced about the same as firewood.

One ton of wood pellets can replace almost two tons of domestic lignite coal, or one ton of imported brown coal, or a little less than half a ton of fuel oil. To meet national demands, Serbia imports more than 80% of its liquid fuel and 85% of its natural gas. Wood waste utilization is important not only for cleaner energy production, but also for decreasing imports of fossil fuels. The energy potential of a prospective wood pellet production of 500,000 tons per year can replace 35% of the coal consumption for energy, or 35% of the liquid fuel consumption for generating heat energy, excluding power plants and district heating systems. It is obvious that the energy potential of wood pellets is significant in Serbia.

Using wood waste in such a productive manner will benefit local communities in forested areas with jobs in wood cutting, collecting and transporting wood waste, plus in producing wood pellets. Since the forested region municipalities are also among the poorest in Serbia, employing local people in wood waste utilization will bring significant economic benefits to the community.

Beside the improvement of forest roads, far better utilization of wood waste requires government backing. Since there is no practical experience with wood pellets combustion in Serbia, and there is only one company manufacturing small boilers for pellet combustion, government support of a model project would be of great importance for introducing wood pellets as fuel in the Serbian market.

The Serbian government needs to promote the use of biomass waste for energy production in residential and industry sectors. It can assisting model projects, or help to develop more domestic firms producing small and medium boilers for wood waste and wood pellet combustion. Finally, and perhaps most significantly, it can enhance market conditions via fuel pricing and tax incentives to encourage greater use of wood waste and wood pellets.

The Kyoto Protocol was ratified by the Serbian Parliament in 2007. The next step for the government would be establishing an institutional framework for Clean Development Mechanism (CDM) projects. When that is in place, projects that replace fossil fuels with wood waste and pellets for energy production can gain additional income through the sale of CO_2 emission reductions.

2. INTRODUCTION

During the 1980`s, as the result of an energy crisis, several programs were launched in Serbia related to the efficient use of energy and the use of renewable energy sources. For the production of biomass, many new plants were installed, including several hundred small biomass boilers, a few dozen big biomass boilers, nine biogas plants using livestock manure, and several small biomass gasification plants for replacing natural gas.

Unfortunately, in 1991 there began a long period of economic blockage and deep economic crisis that destroyed the economy in Serbia. Many biomass related companies were making great efforts to maintain the minimum level of production, but some of them were forced to stop operations. The low price of electricity led to its increased use as the main energy source for many applications of heat supply. As a result, many plants and facilities using biomass energy source in households and industries were replaced by electric heaters.

The economic blockage stopped in 2000, and since then industry has been trying to revitalize and to upgrade its equipment. Higher levels of production activity, the possibility of importing and exporting without administrative barriers, and the transition in ownership of industrial companies and agricultural farms created new circumstances and restarted the use of biomass waste as fuel in Serbia.

In accordance with the Kyoto Protocol, EU directives, and based on taking on the obligation of increasing the share of renewable energy in total energy production, many EU countries promote the utilization of biomass fuel. In some countries, a very developed biomass fuel market has been created, with a constantly increasing demand for biomass fuel. Since the utilization of forest trees and wood residues must be in accordance with sustainability, the increased demand for biomass fuel creates attractive conditions for exporting biomass fuel from other countries to the market of EU countries.

This study analyzes circumstances in Serbia, presents what potential lies in wood biomass for pellet production, assesses the competitiveness of different sectors for utilization of wood waste, recognizes the main stakeholders regarding prospective production and transportation chain of pellets, and the economic feasibility of the production of wood pellets.

The data, information, and statements given in the study are taken from legislative documents, official publications of the government of Serbia, or other state institutions, such as the Statistical Office and Chamber of Commerce. Information was also gathered from studies and reports prepared in the recent period, and from communication with experts of the public company *Srbijašume,* and other experts and officials in the relevant field. Because data for the territory of Kosovo and Metohija have not been available for the last eight years, all the presented data and assessments are related to Serbia excluding the territory of the province Kosovo and Metohija.

3. PRIMARY BIOMASS RESOURCE SUPPLY ANALYSIS

With a territory of 77 474 km^2 and 7,4 million inhabitants (not including the territory of Kosovo and Metohija) Serbia belongs to a group of middle-sized European countries. Generally, the northern half of the territory of Serbia is a plain agricultural area, while the southern half is a mountainous region rich in forests.

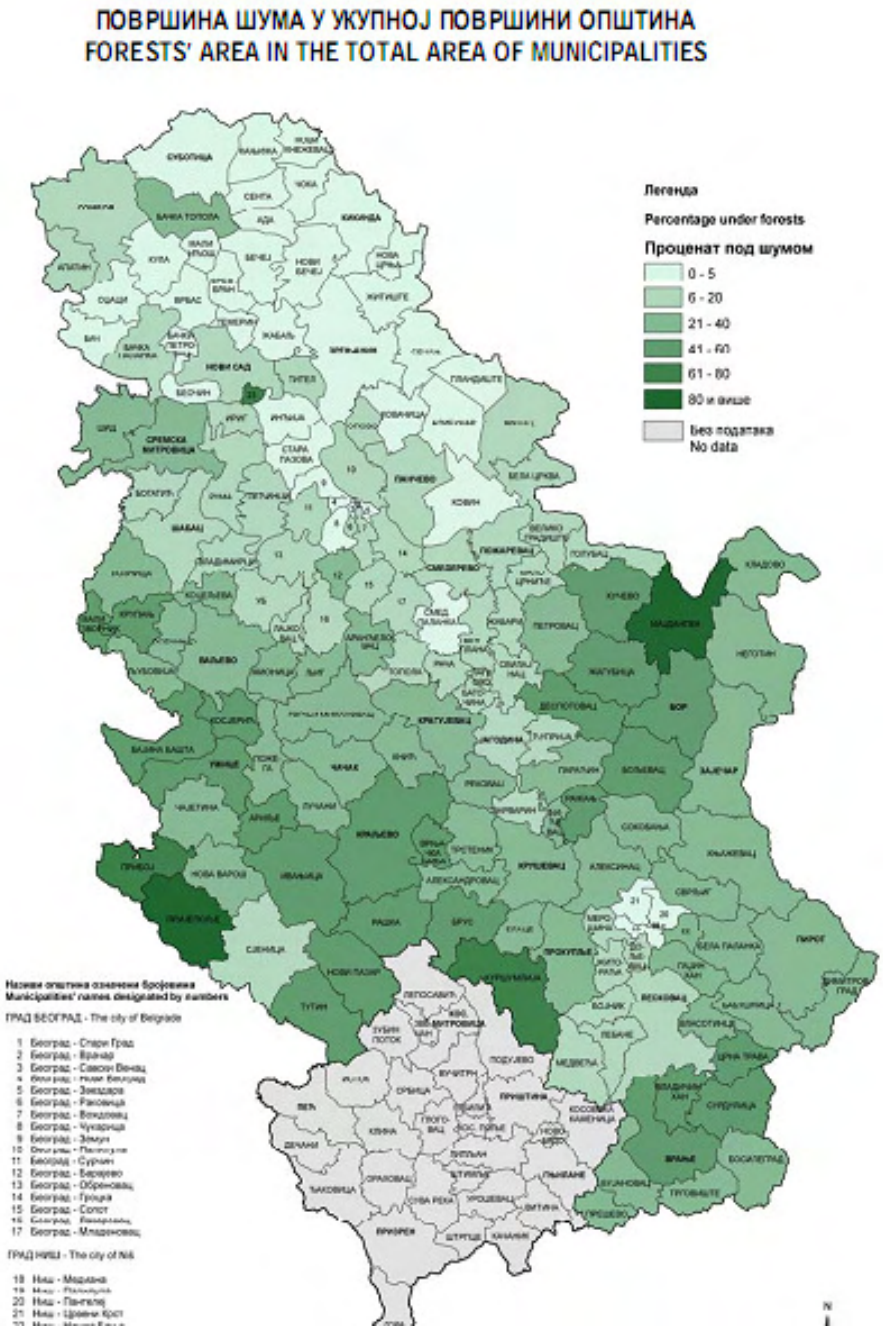

Figure 2.1. Forests` area in the total area of municipalities (*Statistical Yearbook, 2007, Statistical Office of the Republic of Serbia*) [1]

3.1. Forest Wood Potential in Serbia

An area of 1,98 million ha in the Republic of Serbia is covered with forests, which is about 25,6% of the total area of the Republic of Serbia.

The eastern part of Serbia contains a large region of municipalities with a high share of forests area in the total municipality area (Figure 2.1) consisting of municipalities of Majdanpek (over 80%), and Kučevo, Žagubica, Despotovac, Bor, Baljevac (all with 41-60%). Another large region rich in forests is the southwestern part of Serbia, comprising the municipalities of Prijepolje (over 80%), Priboj and Kuršumlija (61-80%), and several neighboring municipalities with forest areas between 41% and 60% of the municipality territory. When analyzing the data of municipalities, it can be seen that municipalities richer in forest area have fewer inhabitants and are less economically developed. That fact could be a barrier for the implementation of wood waste utilization projects, since the vicinity of wood waste resources would offer limited possibilities for project implementation. Wood waste would have to be transported to distant municipalities, and transportation costs would play a significant role in the viability of wood waste utilization projects.

There are 28 out of 146 municipalities in Serbia with forests over 40% of the municipality territory.

The majority of forest trees in Serbia are broadleaved trees (Table 3.1). This kind of tree covers about 1,235 million ha, while conifer trees cover 0,182 million ha. Mixed stands in forests, containing broadleaved and conifer trees, cover about 0,567 million ha.

Table 3.1 Types of forests by area [1]

Area (ha)	Broadleaved trees	Conifer trees	Mixed stands	Total
In Serbia	1,235	0,182	0,567	1,984
State owned	0,627	0,120	0,274	1,021
Private	0,609	0,062	0,292	0,963
Vojvodina Province	0,093	0,001	0,069	0,163

Data for Vojvodina Province are included in other data in Table 2.1

In regard to ownership, approximately half of all forests are state owned, and the other half are privately owned. But it can be seen that a majority of conifer forests are state owned. Regarding the Province of Vojvodina, all forests are state owned, and there are practically no pure conifer forests (Figure 3.2). State forests in Vojvodina are managed by the public company *Vojvodinašume*. State owned forests in other parts of Serbia are managed by another public company *Srbijašume*.

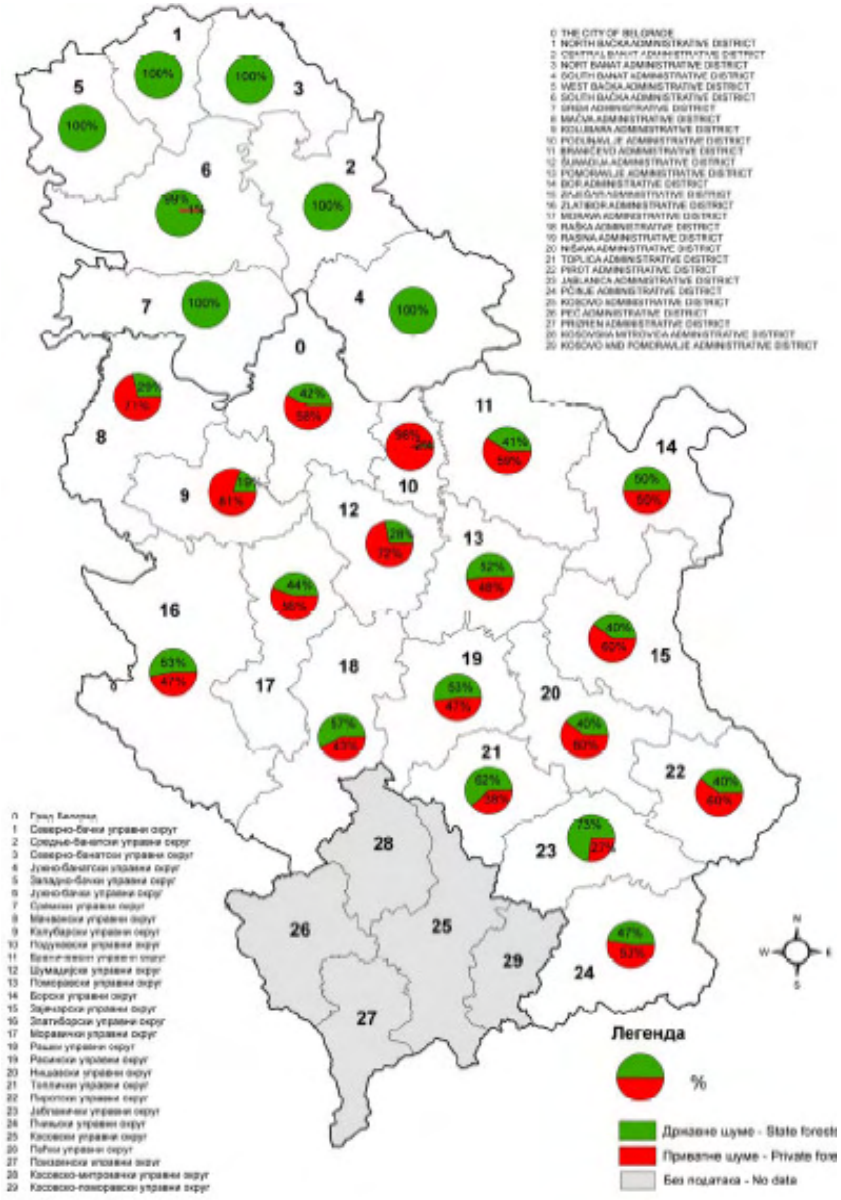

Figure 3.2 Forest owners in the municipalities of Serbia [1]
(green – state forests, red – private forests)

There are four national parks in Serbia. Going from north to south these include: Fruška Gora in the province of Vojvodina (25390 ha), Djerdap along the Danube river (63600 ha), the mountain Tara near the Drina river (19710 ha), and the mountain Kopaonik (11810 ha). Besides these national parks there are a few relatively large protected areas of natural heritage, which are viable as a source of wood waste: the mountain Golija, the mountain Stara Planina, and the upper part of the Ibar River. National parks are state owned companies. Protected areas of natural heritage have mixed ownership, some parts of these areas being in private ownership and some in state ownership.

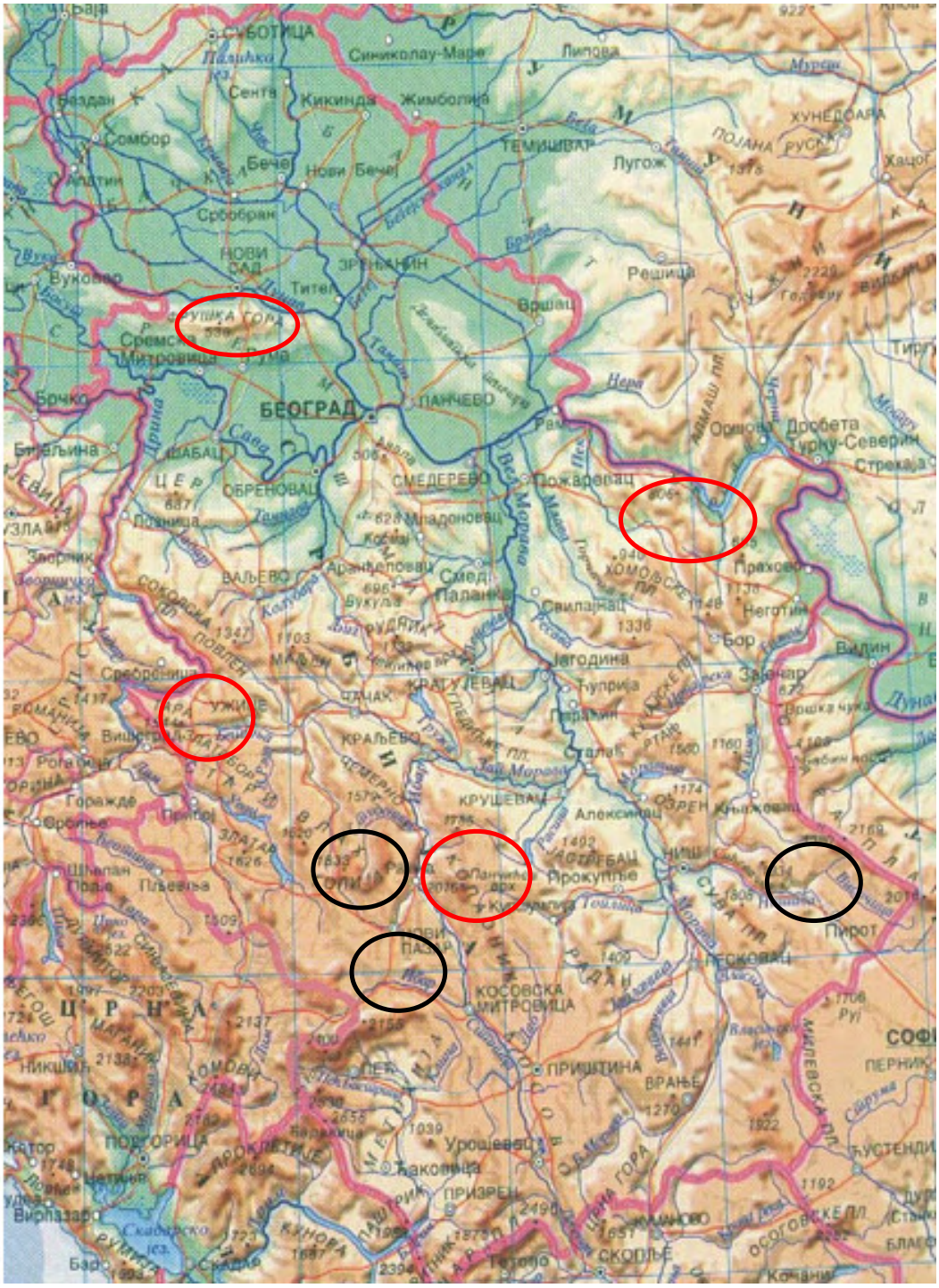

Figure 3.3 National parks (red circle) and protected areas (black circle) of natural heritage

The main species of forest trees are: broadleaves, beech, poplar and oak, and conifers, which include black pine and spruce. But remarkably the greatest share is beech trees, which make up over 40% (Table 3.2) of forest trees.

Table 3.2 Main parameters of forest wood resources in Serbia [1,3]

	total wood volume in	annual volume increase	wood cutting	cutting / increase
	million m3	million m3/year	million m3/year	%
beech*	80.35	1.832	1.009	55.1
oak*	30.81	0.821	0.249	30.3
poplar*	1.39	0.094	0.42	(a) *448*
spruce*	4.51	0.108	0.038	35.2
black pine*	4.09	0.085	0.044	51.9
other	83.46	2.288	0.825	36.1
total	204.6	5.228	2.585	49.4

(*) only pure stands of species

According to the last inventory of forests, completed in 1979, poplar trees were not so prevalent in Serbia. But in the last few decades, there has been an increase in the number of poplar trees planted, especially in plains regions near rivers. This accounts for the discrepancy between the wood volume of poplar trees and wood cutting of poplar trees recorded in the official reports. According to reports completed within the last several years, wood cutting of poplar trees has a remarkable share of the total cutting volume. Poplar is a very suitable species for energy crops, since its annual growth of wood volume is much higher than is the case for other species of trees in Serbia.

Currently, Serbia does not have land set aside specifically for energy crops, but research and analysis show [4] that land which is not suitable for conventional agricultural crops would be suitable for planting poplar forests. These forests could be used as energy crops, as so-called short rotation coppice. This area in the plains regions near rivers and channels has an estimated area of about 200,000 ha. This is an opportunity for the potential increase of energy wood in Serbia.

The ratio between wood volume cutting and wood volume increase in forests in Serbia is about 50% on average. Countries with developed forest infrastructure and good forestry management have up to 75% utilization of wood volume increase in forests. By the term *good infrastructure* the dominant meaning is a widely developed network of forest roads covering all forest areas. By improving the infrastructure in forests, Serbia will have greater potential for sustainable use of wood from forests.

Serbia has the potential to increase the area of land covered with forests. In accordance with the *Spatial Plan of Serbia* [5] from 1996 the forest area in Serbia should be increased by 31,5% by 2010. Unfortunately, this target would not be reached since the economic crisis, especially in the last decade of the 20th century, disrupted many plans. The next target, according to the *Spatial Plan,* is to have the forest area increase by 41% by 2050. That value is estimated as the optimal forest coverage for Serbia. In order to achieve that target, the forest area would have to be increased by 29,000 ha every year. During the period of intensive afforestation in 1980s, the afforestation rate was 20,000 ha per year.

Afforestation conducted in the last several years (2002 -2006) shows that the rate is much lower than needed. It accounts for a maximum 5,300 ha per year [1]. That increase of 5,300

ha of forest area should bring a proportionally greater wood volume cutting for cutting of about 6,900 m^3.

State owned land and forests are almost completely afforested and filled out, respectively. According to the statement of the management of the public company *Srbijašume*, only 10% of the state owned land can be afforested, which means that the state owned forests can be enlarged only by 10%. The majority of land, which should be planted with forest trees, is private land. Because of migration of people from small villages to towns, many parcels of agricultural land in forest regions are out of use. These parcels are practically under the slow process of natural afforestation, but it would be much better if forest trees were planted through artificial afforestation. Private persons do not express great interest for afforestation. *Srbijašume* is offering, free of charge, young trees for planting for the sake of improving the afforestation rate.

The private forests area is on average about 0,5 ha, and therefore it cannot be expected that every forest owner can complete all of the tasks of wood cutting, which includes collecting and transporting, by himself. Associations of private forest owners could solve that problem. Many private forest owners could hand over their forests management to these associations. The associations would organize all necessary activities: afforestation, tree felling, collecting wood and wood wastes, transportation, and placement of products on the market. In the case of private owners of unused, viable forest land, associations would encourage forest tree planting, because there is no need for private forest owners to provide all the necessary forestry machines, and all activities can be executed without the owners actual participation. For these reasons, forest owner associations should be established.

Some other measures, such as paying tax for unused land in forest regions, would force many owners to plant forest trees on unused land.

3.2. Forest Wood Potential in the region (Serbia, Croatia, Montenegro and Bosnia & Herzegovina)

A comparison of the basic data related to wood resources between countries of the former Yugoslavia (Serbia, Montenegro, Croatia, and Bosnia & Herzegovina) shows that Serbia has the smallest potential of forest wood (Table 3.3). The forest area in Serbia is the smallest, covering only 25,6%, while surrounding countries have over 43% to 52,7%. Among those countries Serbia is the most densely populated, and this fact decreases the value of forest area per capita down to 0,264 ha. This area is small when compared to the values of other countries, which are at least double that area. That lowest potential of forest wood per capita led to the lowest cutting rate per capita as well, only 0,345 m^3 comparing to the values of over 1 m^3 for other countries from the region.

Even with an achieved optimal share forest area of 41% of the total area of Serbia, that value will not reach the values of forest areas in countries from the region. The reason for the relatively small forest area is the fact that Serbia has a great share of arable land.

Table 3.3 Forest wood resource in the region [1,10,16,17]

	Serbia	Montenegro	Croatia	Bosnia and Hercegovina
country area (ha)	7 747 400	1 381 200	5 654 200	5 119 700
population (million)	7,50	0,62	4,44	3,98
forest area (ha)	1 980 000	621 000	2 485 000	2 700 000
forest wood volume (million m^3)	205	70	300	502
forest area (%)	25,6	45,0	43,9	52,7
forest area per capita (ha)	0,264	1,002	0,560	0,678
wood cutting (m^3/year)	2 585 000	631 000	5 300 000	7 250 000
ratio cutting/volume increase	49,4 %	36 %	66,2 %	48,8 %
wood cutting per capita (m^3)	0,345	1,018	1,195	1,031
consumption of fuel wood (m^3/year)	1 415 000	175 000	1 500 000	1 459 000
consumption of fuel wood per capita (m^3)	0,189	0,282	0,169	0,367

Croatia and Bosnia & Herzegovina have a greater share of forest area than Serbia, at 30%. Bosnia & Herzegovina has the greatest area covered with forest, the greatest share of forest area in the total country area, and the greatest wood cutting in forests .

In Croatia, the total wood volume of all forests is about 300 million m^3, while the annual increase of volume is about 8 million m^3. The total volume of forest wood in Bosnia & Herzegovina is 502 million m^3, while the annual volume increase of wood is 5,5 m^3/ha [10]. The value of volume increase of wood in Montenegro is adopted on the basis of the volume increase rate in Serbia.

The southwestern part of Serbia and the northern part of Montenegro are the regions with the largest forest areas of these countries. Since these regions are adjacent, it is assumed that the climates in these two regions are very similar, and since the most frequent tree species are the same (beach and oak share of 50%, then spruce), it can be assumed that the specific rate of volume increase of forest wood in these regions is the same as well and accounts about 0,025 m^3/m^3.

Regarding the cutting vs increase volume rate ratio, which means the degree of forest utilization, Croatia has the highest value (66,2%). In Serbia and Bosnia & Herzegovina the ratio is little lower than 50%. The ratio in developed countries, which have sustainable forestry, is up to 75%, therefore there are possibilities in the Balkan region countries to increase forest wood cutting.

Consumption of fuel wood per capita in Bosnia & Herzegovina is much higher than in other countries of the region. Their numbers double the consumption of Serbia or Croatia.

Consumption of fuel wood in Serbia accounts for a little more than 50% of the total volume of wood cutting. In other countries of the region, which have higher consumption of fuel wood per capita, the ratio of the consumption of fuel wood versus total wood cutting is much less, between 20 and 30%. The great share of fuel wood consumption in the total volume of

wood cutting in Serbia in comparison with Croatia and Bosnia & Herzegovina is consequence of smaller forest area and significantly smaller volume of wood cutting.

The great share of the fuel wood in the total wood cutting in Serbia could have implications for prospective production of wood pellets. Assuming that the volume of forest residues is the same for every type of cutting in forests, be it for fuel wood or technical wood production, then in the case of fuel wood production there is no additional wood waste, which would be produced in wood processing firms.

It could be said that, in general, the region of the four countries of the former Yugoslavia has remarkable potential for forest wood utilization, either for wood products or fuel wood.

3.3. Wood Processing Industry in Serbia

Forest based industry represents a significant branch of the Serbian economy with a relatively high share in GDP (1,24%) and industrial production (3,63%) [6].

There are about 2,760 companies dealing with wood processing and furniture production [9]. The majority of them (2,360) are in the wood-processing sector producing sawn wood, panels, joinery, and veneer. The other 400 firms produce furniture. Regarding the size of the wood processing enterprises, the dominant share has small enterprises[2] comprising over 90% of these kinds of firms. Until 1990 this branch of the economy had a positive trade balance. But today it has a negative balance of about USD 82 million (in 2004), because there is a large volume of imported wood goods, ten times greater than in 1990. The majority of wood imports into Serbia are wood-based panels, sawn softwood, and furniture.

Despite this negative trade balance, there is a positive trend of furniture export, since the export in 2004 equaled the maximum value from 1990. The export of the wood processing industry amounted to 4,3% of the total share of exported goods from Serbia. Furniture and sawn wood are dominant with 72% of the total exports of wood industries from Serbia. The most important markets for wood products of Serbia are in Italy, Bosnia & Herzegovina, Greece, Germany, the Former Yugoslav Republic of Macedonia, and France. Furniture, sawn wood, and plywood are mostly exported to Italy, furniture, windows and doors, and fiberboard to Bosnia & Herzegovina, and furniture and gallantry were the main products exported to Germany [6].

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[2] *Definition of a small company according to the Accounting Law: "The small companies can be the companies that fulfill, in the business year, two of the following criteria:*

a) that the average number of employees, accounted by the working hours, is not greater then 50;

b) that the annual income is less than 8000 average month gross salaries in Serbia;

c) that the average value of the property (on the beginning and on the end of the business year) is less than 6000 average gross salaries in Serbia."

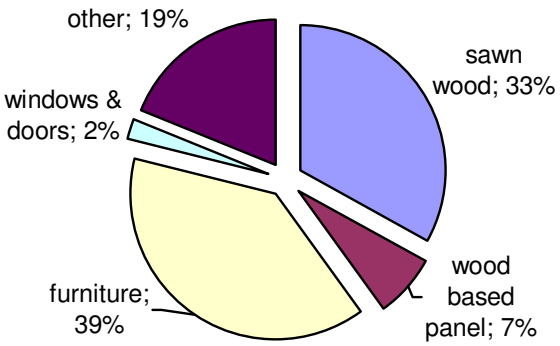

Figure 3.4 Participation of the most important products in total export of wood industry [6].

The majority of wood processing companies are sawn wood producers, following are wood packaging producers, producers of windows and doors, and producers of wood based panels. The existence of a great number of sawmills is the result of available raw materials, relatively low investment costs to start the production, and a short payback period of the investment.

About 96% of wood processing companies are privately owned, with a majority of the domestic capital. About 98% of companies are privatized with capital from domestic sources. Existing laws and regulations currently enable significant preferences for foreign investors, such as free duty on the import of machines and equipment, incentives for employing new workers, different tax benefits, etc. After the adoption of pending new laws, it is expected that these benefits would even be greater.

The production of pulp and paper decreased 10% in 2006 compared to 2005, while production of sawn wood, boards, and furniture increased [1]. The greatest increase was in the production of furniture, at more than 50%. In spite of this increase of furniture production, the number of employees slightly decreased 5% [8]. This opposite trend is the result of the privatization process, during which, generally, the production process is being renewed, while a remarkable number of employees becomes redundant.

3.4. Wood production

A mature tree consists of a trunk, branch wood, thin branch wood, and a stump. Wood production in Serbia is expressed by wood cutting. The term "wood cutting" in official statistical bulletins implies the total volume of wood including all commercial assortments and wood wastes. Wood cutting in 2006 in Serbia was 2,585 million m^3 in forests, and an additional 25 thousand m^3 outside forests (parks in cities, trees along waysides, edges, channels), which gives a total wood cutting of 2,61 million m^3 [1].

Division of entities conducting cutting shows that forest enterprises and citizens are the two main categories for cutting (Table 3.4). The wood process industry and other enterprises have a small share in wood cutting. It can be seen that wood cutting by the wood process industry had some variation in volume, from a maximum of 205,000 m^3 in 2004, to minimum of 96 000 m^3 in 2005. In 2006 there was an increase again at a value of 162 000 m^3. This increase can be explained by the ownership transformation of wood processing enterprises. After the

wood processing enterprises are privatized they start slowly or abruptly to increase the production.

Table 3.4. Felled timber (1000 m^3) by lumberjacks

	2002	2003	2004	2005	2006
forest enterprises	1382	1104	1238	1020	1127
wood process industry	131	152	205	96	162
other enterprises	233	205	247	381	285
citizens (retail trade)	999	1132	1028	988	1036
total	2745	2593	2718	2485	2610

The volume of timber felled by forest enterprises and citizens has had a relatively stable level in the last five years.

Regarding tree species felled in forests, the greatest share has been beech from pure standings, reaching 40% of the total volume of wood cutting in forests (Table 3.5). Poplar trees are not very frequent in Serbia. But this species has been planted more in the last few decades, especially along water channels, large rivers, and roads, and in forests as well. Now poplar trees have remarkable share in total volume of wood cutting and in the total forest area.

The following products are the results of the tree cutting process: sawlogs for cutting and the production of different types of technical wood, pitprops for underground mines, wood pulp for pulp and paper production, fuel wood, and other types of wood including wood for panel production (Table 3.6). About 50% of the wood cutting from state owned forests is used as fuel. The other half is used as construction wood, and also for windows, doors, furniture, for pulp and paper, as well as construction support in underground mines. The statistical evidence of wood cutting in private forests is not as detailed.

Table 3.5. Utilization of forests [1,3]

		wood cutting (1000 m^3)	forest area (million ha)	utilization of forests (m^3/ha)
total (1+2)		2585	1,985	1,30
pure stands of (1)		1974	1,418	1,39
broadleaved		1886	1,236	1,53
	beech	1009		
	oak	249		
	poplar	420		
	other	208		
conifer		88	0,182	0,48
	spruce	38		
	black pine	44		
	other	6		
mixed stands of (2)		611	0,567	
broadleaved		419	0,464	0,90
conifer		50	0,049	1,02
broadleaved and conifer		142	0,054	2,63

(*) The data on wood cutting is from 2006, but the data on forest area is from the last forest inventory in 1979.

Table 3.6. Production of wood assortments from state owned forests in Serbia [1]

1000 m^3	2002	2003	2004	2005	2006
sawlogs for cutting	312	358	368	373	397
mine props	19	21	8	8	12
wood pulp	108	88	98	123	117
fuelwood	748	838	847	779	803
other wood	393	371	401	357	415
total	1580	1676	1722	1640	1744
Felling in state forests					1925
Felling in private forests					685

In spite of the fact that approximately half the forest area in Serbia is in private hands, wood cutting in private forests is three times less. The reason for this is the lack of a market for wood. As a consequence, private forest owners do not have an interest in establishing associations or improving forestry management.

3.5. Wood Waste in Forestry

Out of the total volume of felled trees in forests, two main categories are being produced: technical round wood and stacked wood. In addition to these two assortments there are wood residues, which usually remain in forests. On average, about 90% is round and stacked wood, while about 10% is wood residue just from cutting [3]. Beside these categories, in forest s remain stumps and thin branches. In addition, there are leaves and needles with the share in total tree volume on average of 2% [4], but its volume is neglected in the analysis. Typical shares of different categories of tree in the total volume of trees is given in Table 3.7.

Table 3.7. Average share of different categories of wood in the total volume of tree

	state forests	private forests	average	comments
technical round wood	24	8	16	commercial
stacked wood	34	50	42	commercial
bark of round wood	4	4	4	remain in forests
forest residues with bark	9	9	9	partly used
(1) thin branches with bark	11	11	11	partly used
stumps with large roots	18	18	18	remain in forests
total	100 %	100 %	100 %	

(1) thin branches are typically branches with diameter less than 7cm

The volume of usually unutilized parts of the tree, containing bark, thin branches, and stumps, amounts to about 42% of the total tree volume. This means that according to the present wood cutting in forests, usually about 1,1 million m^3 of wood residues, i.e. wood wastes, remain after cutting. These residues are very different in size and shapes, and are very dispersed over a large area. Regarding the quality of biomass, these forest residues can be used as an energy source, and some could be used for the production of panels. Which part of residues would be used mainly depends on the types of terrain, the forest infrastructure, and the distance of the site for residues utilization.

In forests in plains regions, where it is easy to reach every part of forests, it is possible to utilize almost 100% of wood cutting residues. But in natural forests in mountain region, with very steep slopes, with forest infrastructure in bad conditions, and where it is necessary to protect the soil against erosion, the percentage of volume of forest residues that can be extracted is lower. With better forest infrastructure and with appropriate prices for forest residues, a much greater volume of forest residues would be utilized than is the present case.

It is interesting that about 3% of the volume of wood cutting remains in forests despite the fact that these forest residues are great in size (root swell, branch snag), which can be relatively easily collected and transported. Taking into account the present volume of wood cutting in forests, these big pieces of forest residues account for about 75 000 m^3 per year.

If all wood residues in forests were theoretically summed up, they would add up 1.1 million m^3. However, one part of wood residues is collected and sold as wood wastes. In addition, stumps are not always removed from the soil. Poplar trees are usually young with relatively shallow roots, and after felling the tree the stump is usually removed. But beech and oak trees are usually older and have deeper root, therefore their stumps are usually left in the forest. About 600 000 m^3 wood residues (without stumps) remain in forests annually.

3.6. Production of different kinds of wood products

Production of Sawnwood

Together with furniture, sawnwood represents the most significant forest product of the wood processing industry in Serbia. Sawmills comprise 60% of the total number of wood processing companies (2760), and sawnwood accounts for 37,2% of all forest sector exports [6]. Serbia is tenth in Europe in sawn hardwood production.

In spite of their small number, large sawmills have 50% of installed capacity for sawnwood production. However, utilization of their capacity is low because of financial problems, and because many of these mills must go through privatization.

Regarding capacity, there are only two sawmills with installed capacity over 30 000 m^3 logs per year. The majority of other mills have a capacity of 3000 to 5000 m^3. Many mills are located in rural areas, operating only periodically, usually during the warm season, and produce only 100 to 500 m^3 per year.

From 2000 onwards, with the beginning of intensive ownership transformation, the production of sawn hardwood has grown. In 2005, production was 315 000 m^3, but the maximum value from 1998 of about 357 000 m^3 has not yet been reached.. The relatively low production of sawn wood is the result of low round wood availability, since the process of transition includes the forest resource sector.

The decrease in log production, coupled with the large number of manufacturers, is the most significant factor in the low utilization (50%) of the available capacity in sawmill production.

Softwood sawn timber is one of the rare wood products whose production cannot totally meet domestic needs. This is reasonable, considering that coniferous trees represent only 9% of

Serbian forest reserves. Domestic production covers about 20% of overall softwood sawn timber consumption, while the rest of the needs are covered by imports.

Production of Wood Based Panels

Chipboard has maintained the leading position in Serbian wood–based panel consumption. Furniture-making is the most significant consumption area for panels. Consumption of chipboard in Serbia has steadily increased in the last ten years, but is still much less than many countries in the Balkans. In 2005, the maximum volume of imported boards was 174 000 m^3.

There is only one company producing chipboard in Serbia. It was privatized a few years ago, and increased its production. The factory's installed capacity is 75 000 m^3 of chipboard annually. There is a plan to increase production to 120 000 m^3.

Production of Plywood

Serbian companies produced 13 000 m^3 of plywood in 2005 [7]. However, this production is twice less than in 1990. It is expected that production of plywood will reach the high level from 1990 in the next few years. Two main conditions are present: market existence and availability of raw materials.

Plywood based on poplar is produced mainly in Vojvodina, while plywood based on beech is mainly produced in central Serbia.

Production of windows, doors and furniture

275 registered firms in Serbia deal with production of doors and windows. About 95% of them are small enterprises. There are 420 firms and about 3000 small workshops dealing with production of furniture. More than half of the production is exported.

3.7. Wood Waste in Wood Processing Industry

Wood processing produces three main types of wastes in different sizes: bark, coarse waste (from cutting round wood), and fine waste (wood chips, sawdust, and wood dust). A typical sawmill produces between 50% and 65% of main commercial products. The rest are residues (Table 3.8). Depending on the quality of residues, for example, whether bark has been pulled off, residues can be used to produce panel. Otherwise, it can be used as an energy source. Based on annual production of sawlogs of 397 000 m^3 in 2006, wood wastes in sawmills were about 480 000 m^3.

Most saw mills are small. Assuming that small sawmills process about 50% of all wood processed in sawmills that do not use wood waste, then with total production of 397 000 m^3 of sawlogs in 2006, the volume of waste in small sawmills is (Table 3.8):

- wood chips 68 000 m^3
- sawdust 30 000 m^3
- coarse wood wastes 91 000 m^3

- bark 51 000 m^3

In total: 240 000 m^3.

Table 3.8. Residues in sawmills

	hard broadleaves (beech, oak) (%)	soft broadleaves and conifers (%)
commercial main product	50	65
residues		
coarse	24	12
wood chips	18	14
sawdust	8	7
Total	100	100
bark	14 *	14 *

*) bark is additional residue

For different wood products, different processes are used, and different ratios result between the volume of the commercial main product and the volume of wood residues during production. In general, the volume of wood residues is usually about 50%. For example, during production of wood products, such as furniture or windows, the volume of wood residues is over 50%.

Final wood processing, furniture production, and production of windows and doors uses dried sawn wood. The level of residue depends on the type of finished product and applied technology. Table 3.9 contains the typical share of commercial main product and different residues when sawnwood is used.

Table 3.9. Residues in final processing of wood with sawnwood as a resource

	share (%)
main commercial product	35
residues	
after cutting	57
after final works	3
refused products	5

However, another production process, for making chipboard, can be very suitable for utilization of different wood residues. The primary resources for chipboard are stack wood and coarse wood residues remaining after primary wood processing. Chipboard in Serbia is mainly made of beech wood. As the presence of bark in chipboard is acceptable up to 10%, the stack wood of beech is not usually peeled first to remove bark. Therefore, wood residues after production of chipboard are relatively small; only about 15%, consisting of wood dust and coarse residues from cutting boards in a regular shape. Most of the coarse residues can be recycled for the production of chipboard. Only a minor amount of residues in these companies is left for other uses, such as for fuel or energy production.

The installed capacity of Serbia's only chipboard factory is 75 000 m^3/year. Its actual production is significantly smaller than the installed capacity. The factory's plan is to first reach installed capacity, then increase the capacity to 120 000 m^3/year. With the actual chipboard import in Serbia at 170 000 m^3, this anticipated production would not satisfy

domestic demand. Such an increase in production would not endanger prospective wood pellet producers, because the raw material consumption for chipboard production would be increased by about 70 000 m^3, about 7% of the available wood residues from forests and sawmills. Also, the main raw material for chipboard production is round wood, with a supplement of wood chips from sawmills.

Regarding resources for solid biofuel production (pellets, wood chips), whether wood residues from different processes would be used for chipboard production or for pellet production depends on the market.

Figure 3.5 shows the general flow of wood and wood residues in the wood processing industry. In well-organized and optimized companies dealing with board production or pulp and paper production, nearly all wood residue by-products can be used internally. Some wood residues can be recycled or used as fuel. These production processes require a lot of thermal energy, such as steam or hot water, in addition to electricity, and therefore these companies should not be sites where prospective wood pellets producers could purchase wood wastes. It should be in a case of well-organized companies. But companies in Serbia that produce pulp and paper have wood wastes. Despite the presence of wood waste at these companies, prospective pellet producers should not rely for their production on wood wastes from these sorts of companies. In a well-organized state economy, with well-organized companies, only sawmills should be sources of surplus of wood residues. In these companies, some residue is used internally, but a large quantity is available for other purposes, such as production of pellets, or for direct energy production.

In conclusion, the greatest volume of wood waste for pellet production comes from wood cutting in forests and from sawmills. Other wood processing companies, especially small ones, are also sources of wood waste. The total annual volume of residues available for pellet production is estimated at about 1 million m^3, and consists of about 0,6 million m^3 residues from forestry, about 360 000 m^3 (as a mean value between maximum of 480 000 m^3 and minimum available residues of 240 000 m^3) from sawmills, and from all other wood processing companies not more than 50 000 m^3.

Beech and oak are the most common species in Serbian forests. About 65% of the total cutting volume is beech and oak trees, with poplar in third place. Taking into account that the density of dry beech and oak is 0,58 t/m^3 while that of poplar is 0,38 t/m^3, and that pellets contain about 10% moisture, it follows that from the available volume of wood residues, about 500 000 tons of wood pellets can be produced annually.

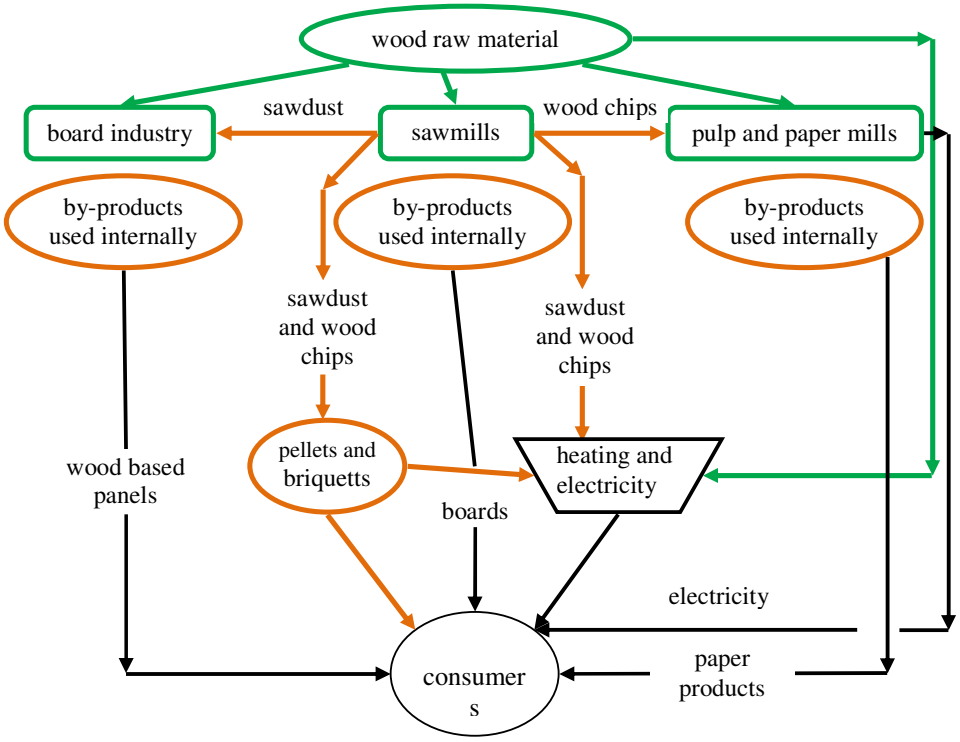

Figure 3.5: Flow of forest wood products and by-products within the wood processing industry

Based on the estimated available volume of wood residues, the planned afforestation rate, the necessary development of forest infrastructure (such as forest roads), and assuming chipboard production will be the main competitive process, the potential for wood pellet production can be estimated (Table 3.10).

There are two scenarios for 2015: the first is based on the current state of forest infrastructure, which means only 50% of forest utilization. In that case, total wood cutting would be slightly increased only by afforestation in the previous period. The second scenario is based on improving forest infrastructure with new and better existing roads, which would lead to higher wood cutting volume, bringing the rate of forest utilization to 75%, as it is in developed countries.

It is assumed that by 2010, there will be six pellet plants with a total capacity of 250 000 t (using 500 000 m^3 residues). With no forestry improvements, the total installed capacity of pellet plants can be 500 000 t by 2015, and 1 million m^3 of wastes would be used. If forestry utilization is increased from 50 to 75%, the available volume of residues would be increased to 1.4 million m^3, which would enable total wood pellet production of about 700 000 t per year.

It is assumed that for chipboard production, only 20% of raw material would come from residues, which can be used for pellets. The main raw material for chipboard production would come from round wood.

Table 3.10 Estimation of wood wastes volume as resource (m^3) and demand in the future

	Actual	2010	2015 (50%)	2015 (75%)
Resource				
Forest residues	600 000	600 000	650 000	900 000
Wastes from Sawmills	360 000	360 000	410 000	600 000
Wood processing wastes	50 000	0	0	0
Used for				
Chipboard	50 000	120 000	180 000	180 000
Wood pellets	10 000	500 000	1 000 000	1 400 000
Fuel wood	1,4 million	1,4 million	1,5 million	1,5 million

Consumption of fuel wood is more or less independent of wood pellet and chipboard production. It is assumed that consumption of fuel wood would not increase in the next year. This assumption is based on expectations that wood residues and wood pellets would have lower prices than logs, and that logs would be used for production of different products which would bring more income than fuel wood.

4. CURRENT MARKET ANALYSIS

4.1. Present Volume of Wood Waste Utilization for Fuel in Industry and Residential Sectors

Serbian industry is generally in a transition period, which means not only transition in ownership, but also transition in the number of number of employees, renewal of production, change of production programs, looking for new markets, or trying to return to the old ones. As a result, from year to year, the main parameters of production in a single company have been changing.

In principal, before privatization, wood processing factories had boilers using waste biomass as fuel. However, it should be pointed out that many boilers are old, usually over 20 years, and that many of them have been out of operation for the last several years.

After the political and economic crisis started in 1990, wood processing companies began losing their markets, revenues went down, and the rate of production decreased. As the economic crisis became severe, the price of electricity became very low, and the general trend many companies followed was switching their biomass or fossil fuel fired boilers to electrical ones. Wood processing companies significantly decreased their rate of production, but the demand for energy was not decreased at the same rate, another reason companies started using fossil fuel and electricity. Some companies were in a favorable position to provide relatively cheap liquid fuel. As a consequence, when the crisis ended many companies had old biomass boilers that had been out of operation for several years. Today, these companies are trying to renew energy production based on available biomass wastes.

The largest wood processing companies in Serbia have not reached the optimal rate of production to date, or even the past production rate. Typically, production does not exceed 50% of installed capacity. The problem is outages of equipment, lack of investments for new equipment, poor quality level of products, and probably an inability to be competitive in the market with products they can produce.

Energy demand is not proportional to the rate of production of wood products. At decreased production levels, energy demand does not decrease as much as the production rate. Therefore, some wood processing companies operating their boilers on wood wastes are in position of insufficient fuel. If they want to operate their biomass boilers, they need additional biomass wastes.

The typical solution is to obtain additional biomass wastes from small enterprises, sawmills that do not use biomass furnaces or boilers, and where a problem with disposing of wood wastes such as sawdust exists. Currently, this cooperation between large and small companies is good, since everyone resolves their problems. But this solution is viable only when small enterprises are relatively close to large ones.

In Serbia, there are only a few large wood processing companies, and more than 2000 small ones. This means that many of the small enterprises should use wood waste resulting from

their own production process or solve this issue in another way. Unfortunately, many of them just deposit wood wastes in their surroundings, or dump them in the closest river.

Regarding the quantity of wood wastes used in industry as energy source or for production of briquettes or pellets, it is very hard to make a precise assessment, as the situation is changing from year to year, and from company to company.

It can most likely be assumed that small sawmills which only operate during the warm seasons do not use wood wastes. Hence wood wastes of 240 000 m^3 from small sawmills with periodic operation is probably available. That value could be treated as a minimum amount of available wood wastes. The maximum value of wood residues from all sawmills is 480 000 m^3 per year. The true volume of wood wastes available for pellet production is somewhere between these two values.

A regular market exists in Serbia for fuelwood with trade of 1,41 million m^3 [3]. But a market for wood briquettes and pellets is practically nonexistent, despite some exceptions such as sales at some coal markets or even at some gas oil stations.

The residential sector in Serbia can use wood wastes as fuel practically only if houses are close to sawmills, i.e. to the site where wood wastes emerge. This is the case in small villages with a great number of small sawmills. The residential sector can use only coarse wood wastes, but not woodchips and sawdust, due to the lack of appropriate transport vessels. If a small sawmill is on the property of a household, this household has surplus of wood wastes, which is over their demand for heating during winter. That surplus even if it is used it is done typically out of market, or usually just put at some disposal site. Therefore, it can be said that wood wastes utilization in the residential sector is very small.

Regarding the use of wood wastes for electricity production, co-generation in boilers out of wood processing industry and for use in district heating systems, no such plant exists at the moment.

4.2. Current and Expected Demand for Wood Waste in Serbia

Some large wood processing companies, with large-capacity biomass boilers, have a shortage of wood wastes for energy purposes because of a low production rate of their main products and corresponding low rate of wood wastes production. As a result, such companies often obtain, usually free of charge, biomass wastes from small wood processing companies. In that sense it can be said that there is a demand for wood waste. But those are cases for only a few large wood processing companies.

In general, there is currently a significant surplus of forest and wood processing wastes not used in any way.

Until two years ago there was no significant producer of wood pellets or briquettes in Serbia. However, for the last two years there has been greater interest in pellet production. Several prospective producers announced the start of wood pellet production in the first half of 2008 with capacity of 18 000 t, 30 000 t and 100 000 t per year, while others plan to start production in 2009. Generally, several small and large investors made the decision to start

wood pellet production based on the possibility of export, and on an assessment that they could generate revenue from the international market.

One of the main reasons for not using biomass as fuel is the low price of electricity, which results in many homes using electrical heaters for space heating.

An additional reason for the practically nonexistent demand for wood pellets is that until 2008, there were no domestic producers of stoves or small boilers using them. Equipment for wood pellets, not only stoves and boilers, but feeding systems as well, can be purchased from developed countries such as Austria and Italy. But such equipment is expensive for a typical customer in Serbia and cannot be sold in high quantities. Some stoves and small boilers made in Serbia are of outdated construction, and despite claiming to be for biomass combustion, are actually designed for coal.. Hence, when burning biomass such units have low combustion efficiency and high biomass consumption.

It can be estimated that in the beginning of 2009, based on estimated production from six factories, production of wood pellets in Serbia would not exceed 250 000 t per year.

The current price for first and second class fuel wood given by the public company *Srbijašume*, which manages the state forests, is 15-30 €/m^3 stacked at the forest road. Based on the inquiry of a stock market seller, the retail price for customers in Belgrade is on average about 50 €/m^3. In this case the stacked volume of wood is1 m^3 .

The price of fuel wood varies from town to town. In Belgrade, where the population has the greatest consumer resources, the price of fuel wood is double the price in Pirot, a town located in southeast Serbia (table 4.1).

The current price of wood waste in state owned forests, given by the public company *Srbijašume* is in the range 4,9 – 11 €/loose m^3 or 11 – 20 €/real m^3 [11], transportation costs not included.

The prices for other fuels and electricity will have an effect on future demand for wood wastes fuel in Serbia. Beside these domestic prices, demand for wood wastes will be affected by the demand of developed European countries for biofuels - wood pellets.

At present, there is no domestic market for wood pellets and briquettes in Serbia. Practically all production of pellets is exported. Therefore, the price of pellets in Serbia is assumed to take into account prices in European countries where wood pellets are used in large volumes.

The values for energy conversion factors (ή) are assumed for medium and small boilers designed for wood and pellets combustion. In case of considering small boilers of actual state in Serbia the conversion factor would be significantly lower, and cost of heating by wood higher. But we expect that future consumers of pellets will install new boilers designed for wood combustion.

The present ratio between prices of different fuels in Serbia generally favors wood-based fuels. The comparison of heating costs by different fuels shows that wood-based fuel is the cheapest (table 4.1). The price of pellets for customers in Serbia is assumed to be 80 €/t, including transportation. VAT is added to that price, resulting in the retail price of 6912 din/t .

Table 4.1 Prices of different fuels in Serbia and the cost of heat

	Retail price*	Heating value	ή conversion	Cost of heat	
Brown coal Banovici	10 000 din/t	18,2 GJ/t	0,81	5,7 (€/m2)	30,5 (€/MWh)
Lignite dry	8 500 din/t	17,2 GJ/t	0,78	5,3 (€/m2)	28,5 (€/MWh)
Lignite raw	4 600 din/t	9,2 GJ/t	0,75	5,6 (€/m2)	30,0 (€/MWh)
Light fuel oil	76 500 din/m^3	37,9 GJ/m^3	0,86	19,6 (€/m^2)	105,6 (€/MWh)
Heavy fuel oil	33 800 din/t	39,7 GJ/t	0,86	8,3 (€/m^2)	44,5 (€/MWh)
Natural gas	28 din/m^3	0,0333 GJ/m^3	0,92	8,2 (€/m^2)	44,4 (€/MWh)
LPG	84 000 din/t	46 GJ/t	0,92	16,5 (€/m^2)	89,3 (€/MWh)
Fuel wood in Bgd.	4 000 din/m^3	14 GJ/t	0,75	5,8 (€/m^2)	**31,2** (€/MWh)
Fuel wood in Pirot	2 000 din/m^3	14 GJ/t	0,75	2,9 (€/m^2)	**15,6** (€/MWh)
Wood pellets	6 912 din/t	18 GJ/t	0,78	4,1 (€/m^2)	**22,2** (€/MWh)
Electric energy	3,265 din/kWh	0,0036 GJ/kWh	1	10,2 (€/m^2)	54,9 (€/MWh)

* 1€ = 80 din

Prices for electricity and natural gas are not retail prices, as there is a special tariff system for these kinds of energy. VAT is afterwards included for obtaining *cost of heat*.

VAT for all energy carriers is 18%, except for natural gas and wood it is 8%.

Price for the installed electric power is 529,8 din/kW for customers connected at low voltage distribution system, excluding householders.

Because of different prices for fuel wood in Belgrade and Pirot, wood pellets would be more expensive than fuelwood in Pirot, but cheaper than fuelwood in Belgrade. The most expensive solution for heating is light fuel oil and LPG (Liquid petrol gas). Then electricity follows, and after that heavy fuel oil (mazut) and natural gas. Heating with different types of coal is relatively close to the cost of heating with wood pellets and fuel wood. Even more, heating in Belgrade based on any kind of coal is little cheaper than using fuel wood. It is worth noting that in Pirot, the price of lignite coal is higher than in Belgrade, due to the fact that the coal mine Kolubara is much father from Pirot than Belgrade. Heating based on lignite Kolubara previously separated and dried is the most cost effective among coals.

The price of heating with wood pellets is competitive to all other fuels probably only in large towns, where the income of the population is high enough, and in the Province of Vojvodina. Vojvodina has relatively small forest areas, wood cutting is low, and therefore the demand for fuel wood is greater than production. Pirot, which is in a region modestly rich in forests, shows that the affluence of the population and the vicinity of forests can lead to a low price of fuel wood. This fact should be taken into account when analyzing the feasibility of pellet production, especially if the production is directed toward the domestic market.

In the domestic market, wood pellets can replace fossil fuels used for heat in different sectors: industry, residential, and agriculture. According to the energy balance of Serbia for 2006, the industrial sector consumed much less coal than the residential and agricultural sectors (Table 4.2). The residential sector includes public buildings. More liquid fuel is consumed in

industry than in the other two sectors. Total fuel wood consumption is at the level of natural gas consumption in residential and agricultural sectors.

With production of 500 000 t/year and an energy value of 210 000 toe [ton of equivalent oil], wood pellets can replace about half the coal consumption in the residential and agricultural sectors, or totally replace the liquid fuel consumption in these two sectors, or totally replace the coal consumption in the industrial sector. Given that wood pellet production can replace 35% of the final energy consumption of coal, or 35% of the final energy consumption of liquid fuel, it is obvious that the energy potential of wood pellets has significant value for the energy sector in Serbia.

Table 4.2 Final energy consumption (toe) of fossil fuels in Serbia in 2006. [20]

	industry	residential + agriculture
coal	175 000	444 000
liquid fuel	451 000	125 000
natural gas	436 000	370 000
fuel wood	350 000	
wood pellet (possible production)	210 000 (production 500 000 t/year)	

Final energy consumption – consumption of fuel for local heat production only, not for electricity generation neither district heating systems.
1 toe – ton of equivalent oil = 41,86 GJ/t
18 GJ /t - Heating value of wood pellets

4.3. Current Wood Waste Utilization in the Region

Serbia, Montenegro, Croatia, and Bosnia & Herzegovina are in very similar positions regarding wood waste utilization.

Forest wood wastes resulting after timber cutting is only partially used, while the utilization of wood wastes from the wood processing industry varies depending on the technological level of companies in that sector.

Until 1992, there were four producers of chipboard in Bosnia and Herzegovina, but currently none are operating. [9]. Furniture production companies have to import chipboard from Croatia and Slovenia, while Serbia has insufficient chipboard production for furniture producers in Serbia.

Chipboard production companies are very good places for utilizing wood wastes for non-energy purposes.

Similar to the trend in Serbia, new enterprises are emerging dealing with pellet production in the whole region. The general motivation for new enterprises or for existing wood processing companies in the region to produce pellets is to sell them in developed countries only. Practically speaking, there is no market or demand for pellets in the region. There are single

examples of using pellets, but the majority of pellet production in the region is intended for export.

Until 2007, there were no pellet producers in Croatia. Now, according to the available data, there are several, including one big producer. The total capacity of all pellet production in Croatia does not exceed 80 000 tons per year. An important step in the development of pellet production there was the creation of a cluster of existing and prospective small pellet.

Reliable information about present pellet production in Bosnia & Herzegovina and Montenegro could not be found. The assumption is that Montenegro has only a few small producers, while Bosnia & Herzegovina has bigger producers. The assumed production in these two countries is about 100 000 t/year.

Comparing the values of pellet production in Croatia, Bosnia & Herzegovina, and Montenegro (together app. 200 000 t/year) with the announced capacity for 2009 in Serbia (app. 250 000 t/year), together with annual wood cutting in these countries (table 2.3, 2,59 million m^3 in Serbia, and over 10 million m^3 in the other three countries), it can be concluded that there is significant potential for pellet production in the region.

4.4. European Union market

In March 2007 the European Union Member States agreed to a 20% binding target by 2020 for renewable energy sources as a response to the European Commission package proposed. Biomass will be the main contributor to achieving that target. According to the European Commission, biomass technology could achieve at that time up to 215-239 Mtoe (only using the indigenous resources). As woodfuels (including wood pellets) are the most available biomass form in most European countries, they will play a crucial role in achieving the 2020 objective. In addition, bioenergy trade (imports) represents a great opportunity to achieve even higher shares.

The main objective of the European Union Biomass Action Plan, put forward in December 2005, is to double the 4% share of biomass energy by 2010.

The availability of raw material, competitive prices, and diversified energy policies favors development of a wood pellet industry in the EU. Sweden, Denmark, Germany, and Austria have the most highly developed pellet markets; others such as Italy, Belgium, France, and the UK recently have been following that trend. In 2006, the production of pellets in the EU was about 4,5 million tons, with Sweden, Austria, and Germany the main producers. Almost 300 pellet plants are located in the EU ranging from small scale producers with an annual capacity from 2000 to 150 000 tons of pellets [18].

In 2006, wood pellet consumption in the EU accounted for around 5,5 million tons, which indicates a significant amount of import. Wood pellets are used both in electricity and heat production (in large, medium, and small scale).

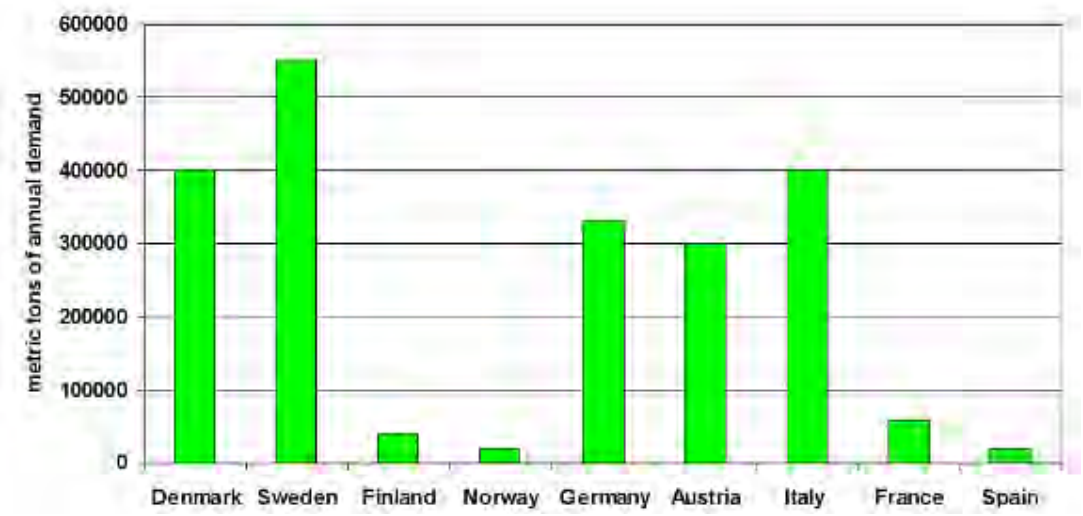

Figure 4.1 EU markets for residential pellet heating in 2005 [18]

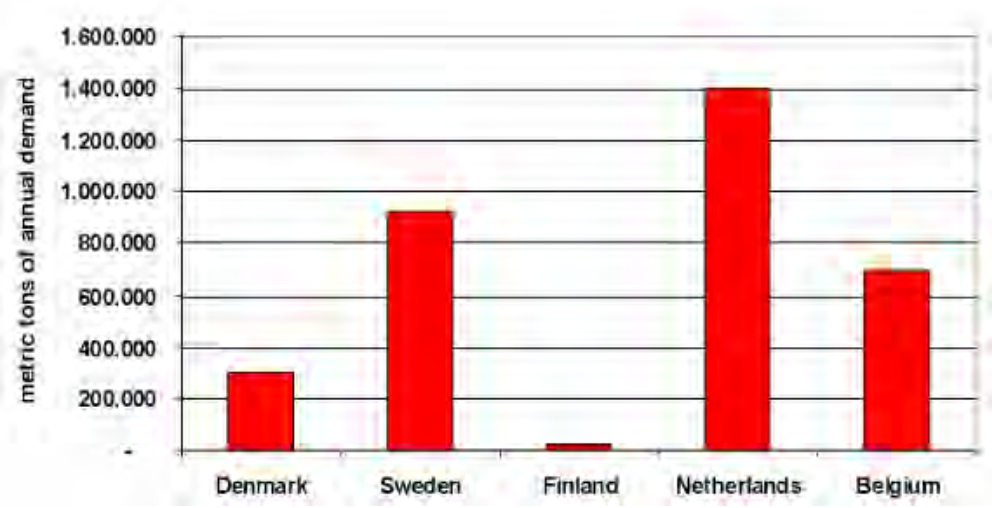

Figure 4.2 Pellet use in power plants in the EU in 2005 [18]

In the EU, the price of wood pellets varies from country to country, which intensifies the trade in wood pellets. The comparison of average prices in Austria, Finland, Germany, Spain, and Sweden in 2005 and 2006 are presented in Figure 4.3.

Austria exports more than half of its pellet production (780 000 tons in 2007 [18]) to other countries. It could be reasoned that this means that the Austrian market has a surplus of wood pellets, and consequently the price of wood pellets would be low. But the price of wood pellets in Austria is high.

Wood pellets are the most expensive in Germany, with Austria and Sweden following. Prices are lower in Finland and Spain. Austria and Sweden have very high prices despite the fact that they have immense wood resources. Their market of biomass use for energy is developed, and the demand for wood pellets is high, which leads to an increase in price.

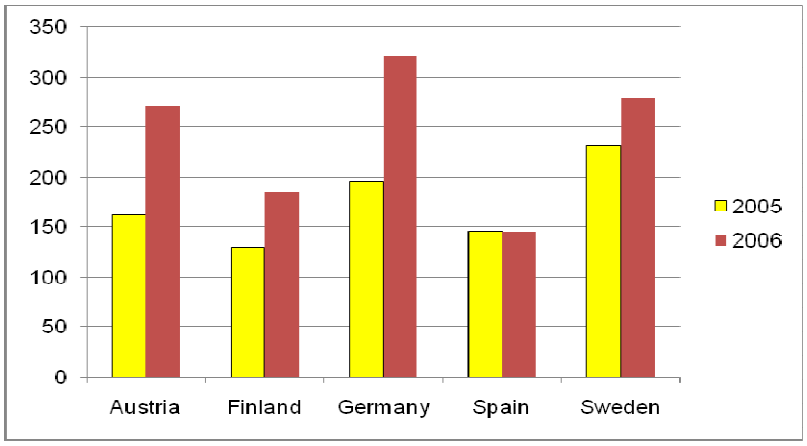

Figure 4.3 Pellet prices (€/t) in Austria, Finland, Germany, Spain, and Sweden in 2005 and 2006. [18]

The price of wood pellets in Austria significantly increased during the winter of 2006/2007 (Figure 4.4). Just after winter the price decreased to the level of the previous year. It can be seen that during the winters of 2005/2006 and 2007/2008 the price of pellets was very stable. After the winter of 2007/2008, the price decreased slightly in comparison with the same period the year before. Since Austria exports more than half of its production to other countries, and a great part to Germany, the jump in pellet price during the winter of 2006/2007 was likely the consequence of the jump of pellet price in Germany in the same period (Figure 4.5). More and more wood pellet producers are emerging in Europe in the European Union (Ukraine, Belarus, Bosnia, Serbia, and Croatia as well) and the offer of wood pellets is larger, and which probably drives the price decrease.

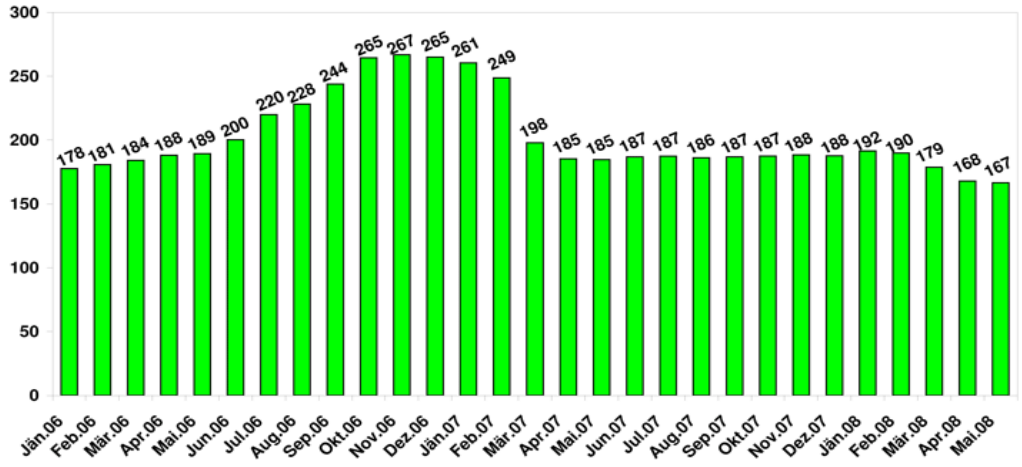

Figure 4.4 Price (€/t) of wood pellets in Austria (January 2006 till May 2008) [19].

In January 2007, the price of wood pellets in Germany was extremely high (265 €/t) and reached the price of fuel oil (Figure 4.5). Very soon after that, in March 2007 the price of wood pellets decreased to the level before of before the winter of 2006/2007 (200 €/t). The probable reason for that increase in price was an increased demand for pellets, and the increased demand could be caused by colder weather or by higher incentives for bio-fuel use. Comparing the prices of natural gas, fuel oil, and wood pellets in Germany, it can be concluded that using wood pellets is the cheapest solution for heating.

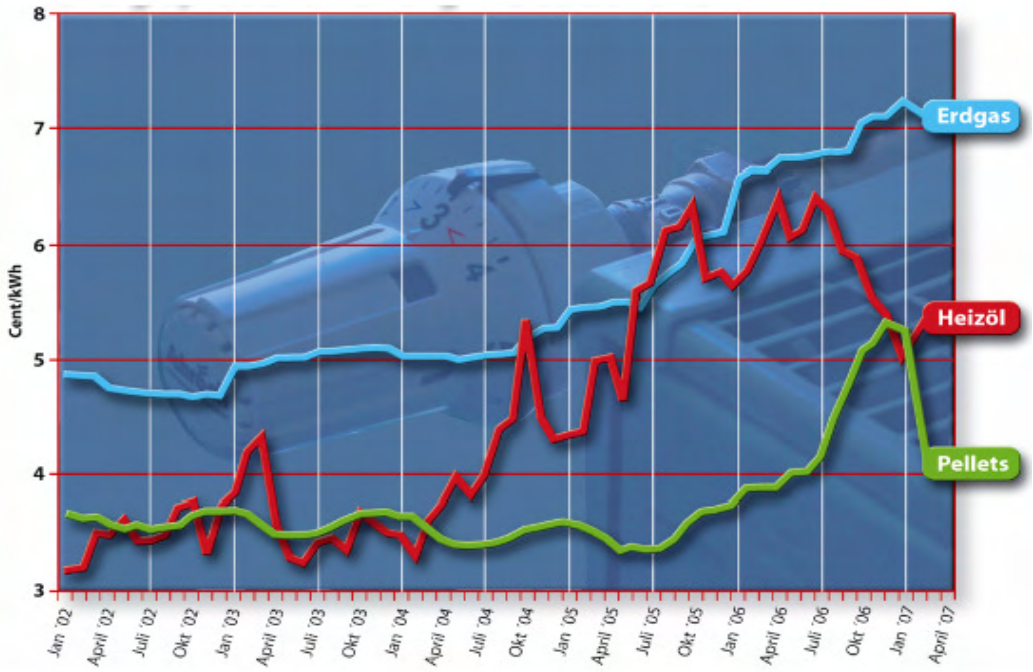

Figure 4.5 Pellet prices (c€/kWh) in Germany January 2002 - April 2007, with comparison to natural gas (Erdgas) and fuel oil (Heizol). [www.interpellets.de, 18]

The Netherlands has very limited domestic resources of wood wastes. But the Netherlands has very great consumption of wood pellets. According to *ProPellets* Austria, the annual demand for pellets in the Netherlands is around 1,4 million tones. Pellets are imported from South Africa, North America (mainly Canada), and South America (e.g. Chile and Brazil) [18].

A comparison of prices in Austria and Serbia (Table 4.3) shows that electricity in Serbia is much cheaper, almost three times cheaper, than Austria, while fuel oil is somewhat more expensive. It is clear that the price of wood pellets in Austria is absolutely the cheapest fuel in comparison with those listed in Table 4.3, while in Serbia, with the assumed price of about 80 €/t, wood pellets is the cheapest fuel in comparison with the listed ones in Table 4.3, but this is not the case in comparison with fuel wood (Table 4.1).

Table 4.3 Prices of energy carriers in first quarter of 2008 [19]

	Austria	Serbia
	c€/kWh	c€/kWh
Wood pellets	3,4	*1,7* [a]
Natural gas	6,24	4,1
Fuel oil	8,87	9,1
LPG	10,35	8,2
Electricity	17,27	5,5

[a)] Price of wood pellets in Serbia is assumed

4.5. Regulatory environment for wood waste fuel products in Serbia

Biomass pellet and briquette production for the Serbian market is practically nonexistent. National standards for their production have not been officially adopted yet. But because pellet production in Serbia is mainly directed to EU countries, producers in Serbia make wood pellets according to standards of these countries (Table 4.4).

The national Law on Wastes is in preparation, specifically, a draft after revision was prepared a few years ago, but the law has not yet been adopted. The Law on Wastes will define different kind of wastes according to their harmful potential, and will define measures for waste handling and disposal, as well as penalties for disobeying the rules.

Serbia currently has two positive acts regarding wastes - the *Law on manipulation with dangerous materials* (Gazette of The Republic of Serbia No. 26/1996), and the *Rulebook on dangerous materials* (Gazette of The Republic of Serbia No. 31/1982) These acts are mainly devoted to toxic materials, which means that they do not cover wood waste from the wood processing industry.

The only act which presently might apply to wood waste is the Law on Waters [14], which prohibits delivering into rivers all materials which can lead to the increase in harmful elements in the water over the prescribed limits. Since wood waste, in a quantity produced by wood processing companies, would endanger quality of water in rivers, it means that it is forbidden to deliver wood wastes in rivers. This prohibition has been enacted, but in practice penalties are very rarely enforced.

The Law on Forests [12] deals with forest management for the optimum utilization of forests, but it does not prescribe treatment or disposal of residues from timber cutting. The general approach is to leave stumps of beech, oak, and conifer, because the cost of removal is high, while the stumps of poplar are removed for clear-cutting. Sometimes biomass wastes in state-owned forests are collected, removed, and disposed of near forest roads, and depending on market value, biomass wastes are sold or are given to local inhabitants. But if a type of biomass wastes does not have any market value, it can be left in forests. Since logs above 7cm in diameter have market value, it can be expected that some quantity of smaller diameter branches will be left in forests.

It can be expected that in the near future, some norms similar to the ones in the European Union would be adopted in Serbia. Such norms consider the balance of different elements in the soil, such as nitrogen and mineral matters. Since the balance of nitrogen in the soil is very important for the regular growth of trees and the development of forests, it is necessary to prevent an overload or shortage of nitrogen in soil. These measures are conducted by removing or leaving some quantities of wood wastes, especially stumps.

Regarding the combustion of fuels, including biomass, there are the *Rulebook on limiting values of emission, methods and periods of measurements* (Gazette of The Republic of Serbia No. 35/1997), and the *Rulebook on limiting value of emission, methods of measurements and criteria for determination of measurement sites* (Gazette of The Republic of Serbia No. 30/1999). Both rulebooks need updating in order to be in accordance with common practices of European countries.

Table 4.5 Emission limits for biomass combustion boilers and furnaces [15]

	Capacity MWth		
	>1 -50	>50 -300	>300
	mg/m^3	mg/m^3	mg/m^3
dust	50	50	50
CO	250	250	250
NO_2	500	400	200
Organic compound expressed as total C	50	50	50

As it can be seen in Table 4.5, the Rulebook defines emission limits for boilers on biomass above 50 MW, which do not exist in Serbia, while it does not prescribe emission limits for medium and small boilers below 1 MW, which constitute the greatest share of installed biomass boilers. According to the Rulebook, the standard JUS M.E6.110 is applied to boilers below 1 MW. The standard was adopted twenty years ago, without defined emission limits for CO and hydrocarbon.

A rulebook regarding the combustion efficiency of different fuels in small and medium boilers is in preparation and is expected to be adopted this year. Its purpose is to enhance the combustion efficiency of existing boilers. Even though it can be said that high efficiency leads to the minimum volume of unburned particles, and CO and CH_4 emissions, this rule will not precisely prescribe emission limits from biomass boilers.

In the event Serbia develops a market for pellets, it would be necessary to develop standards regarding the quality of pellets and briquettes, declarations on products, and standards on the quality of boilers and furnaces.

Specification	**Austria** ÖNORM M7135		**Sweden** SS 18 71 20			**Germany** DIN 51731 / DIN plus			**CEN** CEN/TS 14961:2005 Annex A
	Wood pellets	Bark pellets	Group 1	Group 2	Group 3	5 size classes [cm]			
Origin									Chemically untreated wood without bark
Size	- Pellets : 4 - 20 mm Ø max.100 mm lg.	-Briketts: 20 -120 mm Ø max. 400 mm lg.	max. 4 Ø**)	max. 5 Ø	max. 6 Ø		Length	Ø	D06 ≤ 6 mm ± 0,5 mm and L ≤ 5 × Diameter D08 ≤ 8 mm ± 0,5 mm and L ≤ 4 × Diameter
						HP1	>30	>10	
						HP2	15-30	6-10	
						HP3	10-15	3-7	
						HP4	<10	1-4	
						HP5	<5	0,4-1	
Bulk density			≥ 600 kg/m³**)	≥ 500 kg/m³	≥ 500 kg/m³				Recommended to be stated if traded by volume basis
Fines in % <3mm			≤ 0,8	≤ 1,5	≤ 1,5				F1.0 ≤ 1,0 % F2.0 ≤ 2,0 %
Unit density	≥ 1,0 kg/dm³	≥ 1,0 kg/dm³				1-1,4 g/cm³			
Moisture content	≤ 12 %	≤ 18 %	≤ 10 %	≤ 10 %	≤ 12 %	<12 %			M10 ≤ 10 %
Ash content	≤ 0,5 % *)	≤ 6,0%*)	≤ 0,7 %	≤ 1,5 %	>1,5 %	< 1,5 %			A0.7 ≤ 0,7 %
Calorific value	≥ 18,0 MJ/kg*) ≥ 4,7 kWh/kg	≥ 18,0 MJ/kg*)	≥ 16,9MJ/kg ≥ 4,7 kWh/kg	≥ 16,9MJ/kg 4,7 kWh/kg	≥ 16,9MJ/kg 4,7 kWh/kg	17,5 - 19,5 MJ/kg ***)			16,9 MJ/kg 4,7 kWh/kg
Sulphur	≤ 0,04 %*)	≤ 0,08 %*)	≤ 0,08 %	≤ 0,08 %	anges	< 0,08			S0.05 ≤ 0,05 %
Nitrogen	≤ 0,3 %*)	≤ 0,6%*)				< 0,3			N0.3 ≤ 0,3 % N0.5 ≤ 0,5 % N1.0 ≤ 1,0 % N3.0 ≤ 3,0 % N3.0+ > 3,0 % (actual value to be stated)
Chlorine	≤ 0,02%*)	≤ 0,04%*)	≤ 0,03%	≤ 0,03%	anges	< 0,03			Recommended to be stated in category: CL 0.03 CL 0.07 CL 0.10 CL 0.10+ (if CL>0.10 % the actual value to be stated)
Arsenic						<0,8 mg/kg			
Cadmium						<0,5 mg/kg			
Chromium						<8 mg/kg			
Copper						<5 mg/kg			
Mercury						<0,05 mg/kg			
Lead						<10 mg/kg			
Zinc						<100 mg/kg			
EOX, extractabl.org. halogens						<3 mg/kg			
Fines. bevor delivery to costumer	max. 1 %					max. 1 %			
Additives	max. 2 % only natural		to be stated						< 2w-% of dry basis. Only products from the primarily agricultural and forest biomass that are not chemically modified are approved to be added as a pressing aids. Type and amount of additive has to be stated.
Ash melting point			temperatur to be stated						
Durability									DU97.5 ≥ 97,5

*) of dry basis **) at factory ***) witout ash and water

Table 4.4: National pellets standards for Austria, Sweden, and Germany and European standards for pellets (www.pelletcentre.info)

4.6. Environmental and other impacts of wood waste utilization

The utilization of forest and wood waste should be conducted in such a way that does not have an environmental impact on life in forests. Pursuant to the Law on Forests, the public companies *Srbijašume* and *Vojvodinašume* are responsible for the sustainable use of all forests in Serbia, private and state-owned.

Productive forestry should contribute to biodiversity, which means saving different species of plants and animals. Therefore typical measures in EU silviculture include leaving a number of old trees and dead wood (trunks) on the clear-cut, and preferably some young deciduous trees also. Regarding the branches, whether to remove them or not, the opinion is that once trees have been felled the natural environment is not disturbed further if the branches are also harvested. Consequently, consideration to nature does not imply a barrier to comprehensive use of forest fuel. But it is recommended not to remove all felling residues. Stumps are left in the soil in significant numbers, for both soil-beneficial and technical reasons (erosion prevention), and they favor wood-living organisms.

If the biodiversity in forests is protected and maintained, then almost only positive effects can be reported on the wood wastes utilization.

At the UN Conference on Climate Change in Kyoto in 1997, international obligations were drawn up to limit the emission of greenhouse gases. The greenhouse gases related to forestry and the energy sector are carbon dioxide CO_2, methane CH_4, and nitrogen-oxide N_2O. The EU has resolved to reduce its emission by 8% from the level of 1990 by the period 2008-2012. Serbia is not an EU member and does not have defined obligations for reduction of its emissions. But the *Treaty of Energy Community* of the Balkan countries impose a duty on Serbia to make a plan for contribution to the implementation of Directive 2001/77/EC of the European Parliament and of the Council related to renewable energy sources.

Also, Serbia ratified the Kyoto Protocol in September 2007, and now is eligible to use one of the Kyoto mechanisms: the *mechanism of clean development.* That mechanism makes it possible to generate revenue by selling the quantity of emission reductions of CO_2 through the implementation of projects that result in emission reduction. These projects can be jointly implemented with foreign partners. The next step of the Government of Serbia should be to establish an institutional organization and adopt the Strategy for Implementation of CDM projects. A great number of CDM projects can be based on biomass utilization for energy purposes.

The utilization of biomass for energy production is treated as CO_2 neutral, based on the fact that plants capture CO_2 during growth through the process of photosynthesis. Combustion of biomass releases CO_2 but the same quantity that is already captured in the plant. If the use of forests is carried out in a sustainable way then all the CO_2 released during combustion of biomass would be captured during the growth of the next generation plant. Therefore the EU Directives impose the increase of biomass and other renewable energy sources utilization for energy purpose.

Beside CO_2, the use of biomass as an energy source has other positive effects. Comparing contents of ash in biomass and coal, it is obvious that the replacement of coal with biomass would decrease by several times the quantity of ash generated during combustion. Taking into

account that ash contains toxic metals, and that ash from one plant is usually deposited in a selected site, means that the soil at these sites is very much polluted. Decreasing the volume of ash will help these sites be less endangered.

Comparing the sulfur content of biomass on one hand and coal and liquid fuel on the other demonstrates that utilization of biomass instead of these two types of fossil fuels would lead to a decrease of SO_2 emission. SO_2 is not a greenhouse gas, but its negative effect is the formation of so-called acid rains, which is harmful to forests, causing leaves and needles to drop off, and other forest damage.

In spite of the fact that it is useful for the sake of biodiversity to leave some residues after clear-cutting a forest, leaving all these residues in the forest would cause more damage than benefit. Areas under the residues would be degraded. The degradation would occur because of nitrogen and metals leaching from the residues. Nitrogen is very important for the growth of trees. Neither the lack nor an excess of nitrogen in soil is good for forests. It is of great importance to maintain the balance of nitrogen in forest soil, as well the balance of minerals. The balance of nitrogen can be controlled by leaving or removing some quantity of forest residues, while the balance of minerals, in the case of intensive use of forests for wood production, can be partly maintained by leaving part of residues, but also with wood ash recycling. It means that the ash generated after combustion of wood residues should be prepared in granules and returned to the forest soil.

In addition to the environmental impact, the utilization of wood residues would have positive effects on forest regions. If wood wastes utilization was developed and financially attractive, including residues of forest cutting, forest owners and managers would try to increase the forest area that would be used as a resource. Therefore, it is necessary to improve the existing forest infrastructure and develop new forest infrastructure. This will enable forest managers and staff to reach all forest areas and to act if necessary for the protection of forests against disease and fires.

The regions with the largest area of forests in Serbia are some of its poorest ones. The municipalities of Kuršumlija, Prijepolje, and Majdanpek are examples. Sustainable and intensive utilization of forests and wood residues in these areas would lead to an increase in employment of local people. Since the bulk density of forest and wood residues are rather low, it is not economically viable to transport residues long distances, and therefore industry of wood processing and wood fuel production would operate more intensively and new enterprises would be established.

It is hoped that the intensive exploitation of forests will lead to a greater concern and understanding for sustainability and environmental protection. Activities directly connected to wood processing and fuelwood production, as well as activities related to maintenance of sustainable use of forests, environmental protection would ask for a new engagement of the local population. This new engagement could lead to the improvement of the population's social status. It must not be forgotten, the potential damage, which could occur if the utilization of forests is not sustainable and if wood fuel is not used in an efficient way.

As it was previously mentioned, forests must be used in a sustainable way with protection of the biodiversity. A sustainable way means that the forest area and the volume of trees must not be decreased in the long term and the forest soil must not undergo degradation by the

depletion of minerals and nitrogen. Trees and animal species must be preserved, and animals be provided with secure new settlements prior to new clear-cutting of forests.

The biomass combustion process is generally treated as CO_2 neutral, which contributes to the decrease of greenhouse gas emission. But if boilers and furnaces are inefficient then gaseous combustion products can contain a high concentration of methane, as a result of incomplete combustion. Methane is a gas with potential for greenhouse effects 21 times higher than CO_2. Therefore, incomplete combustion with methane emission decreases the positive effects of biomass use as an energy source on the greenhouse gases balance in the atmosphere.

4.7. Possible utilization of wood waste for non-energy purposes

Different kinds of wood waste appear in forest wood cutting and wood processing. Typical wastes of forest wood cutting are: stumps with large roots, thin branches up to 7cm in diameter, bark of round wood. Some residues from wood cutting result from milling appropriate dimensions and shapes of commercial assortments. These residues have limited potential to be used for production of wood products, or be used for any other commercial purposes other than fuel. That means an estimated volume of 1,1 million m^3 forest residues would be used mainly as fuel.

Wood residues in wood processing firms such as sawmills, pulp and paper factories, wood panel production, or factories producing furniture, doors and windows, are of a different kind. In sawmills and pulp and paper factories, wood residues consist of bark, woodchips, and sawdust, and biomass wastes containing toxic components after the chemical treatment of wood. Woodchips have many different uses, especially for board or panel production. Sawdust can also be used for board production, while bark is mostly used for energy purposes. Biomass wastes containing toxic components can be used as fuel only.

Residues used in the production of wooden windows and doors, and furniture, can be pure wood, contaminated wood, and parts of boards or panels. If the residue is contaminated wood, previously protected with some resins or paint, or parts of board containing resin in glue, then its utilization is limited. If it is not possible to find uses for large pieces of residue in the production of furniture, windows, and doors, this residue should be used as fuel, in an environmentally safe way, in the combustion process. An environmentally acceptable way means the combustion gases should satisfy the defined concentration limits regarding toxic gasses containing chlorine and mercury, while ash with higher concentrations of some metals, such as cadmium, zinc, and lead, should be specially treated.

This means contaminated residues are not suitable for pellet production or for use in households with open fire stoves. Standards for pellets (Austrian, Danish, German, EU) define the maximum content of dangerous metals in pellets. The solution for production of pellets could include mixing low contaminated wood residues with pure wood to keep the level of hazardous metals down, so as not to exceed the maximum levels allowable.

The production of wood based panels in Serbia is low. The process of privatization is ongoing. Some companies are already privatized, and they are trying to reach their former production rate. Only one factory partly satisfies the domestic demand for chipboard, while a factory for medium-density fiberboard (MDF) does not exist. Therefore, it can be expected,

that instead of importing different wood based panels, existing factories will start to produce these themselves. Another solution is to build new factories for that specific purpose.

Particleboard production has good prospects in Serbia for two reasons: expressed domestic consumption that surpasses 100 000 m^3/year, and available raw material for their production. Currently, much of the raw material needed for particleboard production is going unused or is used for heating. These actions could lead to competition between factories of wood based panels and wood pellets. However, taking into account the volume of forest residues, which is about 1.1 million m^3, it can be concluded that forest residues provide enough raw material for production of both wood based panels and pellets.

4.8. Attitude of main stakeholders towards the production and utilization of wood waste for energy purposes

The stakeholders related to wood waste production and utilization can be divided into two main groups: entities in the chain of production and entities in the chain of utilization.

Stakeholders in the chain of production are: forest owners, entities doing harvesting, wood processing companies, and enterprises producing pellets.

Stakeholders in the chain of utilization are: householders, municipalities with heating systems for schools, hospitals and other public buildings, and wood processing companies.

Forest owners, both state and private, are generally very interested in as much utilization of their resources as possible. Of course, they must keep in mind the sustainable use of forests. The sustainability guidelines are defined by the public companies *Srbijašume* and *Vojvodinašume*. These companies mark the trees and define the quantity of trees that can be felled every year in all the forests of Serbia.

Entities dealing with the harvesting the forests also have interests in widening the forest assortments that can be commercial.

Some wood processing companies have opposite attitudes. Companies producing wood based panels where wood residues and bark can be used would have no interest in producing pellets. These companies are more interested in trying to satisfy their heat and electricity demands by using wood residues without the intention to produce pellets.

Others, who produce wood products but cannot use all the wood wastes they make, would try to make their wastes valuable. There are two possibilities for this: the first one is to sell or give the wood wastes to other entities which can produce biofuel or use them for heat production, and the second possibility is to produce biofuel /pellets themselves.

Presently, the first option, to give the wood wastes free of charge to another entity, is not as probable. This is because there is no obligation for producers of wood wastes to solve the wastes problem. A more probable option is to sell the wood wastes.

The second option, to produce the biofuel itself, is a feasible option only if the enterprises have enough volume, have a suitable quality of non-toxic wastes, and have the financial

capabilities for new investments. It should be taken into account that many companies are new or have been recently privatized, which means that many of them have already spent a lot of money on investments in the main production line.

Presently, there are few enterprises in Serbia producing wood pellets. These enterprises are interested in enlarging their production of pellets. Some new entrepreneurs are interested in installing wood pellet equipment; it is just a matter of the market. Since the present price of wood pellets on the international market is over 150 €/ton, it seems very financially attractive for domestic producers. But in the future, the pellet producers who do not base production on their own wood wastes will probably have difficulty locating enough wood wastes.

Regarding consumers of wood wastes, the first place should be taken by wood processing companies. Usually they use wastes from their own production, sometimes supplemented with wastes from neighboring sawmills. But that consumption of wood wastes is out of the market.

Households are potentially great consumers of wood pellets. In addition, municipalities in forest regions with public buildings (schools, hospitals) are potentially great consumers as well.

Presently, households in villages use fuelwood and different kinds of biomass wastes, usually collected on their own land. Among the different biomass fuels, generally only fuelwood is used for heating houses and apartments in cities. Most public buildings in forest regions use fossil fuels, and in only a few cases fuelwood. Wood wastes, or biomass wastes of any kind, are not generally used in these entities.

For example, only few out of 15 agricultural and forestry secondary schools use agricultural and wood wastes for heating during the winter season. These schools mainly use fossil fuels, in spite of the fact that they are usually located at the periphery of small towns and have their own forest and arable land. Different kinds of biomass wastes are available to them, because almost all these schools have their own arable land and forest for conducting practical education of pupils.

There are several reasons entities do not use biomass wastes as fuel. One important reason is the level of fuel prices and electricity. The price of electricity price is fairly low compared to neighboring countries. Prices for light fuel and natural gas are as high as other countries. But the price of heavy fuel oil (mazut) is much lower than light fuel oil, and many entities with liquid fuel boilers would like to replace light fuel oil with mazut. The only investment in that case is changing the burner and fuel reservoir. All other equipment can be retained. The problem with using mazut is its sulfur content, which leads to higher emissions of SO_2 than with other fuels, even domestic coal. Since there are no environmental restrictions on using low-quality mazut in small boilers in residential area, this is a way for owners of liquid fuel boilers to have cheap fuel without a big investment.

Public buildings under the management of municipalities have their heating provided by the municipalities. As a result, these entities are not as motivated to introduce technology using cheaper fuel that requires an operator's skill and responsiveness. Lessons were learned in the past, during the economic crisis, when responsiveness was low and many facilities stopped operations, which forced many entities to replace biomass or coal boilers with another type

where the need for a skilled operator was lower. Now it is not easy to return to technologies that require skilled operators.

A more serious consideration of the municipality budget would show that the utilization of wood wastes from that municipality would improve the economy. These municipalities would not have to pay for imported liquid or gaseous fuel, people of the area would be employed to collect and transport the wastes, and local enterprises of wood processing would have the potential for additional revenue. It should also be noted that the forest regions are mostly regions of low development and a boost to their economy is greatly needed.

Present prices of wood pellets on the international market are very attractive for producers in Serbia to export, but they are not favorable for consumers in Serbia. Taking into account that the present price of heating with the first rank fuelwood is about 31,2 €/MWh (Table 4.1), the price for lignite and brown coal is about 30 €/MWh , considering these priced it cannot be expected for consumers to use wood pellets with a much higher price.

Wood pellets however, are acceptable for wealthy households and small enterprises with their own heating systems. They can afford the additional equipment for the automatic operation of small boilers using wood pellets, and can afford the relatively high price of wood pellets as well.

In addition to the availability of wood wastes or pellets it is very important for the market to offer modern boilers with auxiliary equipment. Presently it is not the case.

The adoption of laws on wastes would change the attitude of many wood processing companies and force them take more care about the wood wastes they make. Adoption of a rulebook on the upper limits of gas emission from small and medium boilers, and strict application of penalties for not meeting the limits would, in many cases, lead to considerations of other options, for example, using wood wastes and providing new boilers. Improving the awareness of municipal management related to utilization of local resources would most likely change their attitude towards using biomass wastes.

However, the most powerful mechanism for a change of attitude is price. With the regulation of different fuel prices, by adding a tax or by tax exemption, some fuels and wastes can be favored or disadvantaged.

Another very important issue indirectly related to the attitude of prospective consumers is the necessity of adopting standards regarding wood pellet quality. Without standards prescribing the main technical parameters of wood pellets, including stability in shape, standard dimensions, and heating value, and without parameters regarding the chemical composition of wood pellets, wood pellets could be found dangerous during combustion. This condition would discourage many consumers from using pellets.

5. WOOD WASTE MANAGEMENT

5.1. Main stakeholders for Supply of Wood Wastes

About 50% of the forest area in Serbia is state owned. The public companies *Srbijašume* and *Vojvodinašume* are in charge of managing the state owned forests. The companies conduct actions on afforestation, cutting, development and maintenance of infrastructure, and all other activities related to improvement of forests.

Since great shares of forest are under the management of the public companies *Srbijašume* and *Vojvodinašume* they have a very important role in the chain, from biomass waste collecting, to pellet production.

Srbijašume and *Vojvodinašume* usually have one-year contracts with firms asking for wood and wood wastes from their forests. The price of different assortments of forest wood, after cutting and transportation to the forest road, is defined by the public companies every year. Table 5.1 shows an extract from the price list of the Public Company *Srbijašume* defined in October 2007.

Table 5.1 Price list of available assortments of Public Company *Srbijašume* [11]

Round wood				**Fuel wood**	
article	Cost (din/m^3)		Cost (din/m^3)		Cost din/m^3 *(din/m^{3}S)*
oak log		**spruce and pine**		**hard wood**	
∅ > 70 cm	39 150	∅ > 50 cm	10 440	1st class	2523 (*1740*)
∅ 40-49 cm	19 575	∅ 40-49 cm	8134	2nd class	1914 (*957*)
∅ > 30 cm	13 050	1st class ∅ >25 cm	5916	stump	1392 (*609*)
3rd class ∅ > 25cm	5 220	3rd class ∅ >20 cm	3828	forest residue	1392 (*609*)
beech log		**poplar**		**soft wood and conifer**	
∅ > 50 cm	18 480	∅ > 35 cm	3567	1st class	1566 (*1131*)
∅ 40-49 cm	13 020	1st class ∅ >25 cm	2436	2nd class	1218 (*783*)
∅ > 30 cm	5 628	2nd class ∅ >20 cm	2001	stump	870 (*392*)
3rd class ∅ > 25 cm	2 688			forest residue	957 (*392*)

delivering site: forest road
din/m^3 *(din/m^{3}S)* – costs per real volume and bulk (loose) volume
1€ =80 din

Having made an agreement with *Srbijašume* on the purchase of a certain quantity of already cut forest wood, every entity has to organize transportation from a site in the forest to the desired location.

Private forests are divided into relatively small parcels with an average area of 0,5 ha. Therefore, if an entity has demands for a considerable volume of forest wood then that entity has to contact and make agreements with several private forest owners.

Presently, there is not an organization that gathers forest owners into clusters or associations. Gathering forest owners into associations, most likely based on a region, would be useful, not only for the owners, but also for the entities that are interested in cooperating with them.

Generally, private owners do not have the appropriate equipment for professional wood cutting. In addition, they do not have the heavy machines for transportation of stems and logs. Therefore, the purchasing of wood, both commercial round wood or wood waste, from forests in private ownership, is much more complicated than it is with state owned forests.

The managements of municipalities, in the territories that the forests grow, generally do not have responsibilities regarding the forests.

Srbijašume has limited capabilities to carry out the process of wood cutting. Only about 30% of wood cutting in state forests is executed by *Srbijašume*, while 70% of the cutting in state owned forests and all of the cutting in private forests is executed by other firms [13].

The capabilities of *Srbijašume* and private owners to transport cut wood and wood wastes are very limited. Therefore, buyers organize the general transportation of purchased wood and wood wastes.

5.2. Securing a regular supply of wood waste

According to the actual state, the prospective producer of pellets or wood chips has to make agreements with many entities. The best solution is for the producer to make two agreements: one with *Srbijašume,* for purchasing wood including wood cutting, and another agreement with a firm to transport the wood.
However, for pellets producers with the remarkable production rate of over 10 000 t/year, this option is not probable. In this case the capacity of *Srbijašume* to carry out the wood cutting is not high. In addition, the wood wastes in forests are generally dispersed, so the limitation of taking wood wastes from state owned forests only and avoiding private forests could make the transportation costs of wood wastes high.

For a prospective pellet or woodchips producer, it would be more realistic to have several agreements for wood waste purchasing, including state forests, owners of private forests, wood processing companies, with one agreement for cutting, and probably one agreement for transportation (Figure 5.1). This organizational scheme however, seems very complicated.

It should be noted again that Serbia has more than 2,000 wood processing companies. This means that a significant number of them have a small capacity. Most of these companies have wood wastes suitable for pellet producers. Therefore, for full utilization of wood wastes for pellet production, a great number of agreements should be made.

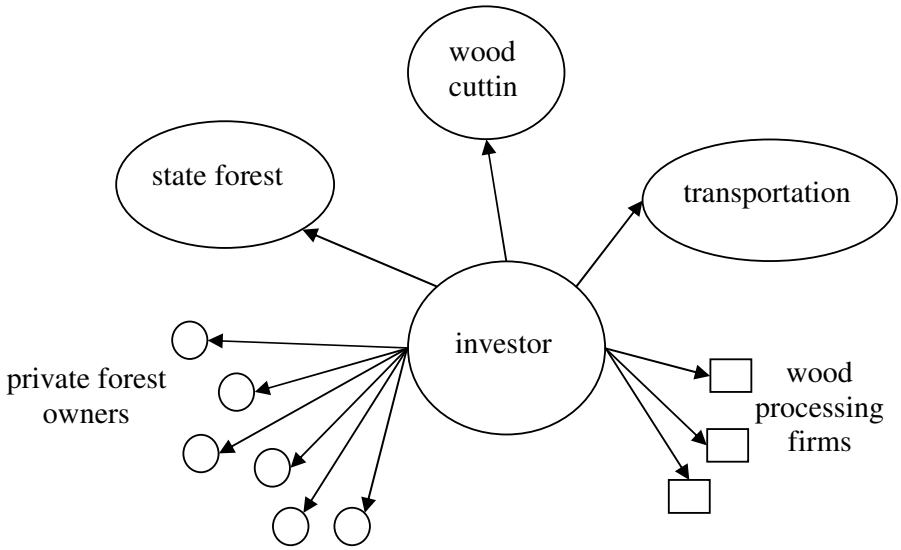

Figure 5.1 Organizational scheme for typical prospective pellet producer

Within the *Serbian Chamber of Commerce* there is the *Association of forestry, wood processing, and pulp and paper industry*. In spite of the fact that the *Association* formally comprises forestry, only state forest representatives are members of the *Association*. Representatives of wood processing companies are active members of the *Association*.

Private forest owners are not organized into any association. Forestry specialists recognize that this is a problem for sustainable and successful management of private forests. Therefore, it is anticipated that in the near future an association of forest owners will be established.

Presently, since private forests owners are not organized, prospective producers of pellets can make contacts with municipalities rich in forests. In spite of the fact that municipalities do not have any responsibilities regarding forests, prospective producers of pellets can find forest owners through municipal entities. The municipality, interested in the improvement of its local economy, will surely help investors and forest owners to make agreements on providing forest wood wastes.

6. STATE OF WOOD WASTE TECHNOLOGIES APPPLIED IN SERBIA

6.1. Production technologies for solid bio-fuels

There are two main types of solid bio-fuels. One type includes fuel wood, wood chips, and other wood wastes without any preparation. The other type is pellets and briquettes, the bio-fuel, which is produced by increasing the bulk density of wood wastes.

Wood chips

Wood chips are usually wood wastes in sawmills and other types of wood processing industry, but can be manufactured specifically for use as fuel for electricity or heat production.

Intentional production of woodchips is usually for household demand. The typical technologies for woodchips production are presented in Figure 6.1. There are machines of different capacities and capabilities. Some equipment is for the cutting of tiny branches for domestic purposes (Figure 6.1a) with a capacity of about 6-10 m3/h, while others are for cutting thin stems (Figure 6.1.b) with a capacity of 100 m3/h.

a)

b)

Figure 6.1 Machines for woodchip production (www.linddana.dk)

In spite of the forest residues availability, the existence of biomass boilers and the relatively low price of machines for wood chip production, these technologies for woodchip production, have not been applied in Serbia yet. The lack of information and promotion of biofuel use, especially of forest wood wastes, is most likely the main reason this technology has not yet been applied.

Pellets and briquettes

The production of wood briquettes and pellets is in a time of expansion.

Briquettes have a greater dimension than pellets. The typical dimensions of wood briquettes are, diameter 60 -100 mm, and length 20 -200mm. Because of their relatively large dimensions, briquettes, unlike pellets, are not suitable for small and medium boilers with automatic feeding. They are more suitable for boilers and furnaces with manual feeding.

Because of their weights and dimensions briquettes are much more inclined to attrition and breaking than pellets. Therefore, wood pellets are a better material for fuel. Pellets can be used in small boilers with automatic regulation, since the feeding rate can be regulated.

There are producers of briquettes in Serbia, but their volume production is very low.

The production of wood pellets is becoming more frequent in Serbia. There are producers of wood pellet production technology in different countries. And several web addresses of technology producers in China can be found on the Internet, these include, *Xuzhou Orient Industry Co., Henan Double Elephant Machinery, Anyang GEMCO Energy Machinery*. European technology producers can be found in different countries, *Andritz* - Austria, *Larus Impianti* – Italy, *Salmatec* –Germany, *SG Strojirna* – Czech, *Sweden Power Chippers Ab* – Sweden.

The principle of pellet production is the same. Pellets should be produced from pure wood, but it is not obligatory. The usual pellet production practice is to make them without adding glue or resin. The technology of pellet production has to meet the request for resistance of mechanical wear, which include the attrition and breaking of pellets caused by their storage and transport. Some European countries, where pellets are in use in great volumes, have adopted very detailed standards regarding the quality of pellets (Table 4.3 Sweden, Austria, Germany).

Pellets can be produced from non-pure wood wastes and additives. But, if this is done, the pellets must not exceed the acceptable level of maximum value of harmful matters. Since the pellets should have a list of specifications, if the raw material is pure wood, the price of pellets is higher on the market.

The ownership structure of the existing pellet plants in Serbia and those, which will be built in the near future, is mixed. Plants can be owned by either a foreign or a domestic company or they can be owned by a combination of both. The technology used for the production of pellets is from European manufacturers. But, the smaller domestic pellet producers usually have second hand technology from European manufacturers or Chinese technology, which is much cheaper.

6.2. Technologies of wood waste use for energy production

The most common way to utilize wood biomass for the purposes of energy production is to burn it in boilers or furnaces. Other technologies, like gasification, are rarely used, and they are experimental.

For combustion of wood biomass in medium scale boilers the typical technology used is grate firing boilers. This means that wood biomass is burning on a static or moving inclined grate or slope. There are several manufacturers of medium scale boilers (0,5 - 20 MW) in Serbia: www.minel-kotlogradnja.co.yu, www.tipokotlogradnja.co.yu, www.podvisterm.co.yu, www.kirka-suri.com. One of the typical solutions for woodchip combustion in a boiler with a temperature-isolated furnace which enables full combustion of biomass fuel is given in Figure 6.2.

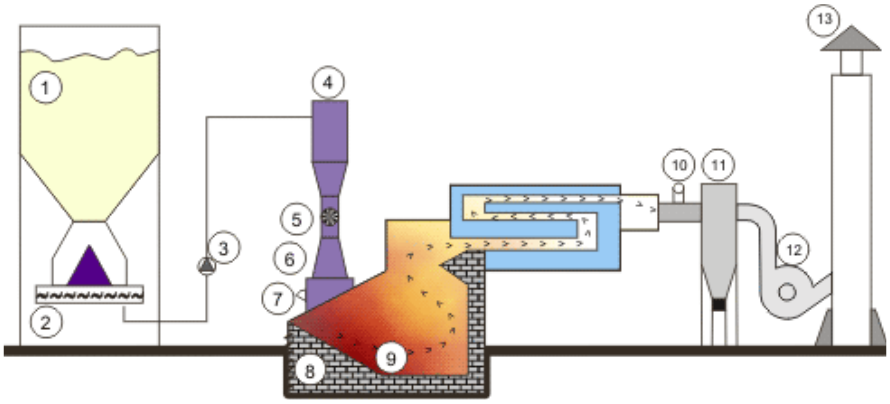

Figure 6.2 Schematic of a woodchips boiler with auxiliary equipment (www.kirka-suri.com)
1–bunker of wood wastes; 2–screw feeder; 3–fan; 4-cyclon; 5,6,7-feeding system; 8–furnace wall; 9-combustione zone; 10–regulator; 11–cyclone; 12–fan; 13–chimney

In regards to small boilers for biomass combustion, which are typically up to 300 kW, there are several manufacturers in Serbia: www.termomont.co.yu, www.podvisterm.co.yu, www.termingkula.co.yu, www.sukom.co.yu, www.alfaplam.co.yu, www.abcproizvod.co.yu, www.megal.co.yu.
But, only one of them offers the small boiler including the auxiliary equipment explicitly for wood pellet combustion (Figure 6.3). Another producer offers auxiliary automatic fuel feeding equipment but mainly just for wood chips. Others usually produce boilers for biomass combustion but mainly for logs, briquettes or coarse pieces of wood waste (Figure 6.4).

Figure 6.3 Boiler with a bunker and feeding system for wood pellets combustion (www.termomont.co.yu)

A short review of boiler manufacturers in Serbia shows that they already produce boilers for wood and wood wastes combustion. Since the production for the market in Serbia and demand for wood pellets are low then manufacturers of small boilers in Serbia do not have an interest in developing boilers or auxiliary equipment for automatic feeding, just for pellet combustion.

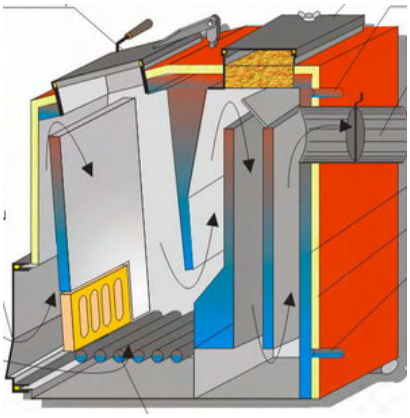

Figure 6.4 Typical design of a boiler for coal and biomass (www.termingkula.co.yu)

All boilers produced in Serbia meet the national standards regarding safety and efficiency. Unfortunately, the standards and regulations regarding combustion in small and medium scale boilers, were defined twenty years ago, and they do not prescribe contemporary maximum levels of gas emissions, combustion and boiler efficiency. Taking into account that boilers, in addition to similar equipment in many wood processing firms, are old, the standards do not impose high requirements regarding the level of gas emissions and boiler efficiency. The result is that many boilers operate with an average efficiency of up to only 70%.

Therefore, the necessary action is an introduction of updated standards and regulations for emissions from small and medium boilers. This measure will force domestic manufacturers to pay more attention to boiler efficiency.

Biomass fuel can be used not only for heat production but for electricity generation as well. Presently in Serbia, all boilers burning biomass produce only hot air, hot water or steam. There is no plant with electricity generation based on wood biomass.

Most wood processing enterprises, except simple sawmills, have chambers for drying wood. Since they use electricity for the operation of all machines, this means that the wood processing industry has a demand for both the heat and electricity. Therefore, from the technical point of view, wood processing firms are the ideal places for installation of combined heat and electricity power plants – CHP.

The advantage of CHP plants is their overall high efficiency of about 80%, when compared to an efficiency of 85% for separate plants for heat, and 35% for electricity generation plants. Higher efficiency means lower fuel consumption, and the lower fuel consumption for the given available volume of wood wastes means higher production of heat and electricity. The

electricity produced in the enterprise can be used for meeting its own demand or it can be sold to the grid. For that reason the enterprise is, in principle, interested in high electricity production, after meeting its own heat demand. A typical, but at the same time modern, solution for a CHP plant based on wood wastes fuel is a steam boiler with a steam turbine. Capacities of CHP plants, which are offered by manufacturers, vary from a few hundred kilowatts up to a few hundred megawatts (Table 6.1).

Table 6.1 Typical parameters of CHP plant with steam turbine

Advantages	Weaknesses	Ratio Heat/El.	Efficiency	Power
High overall efficiency; Satisfying need for different parameters of steam; Possible variation of ratio electricity and heat production; Long working life	Slow start up; Low ratio electricity generation over heat production	3:1 up to 8:1	El: 10 - 20 % Total: up to 80 %	200 kWe – 500 MWe.

Plants with relatively low installed power of electricity generation can be purchased on the market. This means, from technical point of view, that even small wood processing companies can install this kind of plant. However, the final answer about the viability of this technical solution will be given after economic evaluation, which takes into account a very important parameter, the electricity price. Even though the electricity price in Serbia is low, and the Energy Law, adopted in 2004, states that CHP plants, especially if they use biomass fuel, belong to a so called privileged producers group, there have been no new acts or rulebooks adopted specifying subsidies for the privileged producers.

Wood wastes can be burnt simultaneously with other fossil fuels within one boiler. This way of biomass combustion is called co-combustion. If the other fuel is coal of a similar size to wood wastes, the existing feeding system can be used for both fuels, and consequently very small investments are needed. This technical solution of using biomass for energy production is the cheapest one, but it implies that the existing boiler already uses technology, which is suitable for combustion of biomass wastes. In other cases it is necessary to carry out some construction changes on the boiler, as it could also burn biomass wastes. For example, if a boiler burns pulverized coal, and a firm has coarse wood wastes, then the structure of the existing boiler has to be adapted so it can efficiently burn coarse particles of wood wastes.

Co-combustion is a good option for wood processing companies with a relatively small volume of wood wastes compared to their needs of fuel and to the already installed boilers, especially if some of them use coal. Some types of co-combustion can be done with biomass and liquid or gaseous fuel, but in this case it is usually necessary to carry out several significant modifications on the boiler structure. However, these modifications are usually cheaper than having two boilers - one for biomass and one for fossil fuel combustion.

Presently in Serbia, the co-combustion of biomass and coal is only used in a few companies. Some of them are not in the wood processing sector, but are located in the region rich in forests and sawmills. Sawdust, as a by-product of small sawmills, is not always used on site, and the mills are willing to give the sawdust free of charge. Companies that take advantage of this opportunity mix the sawdust with the coal used in their boilers. This co-combustion is conducted usually without any modifications of the feeding or combustion systems. Since the

biomass fuel is free then the interest in these companies for high combustion efficiency is not expressed.

7. PRE-PRODUCTION LOGISTICS

Pre-production logistics depend on whether the prospective pellet plant is located within a wood processing company with available wood wastes for pellet production.

A simple solution would be locating the pellet plant within a wood processing company and meeting the demand of the pellet plant with available wastes from the company. In that case, wood wastes would move within the company from one site to another close to the pellet plant. For that, transportation could be conducted through pipes, or by conveyor belt with protection from rain and snow.

If the pellet plant is not close to a wood processing company, and the source is raw material which would be collected in the forest, or brought from a remote wood processing company, management of the pellet plant would need a solution to the problem of a reliable supply of raw material. Reliable supply is not a matter of transportation costs and vehicles, but the long-term availability of wood wastes. It is likely investors would install only small pellet plants if they do not have their own wood wastes, at least at some limited volume. In any case, if someone decided to install a pellet plant in agreement with forest owners and wood processing companies, it would be necessary for him to rent or buy a truck for transport. Wood wastes in forests are collected in volume, and stored near roads, while some wastes are left in the forest. Usually this consists of branches smaller than 7cm. All these wastes should be collected manually.

Serbia has 1.98 million ha covered with forests, with 2.58 million m^3 wood cutting and about 1.1 million m^3 wood residues of different kinds. Taking into account that only approximately 60% of the total volume of wood residues in forests is available for pellet production, and that of all companies dealing with wood processing, only wood wastes from sawmills are available for pellet production, then it can be said that each forest hectare yields an average 0.3 m^3 of forest wastes and 0.2 m^3 of different wood processing wastes available for pellet production.

Taking into account the largest forest areas only, the conclusion is that the most suitable municipalities for installing pellet plants are: Majdanpek, Kuršumlija, and Prijepolje. According to available information (Public Company *Srbijašume*, www.ebrdrenewables.com, www.pellets.ua, www.tradekey.com, www.vitalsource.info) six companies with wood pellet production of over 10 000 ton/year will be in operation by 2009. Some are in the final stages before operation and some are under construction. There is not a wood pellet plant with significant production, over 10 000 t/year, in operation.

In Nova Varoš, in southwest Serbia, where a few years ago there was the highest concentration of sawmills, a factory producing wood briquettes and pellets was expected to start in May 2008 with a capacity of 10 000 t/year with the intention of expanding production. A factory with the largest capacity in Serbia will be built in Negotin and is expected to be operational in 2008 with a capacity of 100,000 t/year. Wood pellet factories in Beograd (company *Lika system,* capacity 60 000t/year), Bajina Basta (in western Serbia on the Drina River), Prokuplje, and Doljevac (30 000 t/year) which is not far from Niš, should have a combined production of less than 150 000 ton/year. It can be expected that the total production of these factories would be up to 250 000 t annually.

According to estimates of the available wood wastes in forests and from wood processing companies, it can be concluded that there is availability for an additional production of 250 000 t of wood pellets, in total about 500 000 t of pellets per year.

In choosing locations for new pellet plants, the vicinity of any of the big aforementioned pellet plants (Prokuplje, Negotin, Beograd, Doljevac, Bajina Bašta, and Nova Varoš) should be avoided. Therefore, seven locations are suggested for potential locations of new plants. These seven locations comprise 16 municipalities. They are selected because they would not be affected by the six existing pellet producers (Figure 7.1). The selected locations would allow for production greater than 10 000 t per year for each. This assumes that most of the raw material for the pellet plant, forest wastes and wood processing wastes, would be collected from the area of the listed municipalities, meaning transport distances would not be longer than 50 km.

Table 7.1 Selected municipalities for potential pellet production

Municipality	Forest area (ha)	Possible production of pellets (t/year) based	
		on forest wastes	on all wood wastes
Sremska Mitrovica	18 900	2 840	4 730
Šid	21 370	3 210	5 340
Mali Zvornik	14 510	2 180	3 630
Krupanj	24 250	3 640	6 070
Loznica	36 205	5 430	9 050
Prijepolje	69 740	10 470	17 450
Priboj	36 060	5 410	9 010
Kraljevo	73 200	5 210	8 680
Novi Pazar	34 700	9 070	15 110
Raška	32 610	4 900	8 160
Boljevac	31 700	4 760	7 930
Bor	80 600	12 100	20 170
Despotovac	34 910	5 240	8 730
Vranje	37 060	5 560	9 270
Vladičin Han	16 200	2 430	4 050
Surdulica	25 700	3 860	6 430
Pirot	42 580	6 400	10 660
Babušnica	19 360	2 900	4 830
Bela Palanka	14 860	2 230	3 710
Total		**97 840**	**163 010**

The cost of raw materials depends mainly on the plant location. If the plant is located within a wood processing plant, the raw material is free. This is the optimal solution, not only because the price of raw material is zero, but more importantly because its supply is ensured.

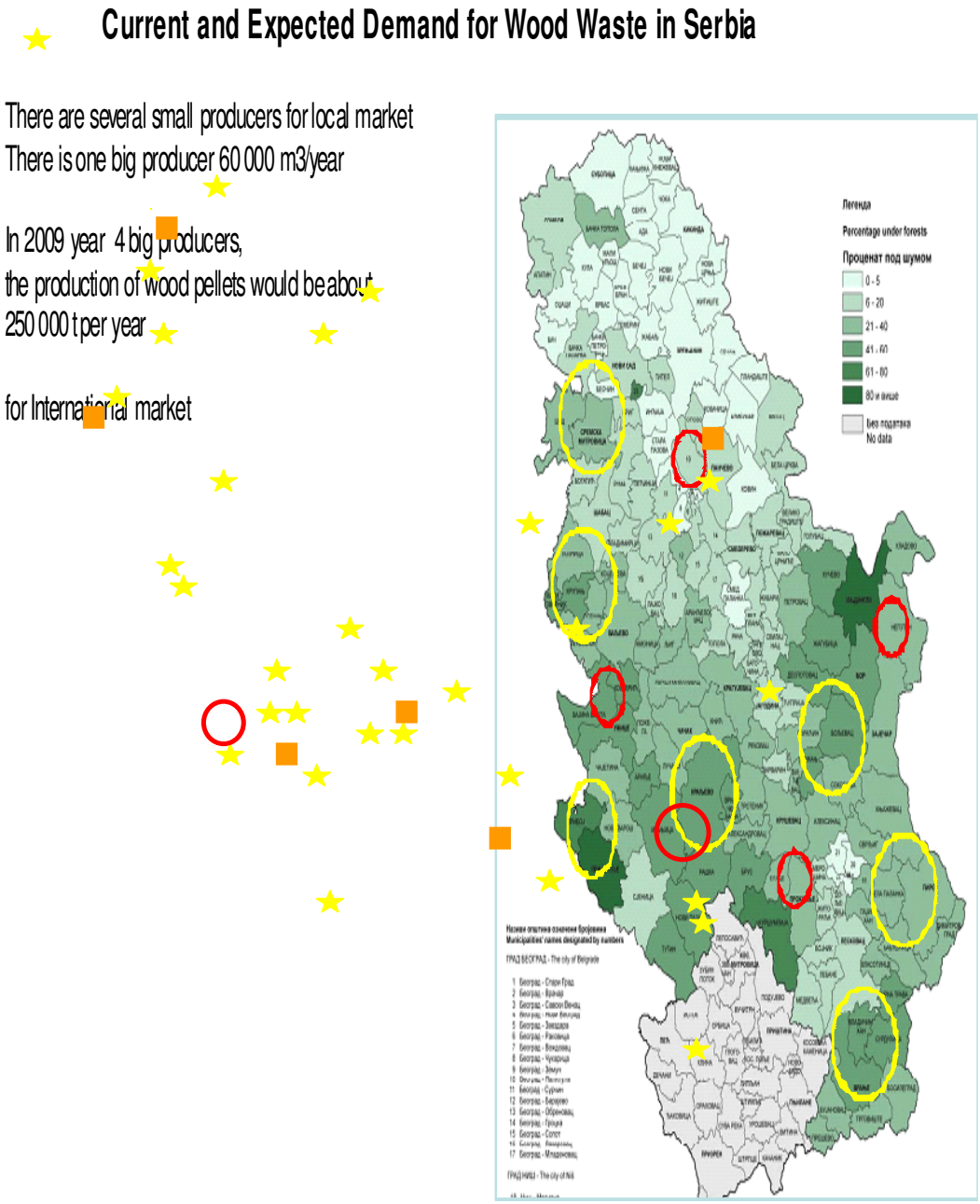

Figure 7.1:
Pellet plants in operation in 2009 (red circle), potential locations for new plants (yellow circle), locations of the first 100 sawmills (yellow star, 1 star = 1÷4 sawmills) with the greatest revenue, and locations of several of the biggest wood processing companies (orange square).

If the pellet factory has to provide resources for production, then transportation of wood wastes (sawdust, woodchips, and bark) would be by trucks or tractors, depending on the distance and the type of wood wastes. If the raw material is more compact, such as bark or wood parts, the transportation cost per ton would be lower. If the transportation distance is short, for example up to 10km, then transport can be by tractor, and would be cheaper than by truck. But if the transportation distance is longer, then the capacity of the vehicle is an important factor, and should be done by truck.

The total number of sawmills in Serbia is more than 1500. In Figure 7.1 only the first 100 sawmills with the greatest annual revenue are presented. Other sawmills, obviously small enterprises, are located primarily in the most forested regions.

The resource for wood pellet production can come directly from the forest or from sawmills. If the pellet producer has to provide some wood wastes directly from the forest, the price of wood wastes would be a maximum 25 €/t. This is the value from the price list of the public company *Srbijašume* (Table 5.1). It is anticipatedthat wood wastes from private forests would be cheaper.

Assuming that the transport of wood wastes by truck would be similar to the transport of coal, the price would be within the range of 0,7 and 1,4 €/km for distances up to 50km for trucks with a capacity of 25 tons. Converting this to the cost per ton of pellets, the price is between 1,8 and 3,6 €/t. The price greatly depends on the density of the wood wastes when transported. If the wood wastes are wood chips and sawdust, with a low bulk density, then the transport price would be higher than for thin branches and stumps.

8. PRODUCTION PROCESS

8.1. Production technologies for wood pellets

The simplest pellet plant is one installed within a sawmill enterprise, where sawdust and cutter shavings are biomass wastes. In that case, the raw material is dry, the plant does not need a dryer and grinder, and the greatest attention has to be paid to protect biomass wastes from impurities (metal). In addition, if the capacity of the pellet plant is small, for example up to 300 t per year (1 t per day), then the only equipment is a pelletizing machine. All other tasks can be executed more or less manually, such as packing, internal transport, and storage.

If the raw material is wood wastes consisting of bark or other coarse pieces of wood, wet sawdust, and wood chips, and the capacity is relatively large, over 10 000 t per year (30 t per day), then the pellet plant should consist of more machines with considerable level of automation.

The main processes in a pellet plant are (Figure 8.1):

- Reception of raw material - unloading of road or rail vehicle;
- Storage system – enabling optimal conditions for further steps in manipulation;
- Cleaning - before grinding, sieving machines and magnetic separators remove various impurities such as stones or metal particles;
- Conveying – an internal transport system for horizontal and vertical conveying of the raw material;
- Grinding – necessary if the raw material is not sawdust or wood material with dimensions under the upper limit, usually up to 3mm, but at least less than the diameter of pellets.
- Conditioning – prepared in appropriate size, sawdust and woodchips are heated, usually by steam, releasing the lignin contained in the wood, which is then available as a binding material during the pelletizing process; also, the raw material should be dried up to a maximum 20% of moisture, and then can be pressed in order to produce pellets;
- Grinding or milling and drying of raw material can be combined, if drying is necessary. In a miller-dryer the crusher changes the particle size of sawdust, which is dried. Crushing makes the process of drying considerably easier, and dried wood particles are easily crushed. The particles should be of equal size and equal moisture content. As the moisture content of all particles is homogeneous, the pellets are more durable.
- Hot gas generators are used for drying. Usually they use sawdust and other biomass wastes as fuel.
- Pelletizing – pellets are produced unde very high pressure in pellet mills. After the particles of wood wastes are prepared for pellet production, they are put in a press. The process of pressing is carried out in a drum with small holes, through which the crushed wood wastes are pressed, producing pellets. A typical drum with holes for pellets is pictured in Figure 8.2. On the left side of the main perforated drum in Figure 8.2, there is a rolling cylinder for executing the press.
- Cooling under appropriate conditions for obtaining qualitative pellets

- Bagging – bagging lines prepare the pellets for onward transportation
- Loading of road and rail vehicles

If a pellet plant uses round wood (timber) as a raw material, the first step in the process is making wood chips from timber, then grinding the chips to a size appropriate for pellet production. Mobile machines for making wood chips from timber are presented in Figure 6.1b, while stationary machines applying the same technology can process even larger timber.

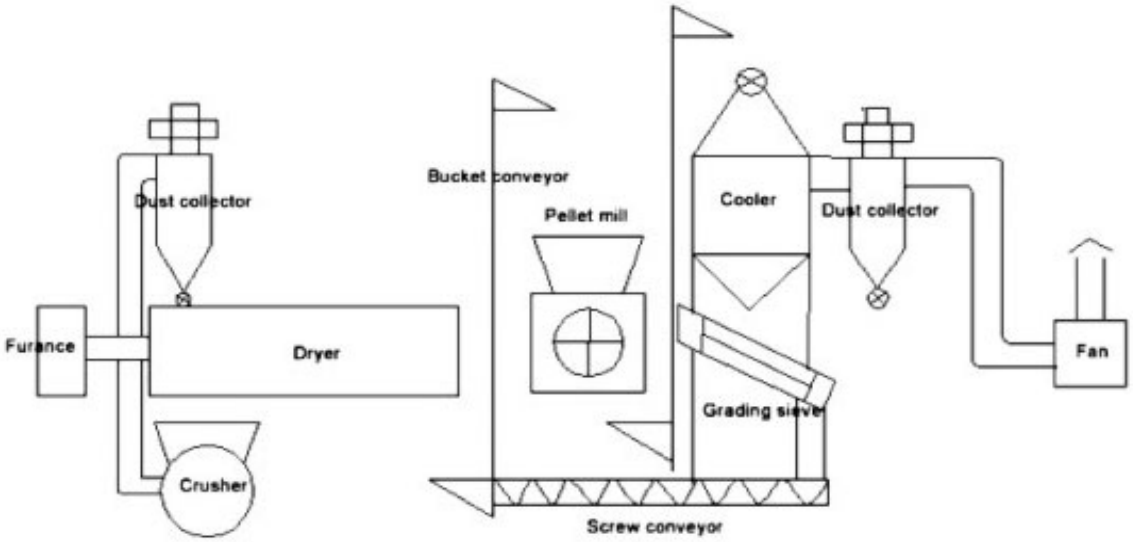

Figure 8.1 Typical plant for wood pellet production

Figure 8.2 Key parts for pellet production (roller and die)

Figure 8.3 Example of a small pellet machine with a capacity of 300 kg/hour.

8.2. Costs of production process[3]

The price of pellets is based on investment costs, operational costs, cost of transport to consumers, tax, and business profit.

Operating costs consist of: the cost of providing wood waste, the costs of energy (electricity and heat), salaries, maintenance, and insurance. The different operating costs are presented in Figure 8.4. If, for example, a pellet factory gets wood waste from the public company *Srbijašume* for the average price of 15 €/t, which is lower than its list price (Table 5.1), then the greatest share in operating costs is the cost of wood waste (51%). Since the maximum price of wood waste offered by *Srbijašume* is 25€/t, the share of costs for wood waste could be much higher.

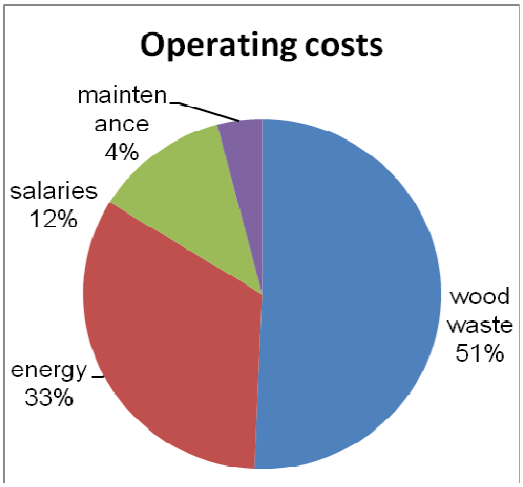

Figure 8.4 Typical share of operating costs for production of wood pellets

Energy consumption costs are of second level importance of operating costs. The process of drying and milling wood wastes as a preparatory phase for production requires electricity for milling and manipulation and the heat for drying. The press, as the main facility for pellet production, also requires electricity. If the price of wood waste is low, then the energy cost can rise to above 50% of the total production cost. This is under the conditions in Serbia, where the price of electricity is three times less than in Austria.

A plant for wood pellet production with a maximum 30 000 tons per year is taken as an example for the economic analysis. This maximum production can be reached only if the plant operates in three shifts.

Investment costs are estimated at 1 million €. It assumes a green-field investment and comprises the following main items: cost of equipment (dryer, press, boiler for heat production), cost of purchasing the land, cost for construction of buildings for storage and operation, connection to the electricity grid, and vehicles for internal transport.

[3] The fugures presented in this chapter are the estimates made by the Energy Saving Group (ESG). Their accuracy is, therefore, the sole responsibility of the ESG and is not guaranteed by Booz Allen Hamilton or United States Agency for International Development (USAID).

A brief analysis of investment and annual operating costs shows that operating costs are very high, and can be higher than the investment cost. Even when costs of raw material are low, the annual operating costs are very close to the total investment cost. Also, an important fact is that the domestic price of electricity is low. It means that investment cost does not play an important role in the assessment of the viability of the project of wood pellet production.

The two main operating parameters for attaining the financial viability of wood pellets production are the costs of raw materials and electricity. Two additional important parameters are the number of shifts for the plant operation and the cost of transport, especially for long distances.

In the case of pellet plants located in Serbia, salaries do not make up a significant share of the total operating cost. Even in developed countries, salaries would not present a significant share of the total operating cost.

The following parameters for techno-economic analysis are adopted:
Investment cost: 1 million €
Annual production: 20 000 tons (2 shifts, 5 working days per week)
Price of wood waste: 27 €/t (including transport cost from forest to plant)
Price of electricity per 1 ton of wood pellet: 7,84 €/t
Annual salary: 6 000 € per worker
Working staff: 6 workers for 1 shift
Transport costs of pellets within Serbia: 6 €/t
Transport costs of pellets to Europe: 36 €/t (truck + ship)
Price of pellets in Serbia: 80 €/t (without VAT, transport included)
Price of pellets in the EU: 120 €/t (without VAT, transport included)
Discount rate: 10%
Operating life: 15 years

The annual income under the above conditions of the pellet plant is 1,6 million € for the Serbian market, and 2,4 million € if pellets are exported to the EU. The annual income exceeds the total investment.

Since the investment cost is relatively low compared to the operating costs, a simple payback period and internal rate of return (IRR) are not relevant to the financial assessment. A simple payback period for a typical pellet plant is not longer than two years, and under some other assumptions it is less than one year. Internal rate of return relates to the value of the total investment and it cannot give a right answer on the financial viability of wood pellet plant.

The relevant financial parameters for assessment of the viability of the project are: the ratio of the total benefit versus total cost (B/C) and profit (B-C). Benefit (B) and cost (C) are the present values of total discounted income and costs for the total period of the working life of the plant.

If wood pellets are sold in Serbia (Figure 8.5) the use of wood wastes with a price of 25 €/t leads to a total profit during the whole working life (B-C) of 3,58 million € present value, and the ratio B/C is 1,46. If the wood pellet producer purchase get wood wastes for a lower price, for example only 8 €/t, then the pellet production would achieve better financial parameters: the total profit during the working life of the plant is 6 million € and the ratio B/C is 2,11. In both cases, the internal rate of return is very high, 38% and 49% respectively.

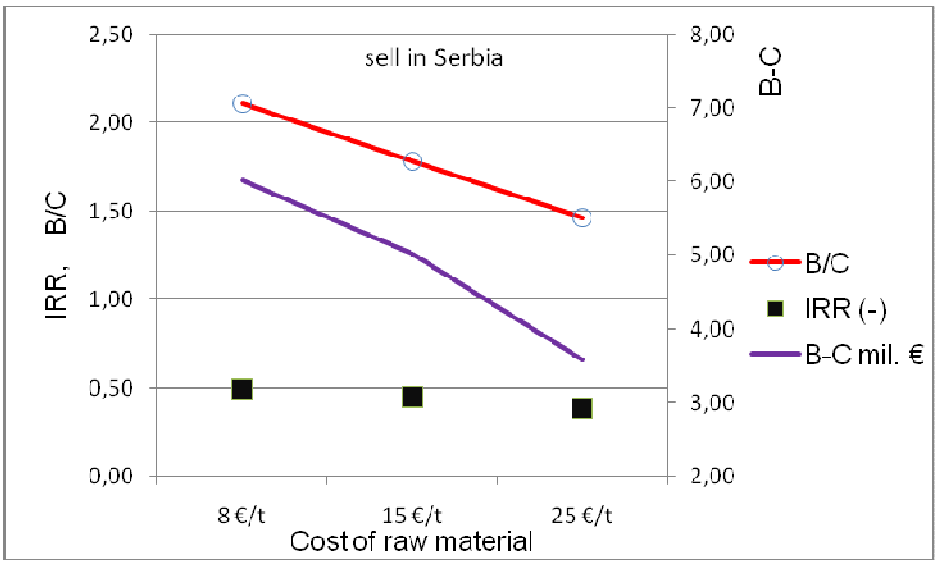

Figure 8.5 Influence of wood wastes cost on financial parameters when wood pellets are sold to domestic consumers

A similar analysis can done assuming the pellets are exported to Europe with the price of 120 €/t including transport cost (Figure 8.6). Since the transport cost to the international market is a significant share in the total costs, the wood waste price has less influence on B/C ratio and profit. The decrease of the raw materials price from 25 €/t to 8 €/t leads to an increase of profit from 5 to 7,44 million €. The ratio B/C is increased from 1,41 to 1,77, while the internal rate of return (IRR) is again very high, 45% and 54% respectively.

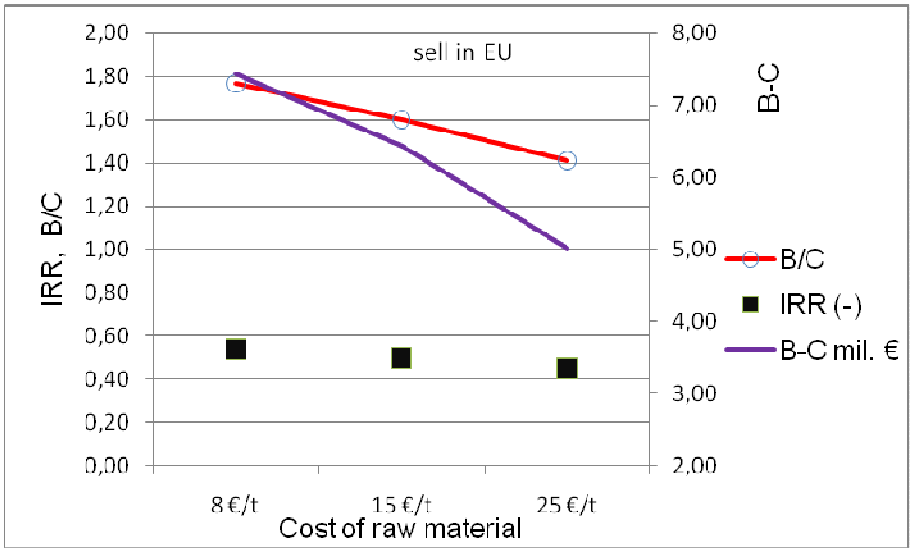

Figure 8.6 Influence of wood wastes cost on financial parameters when wood pellets are exported

The previous analysis was conducted based on the wood pellet price in EU of 120 €/t. This price includes transportation by truck (within Serbia) and ship (from Serbia to the EU). According to information from the Serbian company *JRB* dealing with transportation over rivers and seas, the ship transport to 1000 km distance is 30 €/t including loading and unloading. Then the total transport cost, including transport by truck in Serbia, is 36 €/t.

A potential problem is that the Belgrade port does not have the appropriate equipment for loading pellets onto ships. In that case another option is to use trucks for all transportation. But this option is much more expensive.

The increase of transport costs from 36 €/t to 50 €/t leads to the decrease of profit (B-C) from 5 million € to 3 million €. If the transport costs increase to 60 €/t then the profit for the whole working life of the plant is only 1,58 million € present value (Figure 8.7). The ratio B/C is going down from 1,41 (for the price of 36 €/t) to 1.10 (for 60 €/t). The internal rate of return (IRR) is very high (45%) for relatively low transport cost of 36 €/t, but for higher price of 60 €/t, IRR is decreased 26%.

It can be concluded that increase of transport costs dramatically influences the viability of wood pellet production. Therefore, it is necessary to carefully investigate different transportation methods and carefully select the destinations for selling the pellets.

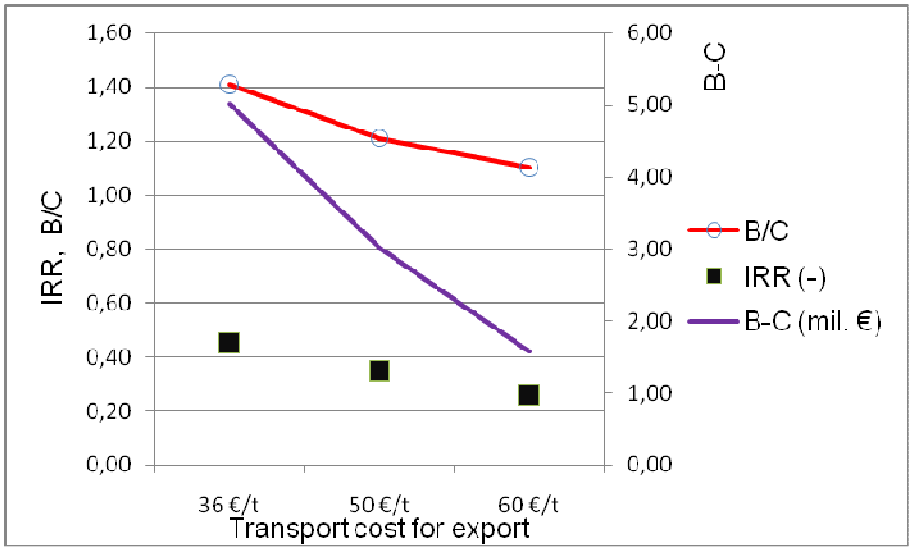

Figure 8.7 Influence of exporting transport costs on financial parameters

Since the operating costs are dominant for assessment of the viability of the project, it is necessary to investigate every possibility of reducing any operating costs elements.

The factory can operate in one, two or three shifts. The change in number of shifts does not change the consumption of any resource such as, raw material and energy, nor the transport costs expressed per volume of products such as, tons of pellets, but the investment is better utilized. If the operation is in three shifts, the plant is more intensively engaged and should have a higher profit. But, the investment cost has very limited influence on the profit of wood pellet production.

The increase of shifts from one to two or three shifts would increase the number of employees, but not linearly. The night shifts have no need for workers who receive the raw material and workers who deliver wood pellets.

The tariffs for paying electricity take into account not only the energy consumed and the power engaged as well. Therefore, the electricity price per ton of wood pellets decreases, as the time of engagement of electric machines is longer. For plant operation in one shift the overall electricity price is 9.9 €/t, while for operation in three shifts the overall price is 5,76 €/t.

Therefore, the increase of operation of three shifts instead of two shifts leads to a decrease of costs of electricity and probably salaries. And vice verse, if number of shifts is decreased from two to one, then the electricity costs increase. With increased shifts the production rate is increased. The overall financial parameters change with a variation of working shifts. With the change from one to three shifts the profit of the plant increases from 1,75 million € to 8,5 million € (Figure 8.8). The ratio B/C is slightly increased from 1,26 to 1,49, while internal rate of return increases from 27% to 57%.

The minimum price, with tax excluded, of wood pellets, including transport costs by truck within Serbia and by ship to the EU, is 66 €/ for the Serbian market and 96 €/t for the EU market. These prices are for one shift plant operation. For three-shift operation, the minimum prices are: 51 €/t for the Serbian market and 81 €/t for the EU market. The term minimum price understands that the profit (B-C) equals zero during the operational life of the facility which is 15 years.

Financial parameters, simple payback period and the internal rate of return cannot be real measures of financial viability for wood pellet production. Investment costs are relatively low when compared to operating costs. For the operation of three shifts with a production of 30,000 tons per year the annual operating costs can be higher than total investment costs.

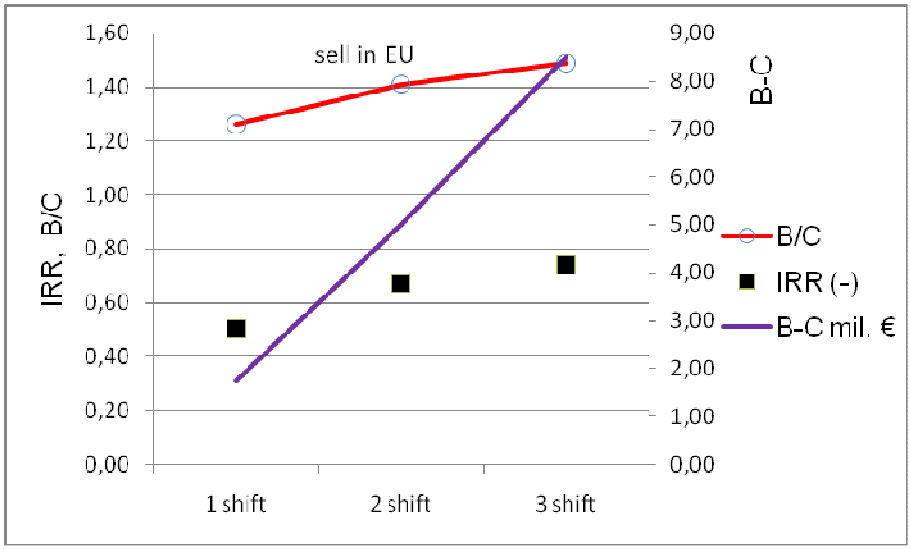

Figure 8.8 Influence of number of shifts on financial viability of the pellet production

As a final result of the economic analysis it can be concluded that an investment in wood pellet production in Serbia would be an attractive option. The conditions for success are as low as possible operating costs, especially costs of wood wastes and transport.
Therefore, all enterprises dealing with wood processing have a remarkable advantage, since they have wood wastes as a by-product, and for them the price of raw material is zero.

For others who plan to build plants for pellet production without ensuring at least a part of the raw material from their own wood processing plant, there is a risk of providing raw material at unacceptable price. With an increase in demand, the price of wood wastes will be higher. On the other hand, a large demand for wood pellets in the EU, and a further increase in demand would increase the price of wood pellets on the market, which would eliminate the negative effects of the increased price of the raw material.

9. POST-PRODUCTION LOGISTICS TO MARKET

In general, pellet producers in Serbia have two possibilities; to export pellets to European countries or to sell them on the domestic market.

Presently wood pellets produced in Serbia are mainly exported. But in the future, after adoption of measures for promotion of renewable energy sources and support measures for their use, it can be expected that wood pellets will be used in Serbia as well.

The main destinations for the export of pellets are, Italy, Greece, Germany, the Netherlands and other northern European countries. The main routes for the prospective export of wood pellets are given in Figure 9.1. There are two main routes for exports to Italy. One option is by road, through Croatia, and the other option is by train to the port Bar in Montenegro and then a ship for transport via the Adriatic Sea to ports in Italy. The closest port is Bari, but Ancona on the north can be used as well. The problem with the second option is the inefficiency of loading an unloading many transportation vehicles. Therefore, it is necessary to have available facilities at the ports, so the wood pellets can be moved from trains or trucks to a ship and vice versa.
If the export destination is for example Germany, there is a possibility to transport wood pellets by ships along the Danube, by train through Hungary or Croatia and then via Austria to Germany.

A cheaper solution is to transport wood pellets in bulk, without packing them in bags. However, in that case, ports and railway stations must have installed facilities for pneumatic transport of wood pellets from one vehicle to another. Since the use of wood pellets in Serbia and Montenegro is not developed, these types of facilities in railway stations or ports are not developed either.

Pneumatic transport for wood pellets manipulation in ports and railway stations could be avoided if wood pellets are packed in big bags, for example 1/2 ton. In that case, typical machines for loading can be used. However, the producer of wood pellets would have to be equipped with the appropriate facilities for packing pellets and for the manipulation of them.

The only way to transport wood pellets in Serbia is by trucks. Transportation by truck is more expensive when compared with trains and ships.
The current price of wood pellet transportation by a truck with a capacity of 25 t capacity at a distance of 200 km would be about 0,7 €/km, or about 6 €/t including insurance. The distance of 200km is assumed as an average distance between prospective pellet producers and the market in Serbia, or the port in Belgrade or Prahovo on the Danube.
If transportation is by the Danube River, the transportation price would be about 30 €/t for distance of about 1000 km, including insurance, loading and unloading.

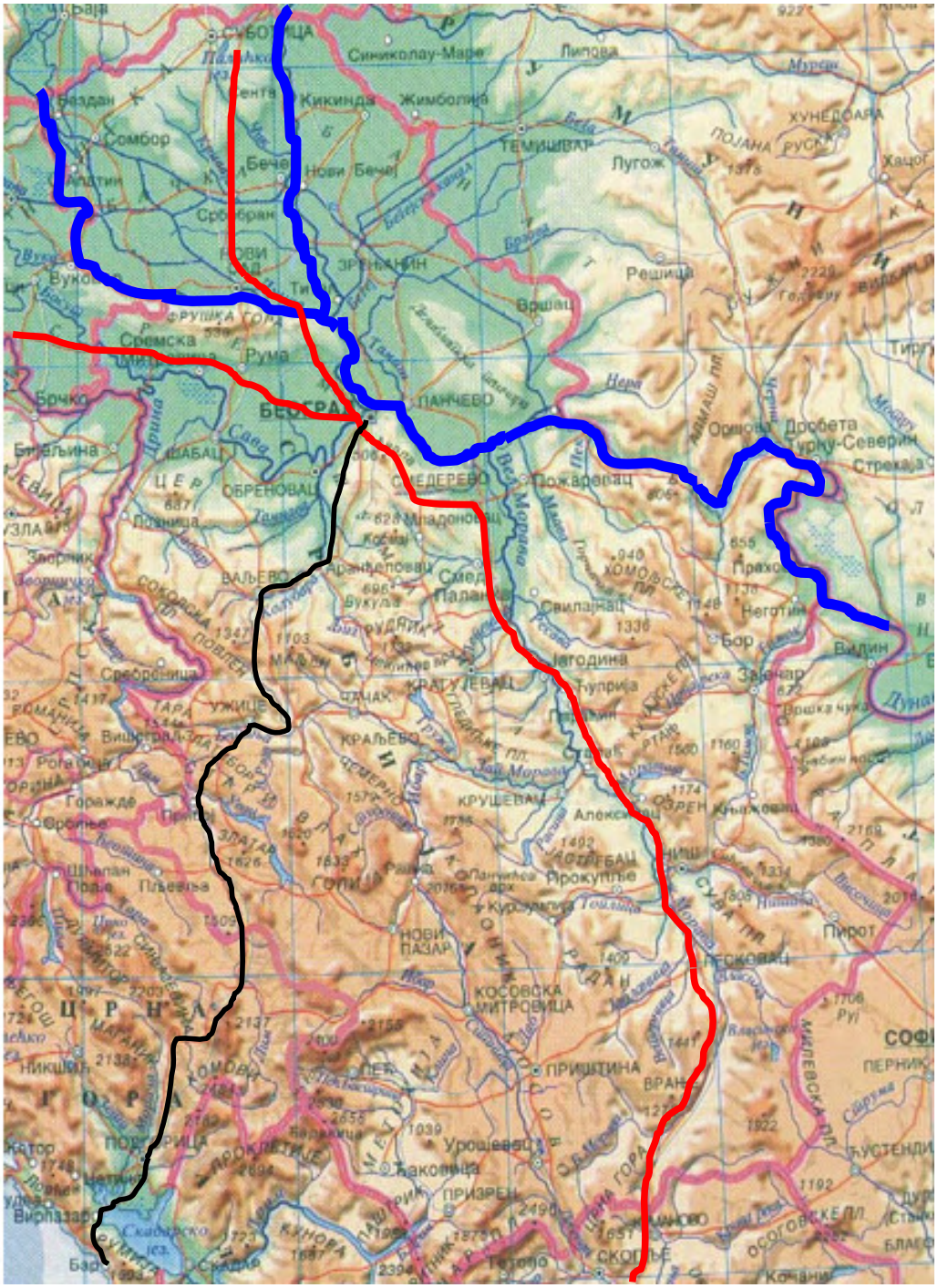

Figure 9.1 Main transportation routes in Serbia
(by rivers – blue line, by railways – black line, by roads and railways - red line)

10. CERTIFICATION OF FORESTS IN SERBIA

The public companies *Srbijašume* and *Vojvodinašume* are in charge of managing all of the forests within Serbia. *Vojvodinašume* is responsible for forests in the province of Vojvodina, while *Srbijašume* is responsible for forests in the rest of the territory.

There are however, four national parks, which are not under the care of these two companies. These parks are Fruska Gora in Vojvodina Province, and Tara, Djerdap, Kopaonik, which are located in the western, eastern and southern parts, respectively. National parks are in charge of management of forests on their territory.

Almost 50% of the forests in Serbia are located on private property. But private owners do not have the freedom to cut trees of their own accord. The Law on Forests [12] states that, in private forests, *Srbijašume* is entitled to mark trees for cutting. Every year, the personnel of *Srbijašume* mark the trees to be cut in forests, which are both private and state owned.

In the province of Vojvodina almost all forests are under state ownership.

This means that despite the fact that the forest is under private ownership, wood cutting is defined by *Srbijašume* and *Vojvodinašume*. Every year these companies define the volume of wood cutting in forests. This is how the sustainable use of forests in Serbia is sustained.

In regards to the international certification of forests (FSC – Forest Stewardship Council) *Srbijašume* intends to certify all their forests. Presently, only one forest organizational unit of *Srbijašume*, the forest estate *Boranja* in eastern Serbia, is certified by the FSC. The certificate was obtained in 2007. Currently, five forest estates within *Srbijašume* are in preparation for obtaining the FSC certificate by the end of 2009. *Srbijašume* intends for all 17 forest estates within its company to receive their FSC certificate within the next several years.

The international certification of private forests would be much more complicated, taking into account that the average area of private forest is about 0.5 ha.

Origins of the legal protection of forests in Serbia can be found even in the 14th century. Article 123 of the Code of Tsar Dushan fro 1349 prohibits forest cutting to Saxon ore miners and defines the obligation to plant where forests have been cut..

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