TCP/CRO/3101 (A) Development of a sustainable charcoal industry

ENVIRONMENTAL ASPECTS OF CHARCOAL PRODUCTION IN CROATIA

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This project was launched in July 2006 within FAO Technical Cooperation Programme withthe objective to assess the current status of the charcoal production in Croatia, in order to develop a programme for the revitalisation of this industry.

Apart from recommendations and best solutions for the technological modernisation, the programme will provide guidelines for the production improvement and amplification with a holistic approach.

Ministry of Agriculture, Forestry and Water management is responsible for the project execution on behalf of the Government of the Republic of Croatia.

ENVIRONMENTAL ASPECTS OF CHARCOAL PRODUCTION IN CROATIA

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Executive summary

This report considers the environmental aspects of charcoal production in Croatia. Environmental impacts of charcoal occur at each step of its life-cycle, which includes feedstock supply, pyrolises of wood and charcoal usage. Impacts originating from feedstock supply, mainly relate to forest stewardship, harvesting practice and extraction of wood from forest. The ultimate impacts may include deforestation, erosion, soil impoverishment. The most significant impacts occurring during charcoal production and usage are emissions into the air and working environment. The pollutants emitted included green-house-gases, tars, MNVOCs and particulate matter. On the global and regional scale they contribute to the global warming, while on the local scale they may impose health risk for the workers and people living in the vicinity of production site.

In Croatia charcoal is produced mainly as barbeque fuel, which is used in restaurants and households. The official records recognise only one major charcoal producer, within the Belišće industrial group. Along with Belišće, there are several other small to medium scale producers, who employ traditional charcoal production techniques in brick- and concrete-kilns. Finally, it is estimated that there are about 400 micro-scale producers scattered in forest areas, mostly in northern part of Croatia. The majority of charcoal produced on the micro-scale is made in brick-kilns, but there are also some cases of production in the charcoal pits. The feedstock is either wood from forests or residues from wood processing industry. The feedstock supply channels include wood processing industry, Hrvatske šume, (the state owned company mandated for forest stewardship and management), and private forest owners.

For the purpose of this project, a number of site visits and interviews with small to medium scale producers as well as with the major industrial charcoal producer in Croatia were conducted. Through the interviews and site visits information on the specifics of the production process and its profitability followed with environmental, health and safety aspects were collected and analysed. Two case studies are presented in this report. The first case study describes the single industrial charcoal production - Belišće, while the second describes traditional way of production, practiced by small and medium scale producers. In both case studies special regard is given to the environmental aspects of charcoal production.

The most important environmental impacts are those occurring during charcoal production. They include emission of air pollutants, primary GHGs and particulate matter. Along climate change impacts, emissions of these substances impose impacts on health of the workers. While, due to the sustainable forest stewardship practiced by Hrvatske šume, which manage 78% of 2.1 million hectares of Croatian forests in total, the environmental impacts of feedstock supply may be considered as insignificant.

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1. Introduction

Biomass is regarded as an environmentally friendly fuel, considering that the net CO_2 emission during its utilisation equals zero. However, the statement should be amended with a boundary: this is the case when biomass fuels, including charcoal, are produced in a sustainable way. The environmental impacts of charcoal production and utilisation can be determined as those related to feedstock supply, e.g. harvesting and extraction of wood from forests, charcoal production and charcoal usage. In other words, there are impacts on both the environment and human health at each stage of the life cycle of charcoal. The impacts vary considerably in magnitude and significance in respect to the management practices and technologies employed in the life cycle, as well as on the state of the environment.

There is a great difference of impact on nature between feedstock supply from an unmanaged, natural, forests and shrubs, harvested via a clear-cut and a sustainably managed forest and/or from residues from the wood processing industry. Harvesting of unmanaged forests through unsustainable harvesting practices or clear-cutting may impose multiple negative effects which can lead to forestry and land degradation, deforestation and consequently erosion or/and desertification. The application of such practices ultimately leads to the increased CO_2 emissions, thus contributes to global warming.

In African countries, where the world's largest charcoal consumption prevails, the significance of the air emissions and the related problems is considerable (Kammen and Lew, 2005; Kituyi, 2004). According to the FAO statistical data charcoal consumption in 1996 in Africa amounted 13.799 million tonnes, out of which 12.350 million tonnes (89.5%) were used in households. In most African countries charcoal is the primary energy source for cooking, as well as major source of income generation and environmental degradation in rural areas (Kammen and Lew, 2005). Although household consumption of charcoal dominates in most of the developing countries, it is also important commodity used in industrial production, e.g. steel production in Brazil (May, 1999) and metal processing and chemical industry in Southern Vietnam (Bhattarai, 1998).

On the contrary to the developing countries of Africa and Asia, in the European and North American countries charcoal is mostly used in different industries as absorbent and as barbeque fuel in households, which can (in a way) be considered as a luxury (FAO, 1985). Hence, the production of charcoal in developed countries is not that extensive and there is a more formalised approach towards feedstock supply, where the greatest amount of wood used for charcoal production is either from forestry and wood-processing industry residues, or it originates from sustainably managed forests. Due to these facts the negative impacts of feedstock supply for charcoal production in developed countries are far less significant (if not negligible, or even positive in some instances) then those in the developing countries.

Charcoal is produced through the pyrolysis (carbonisation or destructive distillation) of carbonaceous materials, which is dominantly medium to dense solid wood such as beech, birch, hard maple, etc. Nevertheless, other types of wood such as softwood, nutshells, fruit pits and vegetable waste can be used, too, especially for charcoal briquettes. There are different methods and technologies used for the production. In many developing countries traditional methods of production in earth pits and earth kilns are still in use, as well as advanced types of small scale production earth kilns with chimneys and steel or brick kilns (Stassen, 2002). Whereas for larger scale, industrial production, different types of batch-wise operated brick or metal kilns, and continually operated multiple hearth retorts are used (EPA, 1995). This type of technology prevails in Europe, North and South America. The named technologies differ in the efficiency of production, resulting in different energy efficiency, product quality and yields and emissions into the environment. For example, for production of 1 kg of charcoal in earth pits and kilns 8-12 kg of wood is needed, while in the improved traditional kilns and for the industrial production 4-8 and 3-4 kg of wood, respectively.

The by-products of charcoal production are pyroacids, primary acetic acid and methanol, tars, heavy oils and water, the majority of which is emitted into the environment with the kiln exhaust. The emissions into the air include gaseous emissions of carbon monoxide (CO), carbon dioxide (CO_2), methane, ethane and volatile organic compounds (VOC); emissions of the particulate matter (PM) coming from the uncombusted tars and charcoal dust, and pyroacids that may form aerosol emissions. The level of emissions depends highly on the technology used for the production, the temperature developed during the pyrolysis as well as on the moisture content of the wood.

The levels of CO_2 emissions from traditional charcoal production in several African countries range from 450 to 550 g per kg of charcoal produced, while the emission of CH_4 about 700 g, CO 450 to 650 and NMHC (non-methane hydrocarbons) 10 to 700 g per kg of charcoal produced, all in C equivalent units weighted by 20-yr GWP (Bailis *et al.*, year?). Such levels of emissions, especially concerning methane, which has the highest global warming potential, can be perceived as significant environmental impact on both regional and global level. For example, in Kenya in 1997 production of charcoal led to the emission of 80 Gg of carbon equivalent of methane, while in Croatia in the same year 28.8 Gg of carbon equivalent methane was emitted from all stationary energy sources (Vešligaj *et al.*, 2006). The main reason for these rather high levels of air emissions is the incomplete combustion of wood and gaseous by-products of charcoal production, which are directly emitted into the atmosphere.

On the other hand, air emissions from industrial charcoal production, where batch kilns and continually operated multiple hearth retorts are used, are considerably lower. According to the EPA's emission factors for charcoal production, the production of 1 kg of charcoal in batch kilns causes average emission of 140 g of CO, 54 g of CH_4 and 560 g of CO_2, while the production of the same amount of charcoal in continually operated multiple hearth retorts 160 g of CO, 50 g of CH_4 and 492 g of CO_2 (EPA, 1995). The use of flue gas to heat the combustion chamber, which contributes to higher temperatures in combustion chambers, and improved environmental performance of equipment, such as cyclones and filters for removal of particular matter and use of pre-drying of feedstock, make it possible to lower the levels of air emissions considerably. Afterburning of flue gases causes oxidation of methane, thus lowering its emissions by more then tenfold. It can also reduce emissions of PM, CO and VOC by at least 80%, while it also considerably reduces emissions of tars and nitrogen oxides. Furthermore, tests conducted on charcoal production management showed that the incineration of flue gases at about 1 000°C allows destruction of 99% of the mass of pollutants apart from CO_2 (Halouani & Farhat, 2003). At the same time, employment of the described practice and equipment increases the production efficiency, thus covering the investment costs for the equipment and bringing additional revenue.

The average air emissions from traditional and industrial charcoal production are presented in Table 1.1 below.

Table 1.1 Comparison of air emission factors for different types of charcoal production (Source: Kammen and Lew, 2005, EPA, 1994)

Air pollutant	CO_2	CO	CH_4	NMHC/ VOC	TSP
Production technology	**in g per kg produced charcoal**				
Continuous kilns*	492	160	50	100	200
Batch kilns*	560	140	54	140	160
Uncontrolled batch*		160 – 179	44 – 57	7 – 60	197 – 598
Low controlled batch*		24 – 27	6.6 – 8.6	1 – 9	27 – 89
Controlled continuous retorts*		8 – 8.9	2.2 – 2.9	0.4 – 3	9.1 – 30
Modern kiln (USA)**	3300	443	147	405	320
Relatively modern kiln (USA)**	1350	700	170		
Mound kilns in developing countries****	1540	233	40	8	5
	2629	86	18		

*According to EPA AP-42(1995).
** According to Smith and Thorneloe
*** WB1992/Briane and Doat 1985
****Lacaux, et al 1994; Hao, et al 1994

Apart from the impacts on the environment, charcoal production and use impose impacts on human health. These impacts are related to the emissions of gases and particulate matter (dust) into the indoor working and living environments: during the production management, unloading of kilns or combustion chambers, collection of charcoal ashes for charcoal-briquettes production and burning of charcoal in households.

Charcoal contains approximately 80% of fixed carbon, 24% of volatile compounds, 4% of ash, 0.53% of nitrogen and 0.01% of sulphur. Long term inhalation of particulate matter, carbon monoxide, nitrogen and sulphate oxides as well as other volatile compounds that are emitted during the charcoal burning may lead to respiratory problems and ultimately diseases such as acute respiratory infection (ARI), otitis media (middle ear infection), chronic obstructive pulmonary disease (COPD), asthma, lung cancer, low birth weight and others (Ezzati & Kammen, 2002). Researches on the heath impacts from charcoal burning in households of developing countries, mostly African, have showed that in comparison with other biomass solid fuels, primary firewood, emissions of particulate matter (PM) are much lower (Ezzati & Kammen, 2002, Serenje et al., 1994). Concentration of PM -10 in households due to charcoal burning is about 0.38 to 0.50 mg/m^3, while if fuelwood is burned in open fire, the concentration may rage from 0.89 to 3 mg/m^3. At the same time the concentration of CO is somewhat lower, 8.5 ppm if firewood is used, while 13 ppm if charcoal is burned. For both fuels the concentrations of dust are significantly higher then WHO indoor air quality guideline and USEPA standards, while the concentration of CO hardly meets or is above the standards, too (see Table 1.2). It has to be stressed though, that the emission rate of both, the particulate matter and carbon monoxide depends considerably on the type of stove, (if one is used), and smoke exhaust type.

Table 1.2 Comparison of average concentration of indoor air pollutants when charcoal and fuelwood is used with WHO guideline and USEPA standard

Indoor air pollutants	Charcoal burning	Fuelwood burning	WHO guidelines	USEPA standard
Dust (PM-10)	0.38-0.50 mg/m^3	0.89 to 3 mg/m^3	0.15 mg/m^3	0.15 mg/m^3 average of 24 hours 0.05 mg/m^3 for annual average
Carbon monoxide (CO)	13 ppm	8.5 ppm	8.6 ppm	9 ppm for average of 8 hours 35 ppm for average of 1 hour

As already indicated above, a great difference exists between the developing and developed countries in regard to the production and utilisation practices of charcoal. In the developed countries charcoal is rarely used as a fuel for indoor cooking, but mostly as a barbeque fuel. Thus, the impacts of the charcoal use on human health are insignificant (if not negligible). However, dust and poisonous substances may affect health of workers employed with charcoal unloading within the production process, as well as those employed in the production of charcoal briquettes, in case when the occupational safety standards are not complied with. In Table 1.3 maximal allowed concentrations of carbon monoxide and dust (PM-10) according to NIOSH (USA) and Croatian Occupational Safety Standards are given.

Table 1.3 Maximal concentrations of CO and dust in working environment according to NIOSH and Croatian Occupational Standards

Indoor air pollutants	NIOS OC Standard	Croatian OC standard
Dust (PM-10)	2.5 mg/m^3 per 8 hours	3 mg/m^3 per 8 hours (1 PM-2,5 mg/m^3 per 8 hours)
Carbon monoxide (CO)	50 ppm per 8 hours	30 ppm per 8 hours 400 ppm, max 1 hour during working time

2. Forestry in Croatia

2.1 Background

Forests cover approximately 2.1 million hectares of Croatia, which is about 43.4% of total land area (excluding the Adriatic Sea). In terms of phytogeographic diversity there are two forest types: Euro-Siberian type, prevailing in the northern part of country, and Mediterranean type, spread in the karst region. Croatian forests are characterised with high species and community richness, with about 60 different forest communities (National Forestry Policy and Strategy, 2003). In the lowlands communities are mainly composed of deciduous tree species, while at the higher elevations mixed deciduous-coniferous or coniferous associations prevail. The Euro-Siberian forests predominate with 57%, as well as deciduous species which make 85% of all tree species. It has to be emphasised that 95% of Croatian forests are natural forest, which means that the species composition of the forests is almost the same as that in the virgin forests of this region. Table 2.1 shows the main tree species and their percentage in forests' formation.

Table 2.1 Main tree species and their percentage in Croatian forests formation (Source: National forestry policy and strategy, 2003)

Deciduous species		Coniferous species	
Beech (Fagus silvatica)	36%	Abies and spruce (Abies sp. and Picea sp.)	11%
Pedunculate oak (*Quercus robur*)	14%	Pine tree (*Pinus sp.*)	2%
Sessile oak (*Quercus petrea*)	10%	Other coniferous species	1%
Hornbeam (Carpinus betulus)	8%		
Narrowleaf Ash (Fraxinus angustifolia)	3%		
Other hard broadleaved species	11%		

Soft broadleaved species	4%		

The State owns 78% of all forested land, while the rest 22% or 581 770 hectares are in the private ownership (National Forestry Master Plan, 2006). The Ministry of Agriculture, Forestry and Water Management is the administrative body responsible for the implementation of national forestry policy, while the state-owned company Hrvatske šume (Croatian forests) has a mandate to manage the state-owned forests according to the principals declared in the official documents that have to be approved by the Ministry and Government. Legal persons, other then Hrvatske šume, manage a minor area of state-owned forests. A part of the State-owned forests are situated within protected areas, such as national parks, nature parks, protected landscapes and park-forests, which are administrated by the Ministry of Environmental Protection, Physical Planning and Construction. Forests in the national parks are managed by the national parks' management board according to the management plans of the parks. In nature parks, which have lower level of nature protection, Hrvatske šume manage the forests, but with the implementation of nature protection measures defined by the nature parks' management plans.

The Law on Forests lays down the criteria for forest stewardship, minimal level of education for people employed in forest management as well as obligation for Hrvatske šume to define long-term and short term management plans. Privately owned forests should comply with those long-term management plans, but this is not always the case. The reason could be found in the fact that private forest-holdings are highly fragmented: there are 599 056 forest owners with an average forest-holding of 0.98 hectares. Continuing, privately owned forests are often linked with the lack of professional knowledge in forest management and forest stewardship tradition, insufficient number of forestry associations, through which the forest-owners would exchange knowledge and experience, and coordinate forestry interventions. Finally considerable part of private forests is degraded and requires high investments for rehabilitation.

During the last decade, in the period from 1996 to 2006, the total forestland in Croatia increased for 203 076 hectares, and in the same period the ownership structure changed in favour of private ownership. The total area of state-owned forests, managed by Hrvatske šume and other legal persons, and privately owned forests in 1996 and 2006 are compared in Figure 2.1.

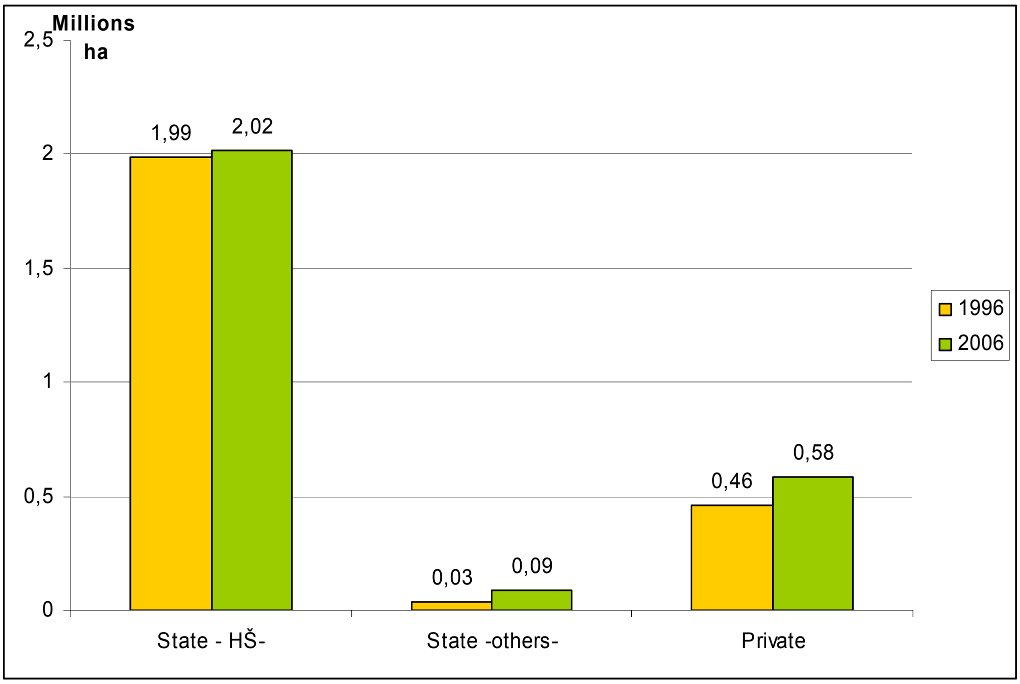

Figure 2.1 Ratio of state owned and private forests in Croatia in 1996 and 2006 (Source National Forestry Policy and Strategy, 2003, and National Forestry Master Plan, 2006)

2.2 Management of forests under the state ownership

The legal document that provides a framework for the forest management is the National Forestry Policy and Strategy (OG 120/03). It includes an overall assessment of the state of forests and forestland, identifies the most important issues to be tackled and defines the corresponding necessary actions. Furthermore, the National Policy and Strategy gives an overview of relations with other relevant national legal acts (strategies, laws and by-laws) as well as evaluation of interrelated issues.

Other laws that have direct impact on activities of the forestry sector are the following:

- Management of state-owned forests in Croatia is guided by the Law on Forests (Law on Forest Seeds and Planting Material (OG 68/98)
- Law on Environmental Protection (OG 82/94)
- Law on Nature Protection (OG 70/05)
- Law on Protection of Plants (OG 10/94)
- Law on Fire Protection (OG 58/93)
- Law on Hunting (OG 11/94)
- Law on Waters (OG 107/95)
- Law on Financing of Water Management (OG 107/95)
- Law on Public Roads (OG 180/04)
- Law on Protection from Natural Hazards (OG 73/97)

Management of state-owned forests in Croatia is guided by the Law on Forests (OG 140/2005), which regulates growing, protection, use and allocation of forest and forestland as natural resource. The Law states that the aim of forest stewardship is to assure the biodiversity of forests and to secure timber production based on the principles of sustainable production, social liability and ecological acceptability. Furthermore, forests and forestland are declared as of national interest and, as such, endure full guardianship of the named law. The Law on Forests names Hrvatske šume as an organisation mandated to manage the state owned forests and forestland according to the principles stated in the law.

Forests in the ownership of the Republic of Croatia are divided into management units. Each unit has its own management master plan based on the principles of sustainable management, according to which forests are treated as renewable natural resource with distinct overall utilities, with postulate that forest rehabilitation has to be prompted, completed and enhanced where it is necessary.

There are sixteen management units which are directed from the central office of Hrvatske šume. The geographical location and name of each unit is presented in Figure 2.2.

Map Label	Name of management unit	Map Label	Name of management unit	Map Label	Name of management unit	Map Label	Name of management unit
A	Vinkovci	E	Bjelovar	I	Karlovac	M	Gospić
B	Osijek	F	Koprivnica	J	Ogulin	N	Buzet
C	Našice	G	Zagreb	K	Delnice	O	Split
D	Požega	H	Sisak	L	Senj	P	Nova Gradiška

Figure 2.2 The geographical location of forest management units of Hrvatske šume. (Source: Hrvatske šume, 2007).

Documents that prescribe type of forestry activities, as well as their spatial and temporal application are National Management Master Plan, Master Plans for Management Units, Programme for Management of Management Units in Karst Regions and Programme for Management of Forest in Private Ownership, Programmes for rehabilitation and protection of forests in particularly threatened areas, Programmes for management of forest with special purpose, Annual forest management plans and Annual operational plans.

These programmes and plans define conditions for forest and forestland usage, scope of growing and protection of forests, and possible level of their utilisation as well as the criteria for wildlife management.

2.3 Forest management in practice

According to Croatian cadastre land data there are 2 688 687 hectares of land classified as forestland. Though, not all of the land classified as forestland is covered with forests or used for wood production. Types of land falling within forestland class, their coverage area and ownership in 1996 are presented in Table 2.2, while changes during last ten years are presented in Table 2.3.

Table 2.2 Types of land within forestland class, their coverage area (ha) and ownership. **(Source: National Forestry Master Plan, 1996).**

Land type	State owned - HŠ*-	State owned -others**-	Privately owned	Total
	Coverage area - ha			
Forested	**1 592 869**	**31 287**	**454 133**	**2 078 289**
Unforested used for production	**323 130**	**1 229**	**6 975**	**331 334**
Unforested non-used	**14 490**	**107**	**20**	**14 617**
Loam	**61 048**	**314**	**8**	**61 370**
Total	**1 991 537**	**32 937**	**461 136**	**2 485 611**

*Managed by Hrvatske šume
** Managed by legal person other then Hrvatske šume

Table 2.3 Change of land type of forestland from 1996 to 2006. **(Source: National Forestry Master Plans, 1996 and 2006).**

Land type	1996		2006	
	Area (ha)	%	Area (ha)	%
Forested	2 078 289	84	2 392 931	89
Unforested	345 951	14	241 982	9
Loam	61 370	2	53 774	2
Total	**2 485 611**	**100**	**2 688 687**	**100**

There are 2 392 931 hectares of forested land in Croatia, on which different types of forests exist, each requiring specifically adopted management practice depending on the biocenologic, pedologic, climatic and other environmental factors prevailing in the area as well as function of the managed forest.

The forests can be divided according to their purpose into production forests, protection forests and forests with special purpose. The current coverage area of each type of the named forests and the ownership structure can be seen in Table 2.4.

Table 2.4 Coverage area of forest types according to their purpose (Source: National Forestry Master Plan, 2006)

Forest type	State owned - HŠ*-	State owned -others**-	Privately owned	Total
	Coverage area - ha			
Production forests	1 838 783	492	576 832	2 416 107
Protection forests	145 634	10 499	4 507	160 640
Forests for special purposes	34 570	76 939	431	111 940
Total	**2 018 987**	**87 930**	**581 770**	**2 688 687**

There are several forms of forests, which mutually differ on accord of the growing form, forest succession stage, and management practice applied. The "management forms", their coverage area and ownership are presented in Table 2.5.

Table 2.5 Forest management forms, their coverage area (ha) and ownership (Source: National Forestry Master Plan 1996)

Management form	State owned - HŠ*-	State owned -others**-	Privately owned	Total
	Coverage area - ha			
Forest of seedling origin	1 018 054	25 582	183 905	1 227 541
Coppice forest	252 137	2 404	250 360	504 901
Bushes	258 129	1 202	19 688	279 019
Shrubberies	6 900	-	-	6 900
Macchia	29 255	1 569	-	30 824
Garig	13 072	132	-	13 204
Plantations	15 322	398	181	15 901
Total	**1 592 869**	**31 287**	**454 134**	**2 078 289**

*Managed by Hrvatske šume
** Managed by legal person other then Hrvatske šume

As already indicated Hrvatske šume manage 78% or 2 018 987 ha of all forests in Croatia. There are two main management practices applied by Hrvatske šume: *regular cut* and *selection cut* management (Hrvatske šume, 2007). *Regular cut* management practice is commonly applied in low-land forests where *Quercus* species predominate. Trees in the canopy of these forests are commonly in the same development stage (i.e. of the same age and growth), and canopies are divided into development classes in the forestry unit management documents. Harvesting of *regulated* forest implies felling of canopies of higher development classes (mature and optimum forest development phase), thus providing space for further development of juvenile trees in the same area. Upon the felling, the harvested areas often look like area where clear-cut has been applied, but as juvenile trees and seedlings are not harvested this practice ensures the afforestation of the area. It is also important to emphasize that harvesting in this type of forests usually takes place on relatively small areas, and that on the level of management unit the net wood is constant or even increases over time.

The second management practice, *selection* management, is practiced in the mountainous forests of Croatia, where mixed beech (*Fagus sp.*) and hornbeam (*Carpinus sp.*) and coniferous forest communities dominate. In these forests canopies are composed of trees which are in different development stages, thus differing significantly in stem thickness as well as stem high. Based on the stem thickness trees within the canopies are alineated into diameter classes. As a result of forest characteristics, as described above, individual trees in mature and/or optimal development phase are selected and designated for harvesting on a several-years bases. The forests managed by *selection management* practice give an impression of steady canopy composition, because felling of mature trees provide space for further development of juvenile trees, while providing approximately the same amount of harvested wood as when *regulated management* is applied.

The application of the described management practices through a long-term periods results in relatively high harvested wood production and forest increment at the same time. One of the reasons is continual and well-planned reforestation, which is conducted through natural reforestation and man-induced forestation via plantation of seedling. Hrvatske šume produce about 15 million seedlings annually (Meštrović, 1998). In 1996, Croatian wood-stock amounted 278 323 621 m^3 (140 m^3/ha), annual increment 8 123 496 m^3 (4.1 m^3/ha) and annual falling 4 934 199 m^3 (2.5 m^3/ha). In 2006 the wood-stock increased to 397 963 000 m^3, annual increment to 9 643 117 m^3; while the planned annual cut for the period 2006-2015 amounts 6 564 400 m^3.

In Table 2.6 percent shares of all tree species in forests managed by Hrvatske šume are listed, as well as the total wood stocks of each tree species in 1996 and 2006, and planned annual yield cut for the period 2006-2015.

Table 2.6 Percent shares of all tree species in forests managed by Hrvatske šume **(Source: Hrvatske šume)**

Tree species	% in production	Wood stock in 000 m^3		Planned annual yield cut in 000 m^3
		1996	2006	
Pedunculate oak	20.9 %	44 359	48 640	820.3
Sessile oak		32 237	38 410	610.6
Beech	35.6 %	117 676	143 345	2 401.1

Hornbeam	6.5 %	24 750	36 340	617.6
Ash	3.1 %	10 239	12 762	281.4
Abies	13.0 %	30 374	31 406	542.9
Spruce		6 007	8 549	118.2
OTB	11.8 %	58 614	78 512	1 172.2
Poplar	3.1 %			
Lime	1.8 %			
Alder	1.1 %			
OMB	1.4 %			
Acacia	0.6 %			
Fruit species	0.2 %			
Pine	0.5 %			
Other coniferous	0.4 %			
Total		**324 256**	**397 963**	**6 564.4**

Table 2.7 shows falling in half-period of 1996-2005, according to ownership forms.

Table 2.7 Falling in half-period of 1996-2005, according to ownership forms (Source: Hrvatske šume)

Ownership form	Unit	State owned - HŠ*-	State owned -others**-	Privately owned	Total
Main revenue	ha	75 967	340	15 055	91 361
	m^3	20 847 472	91 960	1 142 690	22 082 .122
Common revenue	ha	339 417	12 824	22 820	375 062
	m^3	13 439 038	697 908	460 921	14 597 867
Aforetime revenue	ha	539 490	2 197	102 712	644 398
	m^3	15 055 482	78 094	1 726 611	16 860 187
Total	**ha**	**954 874**	**15 360**	**140 587**	**1 110 821**

	m³	**49 341 992**	**867 962**	**3 330 222**	**53 540 176**

Out of average 3.5 million m3 annual gross harvest of Hrvatske šume about 50% is roundwood (unconverted wood), while the rest 50% of stock wood include fuelwood and wood for industrial processing. The dominant tree species in forestry production are beech and oak with over 50% share. The ratio of roundwood and stock wood production of Hrvatske šume in the period of 1998 until 2005 is shown in Figure 2.3 (Hodić et al., 2006).

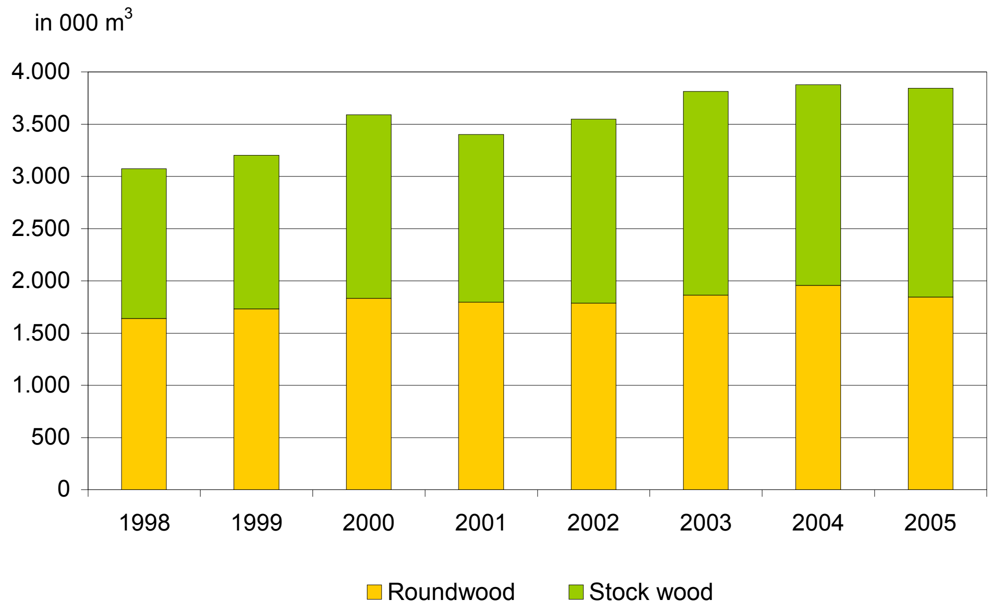

Figure 2.3 The ratio of round-wood and stock-wood in the production of Hrvatske šume from 1998 until 2005 (Source: Hodić *et al.*, 2006)

2.4 Certification of Hrvatske šume and forest management tradition

Conformation and verification that Hrvatske šume practices sustainable forestry, which considers ecological, social and economic aspects of forest stewardship, is the certification given by the Forest Stewardship Council – FCS.

The mission of FCS is to promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests (FSC, 2007). *Environmentally appropriate* forest management implies that the harvest of timber and non-timber products is such as to maintain the forest's biodiversity, productivity and ecological processes. *Socially beneficial* considers that the forest management helps both local people and society at large to enjoy long term benefits and also provides strong incentives to local people to sustain the forest resources and adhere to long-term management plans. *Economically viable* forest management stands for forest operations that are structured and managed so as to be sufficiently profitable, without generating financial profit at the expense of the forest resources, the ecosystem or affected communities. The tension between the need to generate adequate financial returns and the principles of responsible forest operations can be reduced through efforts to market forest products for their best value.

Hrvatske šume are actively involved in FSC certification since 2000. At that time, the carriers of the certification were the individual regional branches of Hrvatske šume - the first branch offices being ones in Vinkovci, Delnice, Zagreb and Bjelovar. During the assessment for the certification of these four branches, Hrvatske šume decided to assess all of the forests under its management. On the basis of that assessment, Hrvatske šume were granted the FSC Certificate for all of its 16 regional branch-offices, thus verifying that Hrvatske šume apply sustainable forest stewardship on the whole area of forestland under its management. The Certificate is valid from 17th October 2002 until 16th October of 2007, and has to be confirmed on the basis of annual assessment. Upon the expiry of the Certificate, the recertification has to be conducted.

The obtaining of the FSC Certificate does not mean only that the current practice of forest management of Hrvatske šume leads to sustainable forestry, but Hrvatske šume also took the responsibility to steward the forests according to the principles and criteria prescribed by the FSC International Standard (FSC, 2006). There are ten basic principles and criteria that concern environmental, social and economic aspects. The principles and their context are presented in Annex 1.

Considering that Croatia has a long tradition of organised and regulated forest stewardship and forestry, application of FSC principles is not to be a novelty in the practice. The initial stages of organised forestry in Croatia can be tracked in the statutes of several cities, such as Statute of Town of Nin from 1103, Statute of Korčula from 1214 and that of City of Dubrovnik dating from 1272. Furthermore, forestry inspection was established in 1532 in Istria, where also the forestry cadastre was created in 1584, being the first forestry cadastre in the world (Meštrović, 1998). The first document that had a form of legal act was declared by Maria Theresa in 1769, at the time when Croatia was a part of Austro-Hungarian monarchy. The Act regulated forest harvesting and it included the first postulate of forestry on the rotation period for each tree species in the correspondence with absolute maturity of the stands. The second postulate of forestry, the one on sustainable forest stewardship and harvesting was implemented through the Law on Forestry, declared by Francis Joseph (the successor of Maria Theresa) in 1852. This Law was enforced in Croatia in 1858, and its parts served as a basis of all laws related to forestry activities until the present. In addition, the Law from 1852 included a decree stating that the extant forestland may not, under any circumstances, be transformed into any other type of land. It is interesting to point out that the area of forestland in Croatia has not decreased since that time.

Along with the development of forestry in practice, scientific approach towards forest stewardship, protection and sustainable use was, and still is, taking place. The first forestry school in Croatia was opened in the town of Križevci, in 1860. In 1898, it was transformed into Academia of Forestry as a part of University of Zagreb. The Faculty of Forestry, an autonomous scientific body, was established in 1919 in Zagreb.

The current scientific activities of the Faculty of Forestry, and other scientific institutions and forestry associations are steering for upgrading of Croatian forestry and have an important role as a scientific support for the practical implementation of sustainable forestry which considers ecologic, social and economic features and effects of forestry activities.

3. Air pollutants emissions in the Republic of Croatia

The systematic analyses of anthropogenic impacts on the environment started in the late 1970s, by preparing of the Convention on Long-Range Transboundary Air Pollution and the First World Climate Conference. The results indicated a significant contribution of anthropogenic emissions to acidification, eutrophication and ground-level ozone, as well as to the increase in average atmospheric temperatures and, consequently, the more frequent occurrence of climate extremes.

3.1 International obligations

Under the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP) the Republic of Croatia is obliged to calculate air pollutant emissions on the national level.

Due to its global influence on climate change, development of the greenhouse gas inventory became a fundamental obligation under the United Nations Framework Convention on Climate Change (UNFCCC). In 1996, the Croatian Parliament ratified the UNFCCC (OG – International Agreements 2/96) by which Croatia, as a signatory party, has assumed the scope of its commitments within the framework of the Annex 1 to the Convention. Croatia has signed but not ratified the Kyoto Protocol. With the ratification and enforcement of the Kyoto Protocol, Croatia has the obligation to reduce the emissions of greenhouse gases from anthropogenic sources by 5% in the period from 2008 to 2012 in regard to the base year 1990.

On the 12th Conference of the Parties to the Climate Change Convention (CoP 12) in Nairobi (Kenya), a decision concerning the level of emission for the base year for Croatia was adopted (Parties of FCCC, 2006). The decision, considering the flexibility under Article 4, paragraph 6, allows Croatia to add 3.5 Mt CO_2 equivalents to its 1990 level of greenhouse gas emissions not controlled by the Montreal Protocol for the purpose of establishing the level of emissions for the base year.

Croatia ratified the LRTAP Convention (OG - International Agreements 1/92). Within the framework of the LRTAP Convention several protocols of relevance for energy issues were adopted. Under the ratified Protocol on Further Reduction of Sulphur Emissions Croatia took a commitment to reduce the SO_2 emissions by 22% in 2010 in regard to the 1980 level (117 kt). The Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Multi-Pollutant Multi-Effect Protocol - MPME), which has not been ratified yet, limits the SO_2, NO_x, NMVOC and NH_3 (multi-pollutant) emissions in order to reduce acidification, eutrophication and ground-level ozone (multi-effect). Should Croatia ratify the MPME Protocol it will be necessary to reduce the SO_2 emissions by 61%, NMVOC by 14%, NH_3 by 19% by 2010 in regard to the 1990 levels, while the NO_x emissions should be maintained below the 1990 level. The Croatian obligations according to the MPME Protocol are at the same time the long-term targets of emission reductions set out within the framework of the National Environmental Strategy and National Environmental Action Plan.

3.2 Air emissions

The air emissions are by-product of charcoal production and charcoal combustion. The most important air pollutants are CO_2, CO, particulate maters (PM), CH_4, non-methane volatile organic compounds (NMVOC) and NO_x.

In Croatia, charcoal is not used as primary energy source, but mostly as barbeque fuel in households. Thus, charcoal is excluded from the annual national energy balances reports. Furthermore, as the level of industrial production is relatively insignificant in regard to GHG emissions, it is also not recorded in the National Inventory Report. Additionally, in the case of the largest charcoal producter in Croatia, Belišće, the primary energy source is retort gas originating from wood. According to IPCC Guidelines, the forests are regarded as carbon dioxide sinks and consequently, the carbon dioxide emissions of wood combustion is balanced as to result with zero net emission of carbon dioxide.

3.2.1 GHG emissions

Croatia, as a member of UNFCC convention, is obliged to prepare annual National Inventory Report (NIR) and Common Reporting Format (CRF), as well as GHG projections determined in the framework of National Communication to the UNFCC Convention. In 2006, the new GHG inventory and NIR for the period from the period 1990 to 2004 were prepared, which are made in full compliance with the reporting guidelines, the recommended IPCC methodology and with application of the appropriate IPCC software (Vešligaj *et al*., 2006). The official GHG projections were prepared in 2003 (Jurić *et al.*, 2003).

The CO_2 is the most important greenhouse gas from fuel combustion. Among other GHG, CO_2 accounts for the majority of emissions, and when weighted by the global warming potential factors on equivalent CO_2 emission, the CO_2 represents more than 99% of all GHG emissions from fuel combustion. Because of that, only CO_2 emission will be presented.

CO_2 emissions

According to the latest NIR (Vešligaj *et al*., 2006), the CO_2 emissions from all sources on the territory of Croatia amounted around 22.6 million tons in 2004, which is 1% less than in the previous year and 2% less than in 1990.

The trends in total CO_2 emissions and the contribution of individual subsectors are given in Figure 3.1.

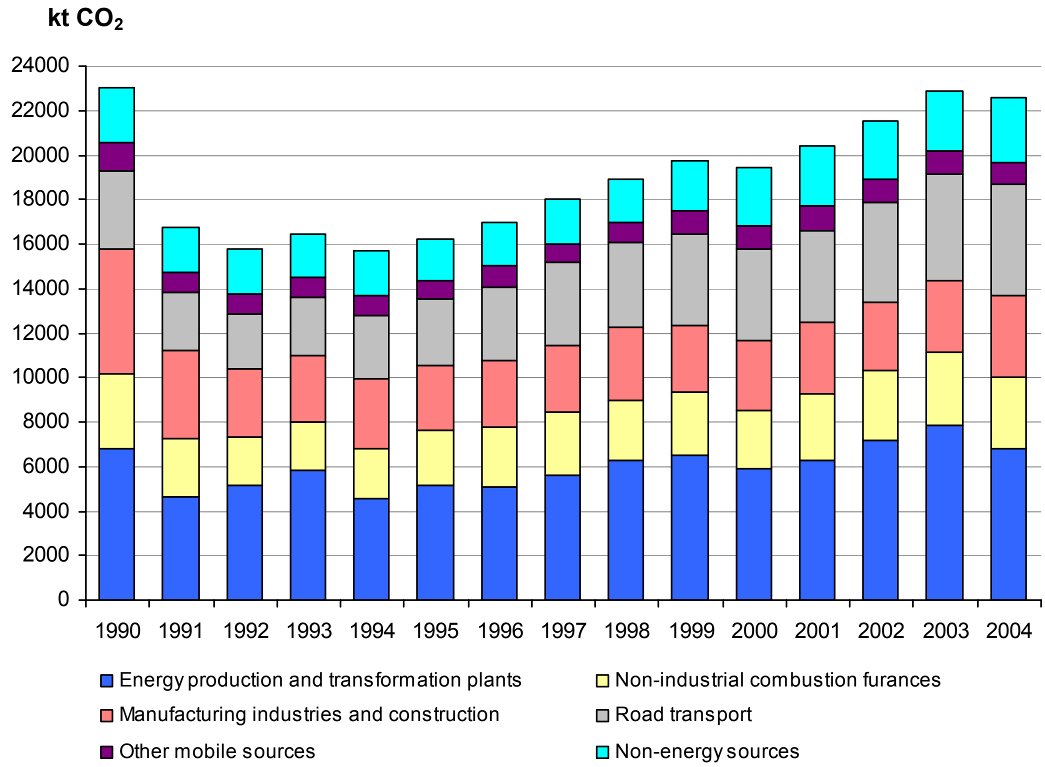

Figure 3.1 Trends of CO_2 emissions in Croatia.

The main source of CO_2 emissions is fuel combustion. In 2004, stationary energy sources emitted 69% of CO_2, namely, 30% of CO_2 were emitted from energy production and transformation plants, 16% from manufacturing industries and construction and 15% from non-industrial combustion furnaces. The road transport contributed to total energy emissions with 22%, while other mobile sources contributed with 4%. In addition to the energy sector, production processes without fuel combustion (mainly cement industry) and extraction and distribution of fossil fuels (CO_2 extraction from natural gas in CPS Molve) are also significant sources of CO_2 emissions (13% in 2004).

CO_2 emission from biomass and biomass-based fuels, in line with IPCC recommendations, is not included into the national emission totals because emitted CO_2 had previously been absorbed from the atmosphere for the growth and development of biomass.

<u>GHG projections</u>

The position of Croatia for fulfilling the obligations defined by the Kyoto Protocol is significantly improved after the decision concerning Croatian level of GHG emission in base year at the CoP 12 in Kenya.

The official projection of national GHG emissions for “Without measures”, “With measures” and “With additional measures” scenarios, prepared for the National Communication to the UNFCC convention, is presented in Figure 3.2, (Jurić *et al.*, 2003). In the figure is also presented new Kyoto Protocol target for Croatia (including 3.5 Mt CO_2 equivalents in base year GHG emission).

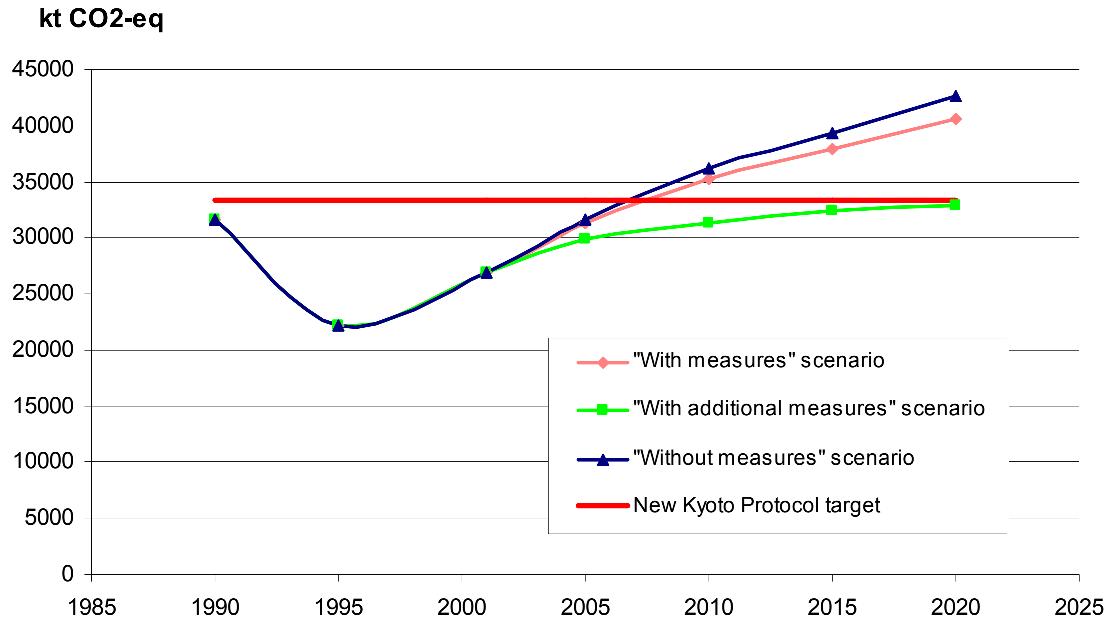

Figure 3.2 GHG emission projections

Figure shows that only with implementation of all additional measures, Croatia will be able to achieve the GHG emission stabilization on the level of the Kyoto target. This scenario assumes full utilisation of reduction potentials, presently estimated on aggregated analysis and data. Aggregated "top down" approach usually gives more optimistic figures than the collection of individual projects' potentials, by "bottom up" approach.

3.2.2 Other air pollutant emissions

An inventory of NO_x, CO, NMVOC and particles for the period from 1990 to 2004 was prepared in 2006 (Poljanec *et al.*, 2006), using the AE-DEM (Air Emission - Data Exchange Module) programme package and following the CORINAIR methodology. AE-DEM programme package was developed by the European Environmental Agency, under the CLRTAP Convention, for the preparation of emission inventories on a national level.

Beside their potential harmful effect on health, the NO_x is also known as „acid" gases as they transform during the remote transport and develop acid components, which are accumulating from the atmosphere as wet (acid rains) or dry depositions. The NO_x cause eutrophication and together with NMVOC generate ground-level ozone. While the emissions of CO and particles are mainly of local importance with negative influence on health and ecosystems.

NO_x emissions

In 2004, NO_x emission was 68.9 kt, which is 3% less than the emission in the previous year and 20% less than in 1990, (Poljanec *et al.*, 2006). The most significant emission sources were road and off-road transport. The trends in NO_x emissions are shown in Figure Table 3.3.

The NO_x emissions were lower than 87 kt (mandated by the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (MPME Protocol), which is the long-term environmental strategy target.

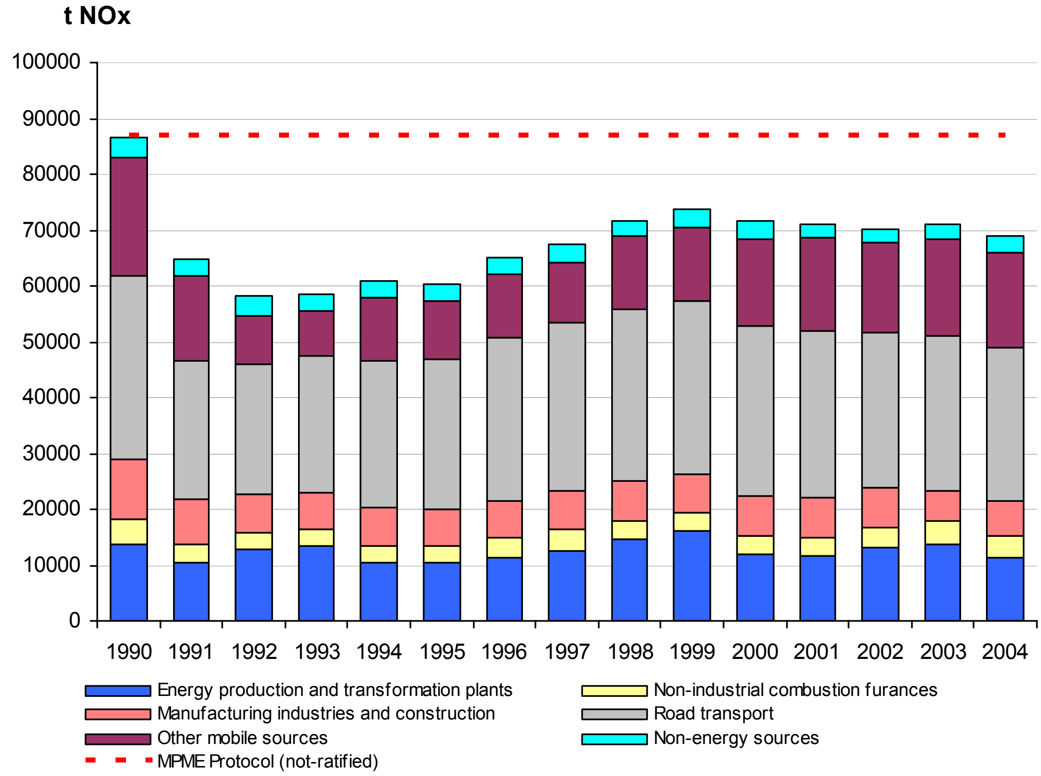

Figure 3.3 Trend of NOx emissions in Croatia.

NMVOC emissions

The emission of non-methane volatile organic compounds (NMVOC) was 92.0 kt in 2004, which is 6% higher than the previous year emission, but 20% less than emission in 1990 (Poljanec *et al.*, 2006). The most significant emission source was sector classified as Solvent and other products use (non-energy sector), with contribution of around 50% in total NMVOC emissions in 2004. The trend of the NMVOC emissions is shown in Figure 3.4.

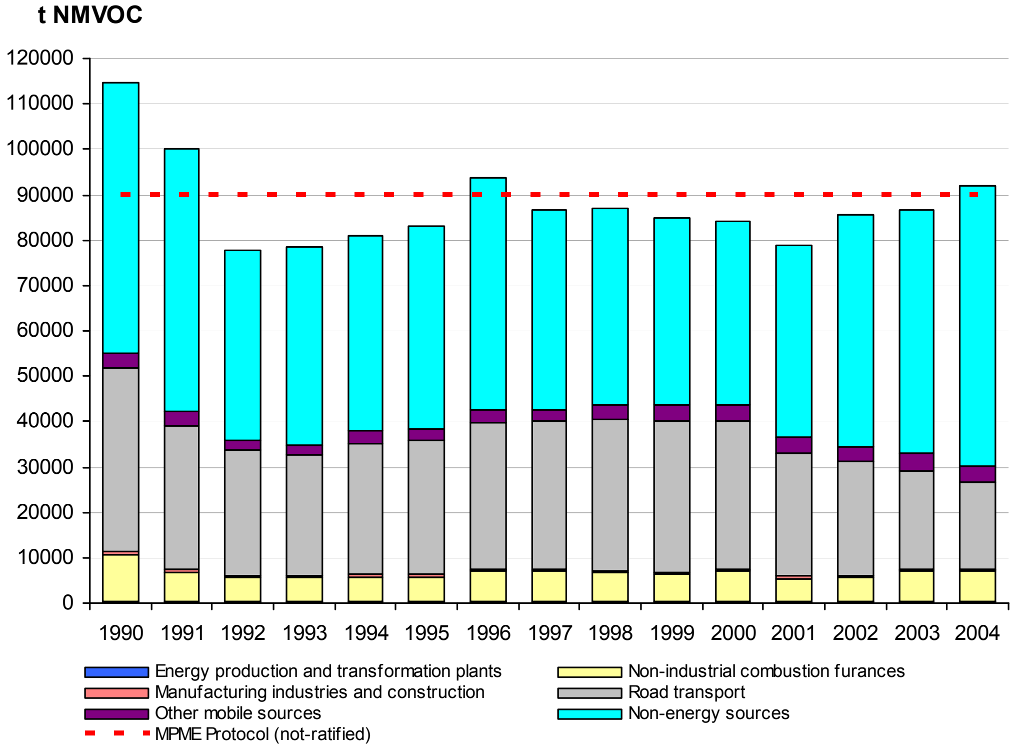

Figure 3.4 Trend of NMVOC emissions in Croatia.

The obligation of Croatia, in the framework of MPME Protocol, is to reduce national NMVOC emission by 14% in 2010 in comparison to the emission in 1990. Before last recalculation of base year emission, the emission of the NMVOC was 90 kt.

CO emissions

According to the last inventory report (Poljanec *et al.*, 2006), CO emission was 311.1 kt (2004), 4% less than the CO emission in 2003 and 38% less than the CO emission in 1990. CO emission is a consequence of incomplete combustion, mostly in road transport and non-industrial small furnaces. The CO emissions trend is given in Figure 3.5.

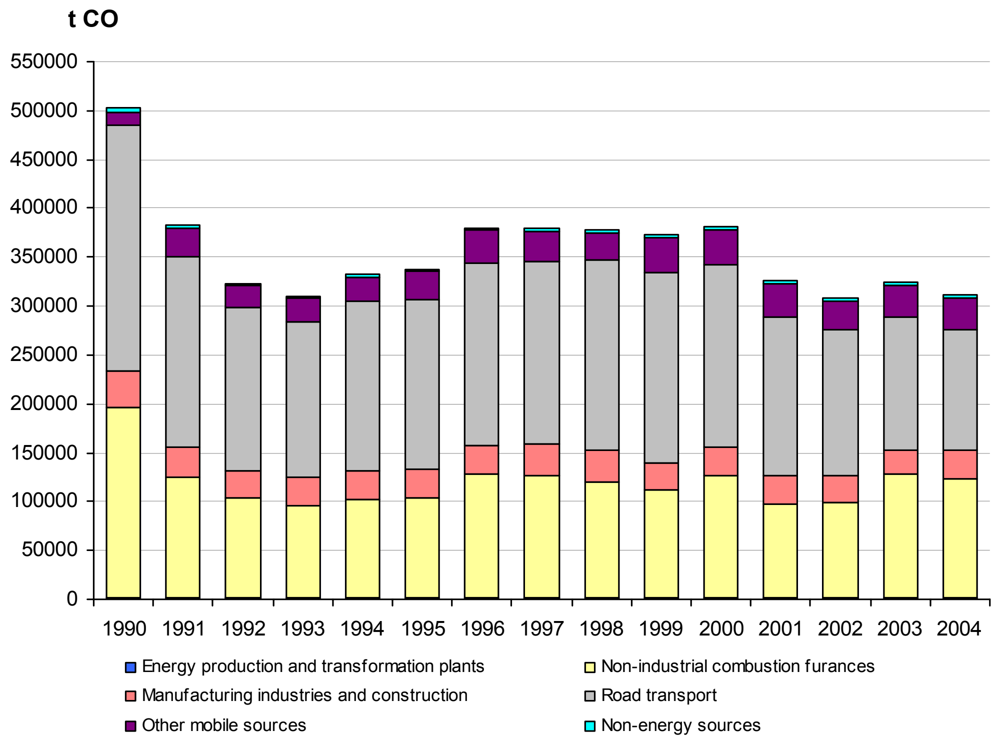

Figure 3.5 Trend of CO emissions in Croatia

While CO emission is mainly of local importance, limitation of CO emissions is not the subject of MPME Protocol. On the other hand, CO emission is significant during production and consumption of charcoal.

Particles emissions

In 2004, the TSP emission was 14.8 kt, which is lower than the emissions in the previous year and 1990, by 2 and 31% respectively (Poljanec *et al.*, 2006). The trends in particles emissions are presented in Figure 3.6.

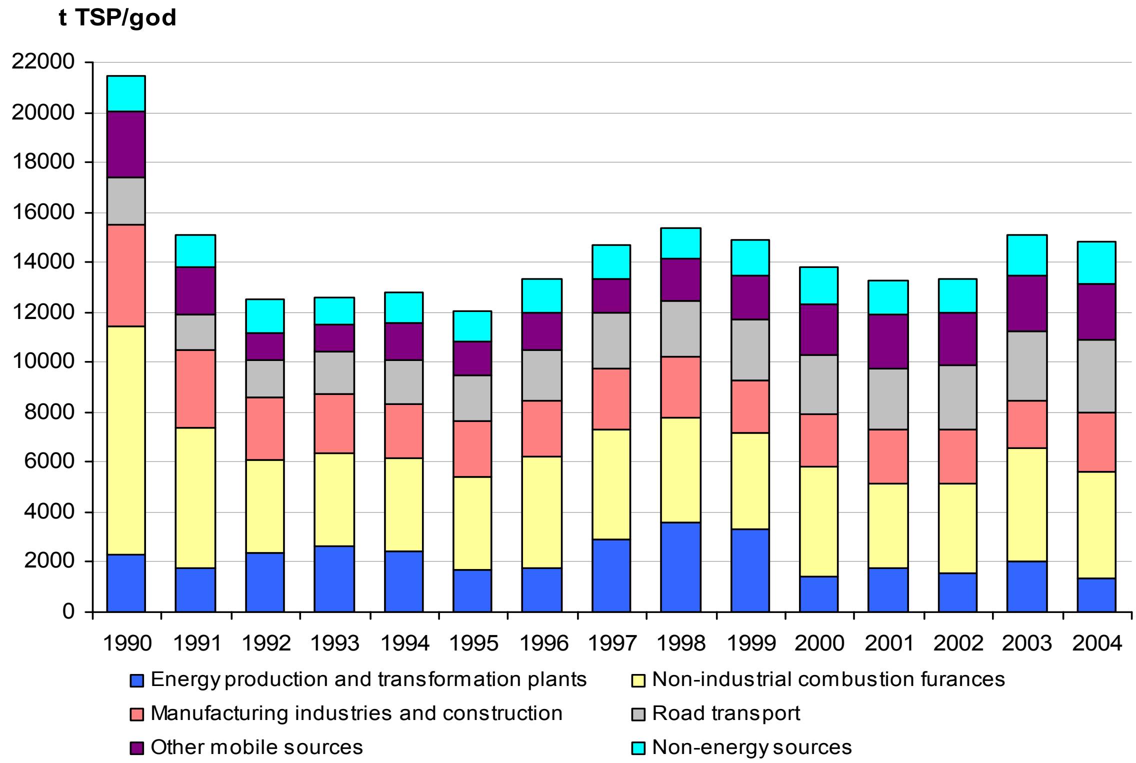

Figure 3.6 Trend of particle (TSP) emissions in Croatia.

The Croatian inventory team calculated the particles emissions (TSP, PM10 and PM2.5) in accordance with CLRTAP recommendations, using CORINAIR methodology. The particles with a diameter smaller than 10 μm (PM10) contributed 55 to 60% in the TSP emissions, while the smallest particles with a diameter lesser than 2.5 μm (PM2.5) contributed with about 45%. Particulate matters (PM2.5) can be transported the farthest by wind and deposited far away from the sources, causing not only local but also regional problems.

4. Charcoal production in Croatia

Charcoal is in Croatia produced mainly as barbeque fuel, which is used in restaurants and households. The official records recognise only one major charcoal producer, within the Belišće industrial group. Along with Belišće, there are several other small to medium scale producers, who employ traditional charcoal production techniques in brick- and concrete-kilns. Finally, it is estimated that there are about 400 micro-scale producers scattered in forest areas, mostly in northern part of Croatia. The majority of charcoal produced on the micro-scale is made in brick-kilns, but there are also some cases of production in the charcoal pits.

The feedstock in all cases is either wood from forests, in the majority of cases smaller-diameter logs of hard broadleaved tree species, such as beech and hornbeam, or residues from wood processing industry. In some cases logs of soft broadleaved species, such as poplar, are used for the charcoal production, too. The feedstock supply channels include wood processing industry, Hrvatske šume, (the state owned company mandated for forest stewardship and management), and private forest owners.

For the purpose of this project, a number of site visits and interviews with small to medium scale producers as well as with the major industrial charcoal producer in Croatia were conducted. Through the interviews and site visits information on the specifics of the production process and its profitability followed with environmental, health and safety aspects were collected and analysed. In the following text two case studies are presented. The first case study describes the single industrial charcoal production - Belišće, while the second describes traditional way of production, practiced by small and medium scale producers. In both case studies special regard is given to the environmental aspects of charcoal production.

4.1 Case study I – Charcoal production in Belišće

The joint stock company Belišće is located in the town of Belišće, in the eastern part of Croatia. The company has a diverse portfolio of products, the most important being packaging papers and corrugated board boxes. Other production activities include production of spiral and plastic containers, electrical equipment, primary and final wood processing and dry wood distillation (charcoal production). The products of the wood processing and dry wood distillation plant are sawn timber, wooden palettes, charcoal, charcoal briquettes and fuelwood briquettes.

Belišće is the biggest charcoal producer in Croatia and the single one with the developed production technology. Namely, charcoal is produced in multiple externally heated retorts, with a production capacity of 10-14 tones of wood carbonised within one production process cycle of 24 hours. Annual production of charcoal amounts about 3 000 tones, maximum capacity being 3 600 to 4 200 tones. The production of charcoal briquettes, which are produced as a by-product of charcoal, reaches 1 120 tones annually, while maximal annual capacity amounts 1 150 tones. The production season usually lasts for ten to eleven months, usually from the beginning of February until mid-December. During the cold months of January and February the annual maintenance and cleaning are preformed. In the production season, the production process runs 24 hours a day, and there are 26 full-time employees, working in three shifts. The production peak follows the demand peak which falls in the “barbeque season”, from May until the end of July.

The feedstock supply

The feedstock used for charcoal production includes residues from furniture and wood processing factories located within a 100 km radius of Belišće. The residues are almost exclusively composed of hard broadleaved tree species, where beech predominates with 80%, followed by hornbeam and minor percentage of oak. Besides the wood residues obtained from other industries, a smaller amount of residues originates from Belišće’s own production. These contribute with 50-100 tones per year, which is approximately 10% of the total feedstock supply. Finally, the third and most important feedstock supplier is Hrvatske šume. Belišće annually purchases about 10 000 m^3 of wood logs for charcoal production. Usually the transport distance of these wood logs ranges from 60 to 70 km, but never more then a 100 km.

The production cycle

There are eight basic steps in the production cycle, starting with feedstock pre-treatment and finishing with packaging, storage and distribution. The core of the production cycle, which includes carbonisation and cooling, lasts 72 to 80 hours in total. The capacity of the carbonisation retorts and cooling chambers is such that within one production cycle in total 12 vessels can complete the cycle, i.e. 144 m^3 of wood logs or 10 to 14 tones of woody residues. The production efficiency is such that for 1 tone of charcoal 7 m^3 of wood logs, which is approximately 4.91 tones, of woody residues is needed. The efficiency of production is somewhat lower when having in mind that 10 to 15 % of produced charcoal is charcoal dust and small pieces that are below the standardised size. Nevertheless, these are used as raw material for charcoal briquettes production.

The steps of the production cycle are as follows:

1. Drying of feedstock

The wood is dried in two driers for 8 hours in order to lower the moisture content of wood. Upon the drying the moisture content from approximately 45% decreases to 10%.

2. Feedstock preparation

Wooden logs are firstly sawn and chopped, while the wood-processing residues do not need any additional preparation.

3. Filling the vessels

The vessels are filled with the woody residues automatically with a machine, but with the wood logs manually. The vessels containing different type of feedstock are connected together and put into retorts.

4. The carbonisation process

When the vessels are placed in the retorts, the retorts’ doors are sealed with mixture of mud, water and saw dust, in order to prevent penetration of air into the retorts during the carbonisation process. There are six retorts with dimensions of

12 m x 3 m x 2 m. The retorts are heated externally. The primary energy sources for heating are retort gases, 85%, and natural gas, 15%.

The carbonisation in the retorts lasts 24 hours at the temperature ranging from 430°C to 480°C. The percentage of fixed carbon in the final product depends on the temperature, thus for 80-82% of fixed carbon, which is a standardized percentage for the barbeque charcoal, the carbonisation should be performed at the temperature of about 430°C. During the dry wood distillation (carbonisation) the exhaust gases, e.g. retort gases, are collected and led via a pipe system to the furnace where they are burned at the temperature of 944°C. Natural gas is used to ignite the furnace and the retort gases.

Upon the carbonisation the retorts' doors are opened and the temperature drops down to about 240 to 250°C, while the vapour is released into the air.

5. Indirect cooling

After carbonisation the vessels with charcoal are put in the cooling chambers. The cooling chambers are cooled externally with circulating water from the pool. The indirect cooling process lasts for 24 hours.

6. Air cooling

Upon indirect cooling the vessels are taken out from the cooling chambers and left in the open air for further 24-hour cooling.

7. Breaking and sieving

Cooled large pieces of charcoal are broken into smaller pieces in a breaker and then sieved in order to remove the pieces smaller then the prescribed size. Namely, according to the DIN 51749 standard for grill charcoal and grill charcoal briquettes, there must not be more then 5% of charcoal pieces smaller then 30 x 30 mm in a single package. In order to fulfil the requirements of the Standard, the size of the sieve screen is 20 x 20 mm.

The charcoal dust and pieces smaller then 30 x 30 mm, which come as a waste of charcoal production, are further used as raw material for charcoal briquettes production.

8. Packaging, Storage and Distribution

Sorted charcoal is packed into small paper packaging of 2.5 kg, which are then gathered into larger packages of 12 or 15 kg, and big paper packages of 10 kg. The packaging material is also produced in Belišće. Only in the case of wholesale, the charcoal can be packed into the packaging of the buyer. On average 300 tones of charcoal are packed monthly. Packed charcoal is stored in a closed but well ventilated storage until distribution.

As already indicated above, Belišće produces charcoal briquettes, too. The main feedstock is charcoal dust and small charcoal pieces from its own charcoal production, while additional quantities are bought from other charcoal producers, if needed.

Apart from the charcoal dust, vegetable starch is used as a bonding material in the production. The ratio of charcoal dust and the vegetable starch, mainly cornstarch, in the briquettes is 86-90% and 10-14%, respectively.

The production cycle of briquettes includes the following steps:

1. *Crumbling and homogenisation*

   The charcoal dust and small pieces of charcoal are additionally crumbled and mixed, in order to achieve homogenised mass.

2. *Mixing of dust and vegetable starch*

   Cornstarch is used as a bonding material to enable forming of the briquettes. In order to reach good quality of briquettes, i.e. long and steady burning, there should not be more then 14 % of cornstarch in the mixture. In Belišće, the portion of cornstarch ranges from 10 to maximal 14 %.

3. *Formation of the briquettes*

   Briquettes are formed in a presser under high temperatures. The formation is followed by drying process at about 400°C.

4. *Packaging, storage and distribution*

   Finally, briquettes are packed in paper packaging of 2.5 kg, and then larger packages; and stored in closed but well ventilated storage places until the distribution.

Figure 4.1 below shows flow chart of charcoal and charcoal briquettes production in Belišće.

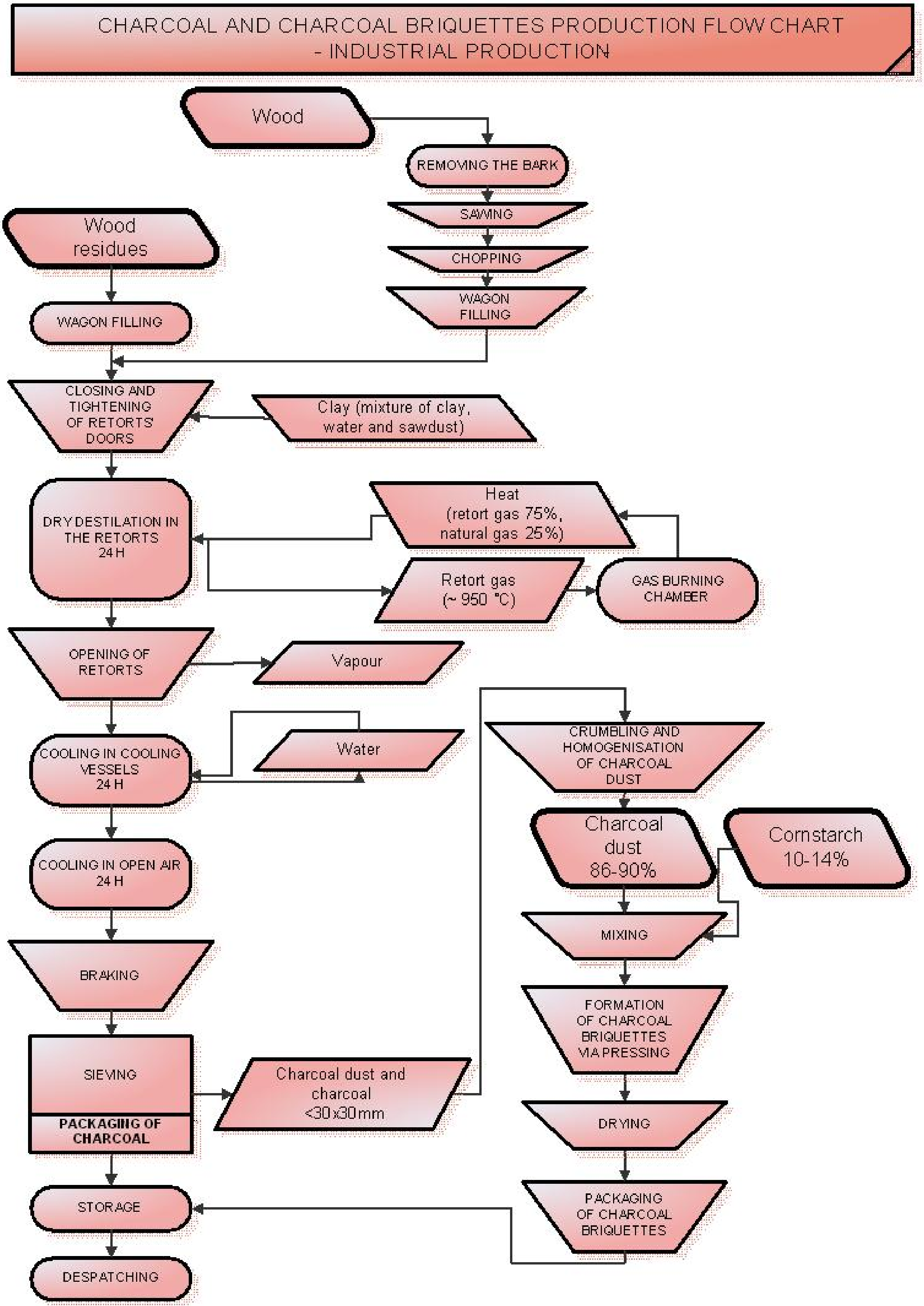

Figure 4.1 Flow chart of charcoal and charcoal briquettes production in Belišće.

The environmental aspects of charcoal production in Belišće

Environmental aspects of charcoal production include aspects related to the natural resources use, emissions into the air and water and waste generation. Natural resources that are used for the charcoal production in Belišće are wood as raw material, woody residues and natural gas as energy sources and water in the cooling process.

As already indicated above, Belišće group comprises several production units, which operate within a system of "industrial symbiosis" where by-products and waste originating from one process serve as a raw material or energy source in another production process. Thus, the woody residues from wood processing units serve as feedstock for charcoal production. Other sources of feedstock are residues from wood processing and furniture industries in the vicinity and wood originating from forests managed by Hrvatske šume. The energy input for the process comes from the combustion of woody residues that can not be used for any other purposes. The energy is obtained in the form of heat, which is used for drying the raw material, but it is simultaneously used for drying the wood used in other production units.

If assessing the use of wood as a natural resource, it can be said that it is used in a sustainable way, because if not used for the charcoal production the named woody residues would be treated as waste. On the other hand, the wood purchased from Hrvatske šume is produced by the application of sustainable forestry practice, which confirms not only long Croatian forestry tradition but also FSC certificate.

In the process of charcoal production water is used only for external cooling of vessels, after the carbonisation process. Belišće has internal water supply system, i.e. there are water wells and part of the needed water is taken from Drava River. The water is pretreated and two categories of water are produced: drinking water and technical water. Technical water from the storage pool for the external cooling of charcoal vessels is circulated, and thus constantly re-used. The Belišće water supply system also includes waste water treatment plant. Upon the treatment water is discharged into the sewage system and its quality is regularly monitored. The monitored parameters include a complete list of all chemical compounds and characteristics that may cause water contamination. According to the monitoring data of both water entering the wastewater treatment plant and the discharged water indicate that the wastewater treatment plant has high purification efficiency. The quality of discharged water complies with the national legal standards on the wastewater quality.

During the production process two main types of wastes are generated: retort gases and charcoal dust. The retort gases are used as an energy source and burned in the furnace, thus producing heat for wood carbonisation. The heat produced from the 20 tones of retort gases that are daily generated contribute by 75% to the total energy consumption for the carbonisation process. During the combustion of retort gases almost all of the contained pyroligneous acids and tars are burned and methane and carbon monoxide oxidised into carbon dioxide. The by-products of the retort gases combustion are gaseous substances and particulate matter. These are emitted into the air, the characteristics of which will be discusses in the following text.

The technology of pipe system and furnace for utilisation of retort gases are relatively new in the production practice. Prior to the current practice the retort gases were used for acetic acid production via fractional distillation. This process was of relatively low efficiency, giving middle-quality acetic acid while at the same time generating high quantities of hazardous waste – approximately 800 to 1 000 kg of tar from 20 tones of distilled retort gases.

The second type of generated waste is charcoal dust and debris. Depending on the quality of feedstock, approximately 10 to 15% of produced charcoal is actually charcoal dust and debris that do not fulfil charcoal quality standards and thus are classified as by-products, i.e. waste. The total amount of generated charcoal dust and debris is used in the charcoal briquettes production, which amounted approximately 300 tones in 2005. In this way all of the waste generated during charcoal production is used within the Belišće group and the net waste production equals zero.

The most significant environmental effect of the charcoal production in Belišće impose the emissions of gaseous substances and particulate matter into the air and workspace. As already mentioned, upon the combustion of retort gases the residues are emitted into the air through two collective chimneys. The exhaust piping and chimneys are not equipped with any kind of flue gases treatment appliances.

Due to the fact that the installed capacity of the retort furnace is 1.5 MW, the retort system is classified as a stationary air emission source according to the Law on Air Protection (OG 178/2004) and Decree on Monitoring of Air Emissions from Stationary Sources (1/2006). Therefore, the periodical monitoring of the air pollutants concentration in the exhaust gases are regularly conducted and the concentration values reported to the responsible authorities.

The retort furnace is classified as a “medium sized combustion facility” according to the Decree on the Limit Emission Values (OG 140/97, OG 105/2002 and OG 100/2004). The named Decree prescribes the following Limit mass concentration values:

- heat losses in flue gases 17%
- particulate matter 150 mg/m3
- carbon monoxide 500 mg/m3
- nitrogen oxides, as NO2 500 mg/m3
- sulphate oxides, as SO2 2 000 mg/m3
- chorine, as HCl 200 mg/m3
- fluorine, as HF 30 mg/m3
- volume content of oxygen 0 mg/m3

The monitoring data show that the outflow gases from retorts comprise of carbon monoxide, carbon dioxide, nitrogen oxides and particulate matter. Furthermore, the data show that the mass concentrations of all the named gases are below the prescribed limits, except for the concentration of particulate matter, Table 4.1.

According to the available data on the mass emissions, annual working load and annual charcoal production, it is possible to calculate the emission factors of air pollutions per 1 tone of produced charcoal. The following table, Table 4.1, includes the data on air emissions and emission factors that can provide a basis for the assessment the significance of air emissions and recommendations on improvements for environmental performances.

Table 4.1 Emissions of air pollutants from the charcoal production in Belišće: mass concentration in flue gases, mass outflow, total annual emissions and emission factors.

Air pollutant	Mass concentration in flue gases	Mass outflow per hour	Total annual emission	Emission factor
	g/m^3	kg/h	t/a	kg/tone charcoal
Particulate matter (PM)	16	145.52	1047.77	349.26
Carbon monoxide (CO)	0.14	1.29	9.28	3.09
Nitrogen oxides (as NO_2)	0.25	2.25	16.22	5.41
Carbon dioxide (CO_2)	217.80	1 980.97	14 262.99	4 754.33

When comparing the emission factors with the emission factors of charcoal production, in some developed and developing countries (Kammen & Lew, 2005) presented in Table 1.1 it can be seen that the emission of carbon dioxide per tone of charcoal produced in Belišće is somewhat higher then those estimated for the production in modern kilns in the US and mound kilns in developing countries. However, at the same time the emission factor of carbon monoxide in Belišće is almost negligible, amounting 3.09 kg per tone of produced charcoal, while the compared factors in other countries range from 8 - 8.9 in controlled continuous retorts in the US, to 443 and 700 kg per tone of produced charcoal in other types of carbonisation kilns. The reason for such emission factors is the fact that both carbon monoxide and the major part of methane are oxidised into carbon dioxide during the combustion of retort gases.

The total annual emission of carbon dioxide, which is estimated to 14.26 Gg for 2005, does not represent significant industrial stationary source of carbon dioxide emissions, having in mind that the total carbon dioxide emissions from Croatian industrial sources in 2004 amounted 5 828 Gg, including emissions from fuel combustion in manufacturing industry and construction, as well as emissions from industrial processes (Vešligaj *et al.*, 2006). The most significant industrial sources of carbon dioxide emissions in Croatia are cement and lime production industry.

Additionally, in the case of charcoal production in Belišće, the primary energy source is retort gas originating from wood. According to IPCC Guidelines the forests are regarded as carbon dioxide sinks and consequently, the carbon dioxide emissions of wood combustion is balanced as to result with zero net emission of carbon dioxide.

Finally, the emissions of particulate matter are relatively high in comparison with the emission factors estimated in other countries. The amount of particulate matter emitted per tone of charcoal produced in Belišće falls within the range of particulate matter emission factor of uncontrolled charcoal kilns in the US (Kammen & Lew, 2005). Yet, the emissions from low controlled and continuously controlled kilns and retorts in the US are significantly lower, ranging up to 89 and 30 kg per tone of produced charcoal, respectively. Having in mind that there is no installed equipment for particulate matter reduction in Belišće, e.g. the emissions are not controlled; the installation of the appropriate equipment may result with significant reduction of particulate matter emission, as well as the reduction of mass concentrations in the flue gases, which are currently above the legally set limits.

4.2 Case study II – Traditional charcoal production in Croatia

Abandoned charcoal kilns scattered on the edges of forests in the northern parts of Croatia and in Istria reveal a long tradition of charcoal production in Croatia. Although it is most probable that charcoal was used as a cooking fuel in the past, today that is not the case. Today charcoal is used almost exclusively as barbeque fuel but also for some handicraft, such as blacksmith.

As already indicated above, it is estimated that there are about 400 charcoal producers who employ traditional technology of production. The level of production and marketing among these producers differs considerably. Namely, there are about ten producers that are registered and present on the market, while the others produce as subcontractors and sell their products either to the registered producers or directly to the restaurants. The annual quantities of production differ from several tones per year for micro-producers, who own one or two charcoal kilns, to two or three hundred tones annually in cases when up to a dozen kilns are used for the production.

It has to be mentioned that charcoal production is not the primary source of income for any of the producers and in many cases private forest owners produce charcoal in order to utilise the wood residues that can not be economically exploited in another way. Furthermore, the micro-level charcoal production is often run as a family occupation for additional earning. On the other hand the registered, medium scale producers employ up to fifteen or more people, depending on the season and level of demand. Production on the medium level usually runs 9 to 10 months per year, while the production on small and micro-level depends on the season of feedstock availability and demand peaks.

The feedstock supply

The feedstock used for the production is exclusively wood, dominantly that of hard broadleaved tree species, such as beach, hornbeam and oak. The wood used for the production is either residues from wood processing industry or smaller diameter wood logs. The feedstock supply among micro to medium scale producers is not completely transparent, but generally there are three main sources. The most common one is wood placed on the market by Hrvatske šume. Namely a number of charcoal producers have a contract or an agreement with a local management unit on purchase of wood residues, small diameter logs and logs that do not meet the quality requirements of wood processing industry. The other two forms of feedstock supply include privately owned forests and wood processing industries, mainly saw-mills.

It has to be emphasised that in order to achieve higher quality of produced charcoal and easier management of production process, the residues from wood processing industry are always mixed with wood logs.

Production cycle

Traditional brick charcoal kilns are commonly used for the production. In some cases they are modified to a certain extent and thus referred as charcoal furnaces. The size of charcoal kilns can vary but sets the volume of the kilns between 30 to 40 cubic metres.

According to the construction type, there are several ways to manage the production. One type of the kilns has the loading opening on the top of the kiln and small exhaust openings around the bottom part of the kiln's walls. Upon the filling the bottom wood is enkindled. Thus the wood is being carbonised from the bottom toward the top of the kiln. The exhaust openings are left open until the fire in the kiln expands and the temperature reaches 180°C, and then sealed. In the later production phases they are used for the regulation of gases exhaust.

The other type of the kilns is built in such a way that the kilns are filled from the bottom part, and enkindled from the top. There are no exhaust openings on the kiln but the top opening. In this type of the kilns, the carbonisation starts from the wood on the top and from the sides and spreads to the inner wood by the end of the carbonisation process.

Due to the fact that there is no specialised technology used for the production, the production cycle is rather simple and lasts for about fifteen days. Upon the filling of the kilns, the wood is enkindled and left in the sealed kiln for ten days, until all the wood is carbonised. The temperature in the kiln ranges from 250 to 350°C. After ten days all of the exhaust openings and the loading opening are open and left for further five days, in order for charcoal to cool. The cooled charcoal is sieved and packed.

The efficiency of production differs on a case basis, but averagely from one cubic metre of stacked volume wood 110 to 120 kg of charcoal can be produced. An average kiln can load about 25 cubic metre of stacked volume wood and in one production cycle 5 to 6 tones of charcoal is produced.

Figure 4.2 shows the flowchart of charcoal and charcoal briquettes production in a medium scale production company Šumooprema. In this company charcoal is produced in two brick kilns with capacity of production of approximately 20 tones monthly and about 200 tones annually.

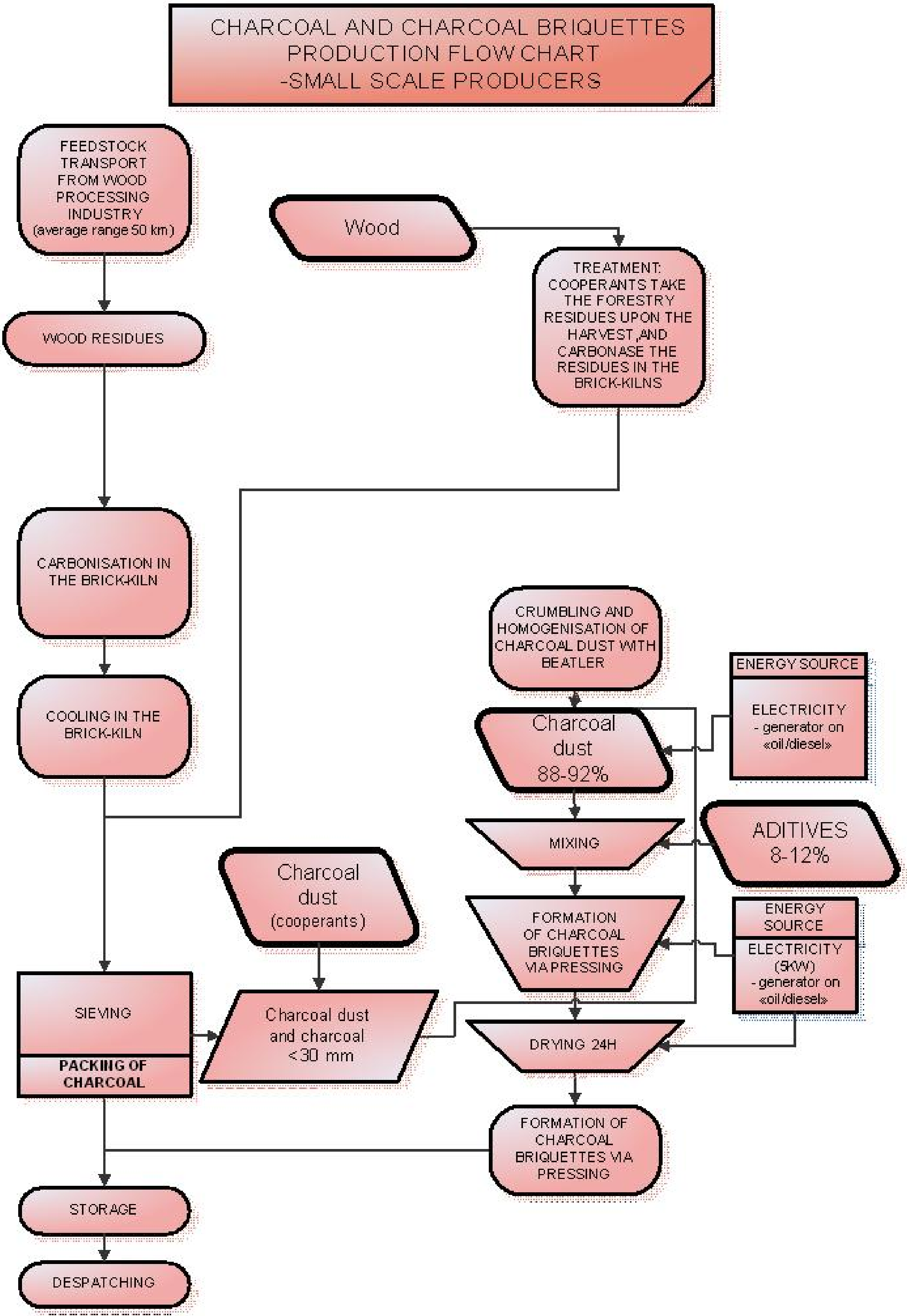
CHARCOAL AND CHARCOAL BRIQUETTES PRODUCTION FLOW CHART -SMALL SCALE PRODUCERS
FEEDSTOCK TRANSPORT FROM WOOD PROCESSING INDUSTRY (average range 50 km)
Wood
TREATMENT: COOPERANTS TAKE THE FORESTRY RESIDUES UPON THE HARVEST ,AND CARBONASE THE RESIDUES IN THE BRICK-KILNS
WOOD RESIDUES
CARBONISATION IN THE BRICK-KILN
COOLING IN THE BRICK-KILN
CRUMBLING AND HOMOGENISATION OF CHARCOAL DUST WITH BEATLER
ENERGY SOURCE
ELECTRICITY - generator on «oil/diesel»
Charcoal dust 88-92%
MIXING
ADITIVES 8-12%
Charcoal dust (cooperants)
FORMATION OF CHARCOAL BRIQUETTES VIA PRESSING
ENERGY SOURCE
ELECTRICITY (5KW) - generator on «oil/diesel»
SIEVING
PACKING OF CHARCOAL
Charcoal dust and charcoal <30 mm
DRYING 24H
FORMATION OF CHARCOAL BRIQUETTES VIA PRESSING
STORAGE
DESPATCHING

Figure 4.2 Flow chart of charcoal and charcoal briquettes production in Šumooprema

The environmental aspects of traditional charcoal production

According to the interviews conducted with the producers and in regard to the feedstock supply, it seems that the most important supplier is Hrvatske šume and wood processing industries, which indicates the sustainability of feedstock supply and that there should not be any significant impacts on the environment.

Due to the fact that there are only several officially registered charcoal producers, who have relatively stable production, while the others run the production from time to time as a source of supplementary income, there are no documented data on the environmental aspects of traditional charcoal production. As the production level of the registered producers is relatively small, they are not obliged by the law to conduct environmental monitoring.

Nevertheless, one of the interviewed small scale producer voluntarily conducted measurements of air pollutants emitted during the production. In this case the production cycle does not take place in a traditional brick charcoal kiln, but in a furnace system previously used for brick production. Although the results of this measurement can not be considered as a reference for drawing conclusions on the level of impact on the air emissions from small scale charcoal producers, they can serve as a basis for estimations.

The measured included concentrations, mass concentrations and mass flows of the following parameters: particulate matter (PM), carbon monoxide (CO), nitrate oxides (NO_x) and sulphate dioxide (SO_2), hydrogen fluoride (HF), hydrogen chlorine (HCl), formaldehyde, phenol, acetic acid, xylene and toluene.

A single furnace in the system has the loading capacity of 10 to 12 m^3, e.g. 700 to 800 kg of wood logs. The measurements were carried out during the maximal production capacity, while the feedstock included wood logs of hornbeam, oak and beech with the share of 2/3 and fir and spruce with 1/3 share. The measurement point was on the top of the furnace outlet.

Table 4.2 Air emissions from a small scale charcoal production unit.

Air pollutant	Concentration in flue gases	Mass concentration in flue gases	Mass outflow per hour
	ppm	**g/m^3**	**kg/h**
particulate matter (PM)		3,72	2,08
carbon monoxide (CO)	2504	3130	586
nitrate oxides (NO_x)	5	10	1,77
sulphate dioxide (SO_2)	11	33	6,2
hydrogen fluoride (HF),	<0,2	<0,2	<0,2
hydrogen chlorine (HCl)	1,1	1,7	0,97

formaldehyde	2,0	2,3	0,44
phenol	1,3	5,3	1
acetic acid	4,3	11,7	2,18
xylene	51,3	226,6	42,92
toluene	26,3	100,3	18,64

When comparing the data presented in the table above with the data on air emissions from the production in Belišće, it is evident that the traditional charcoal making practice results in somewhat higher concentration of air pollutants in the flue gases emitted into the atmosphere. For example, the mass concentrations of NO_x and CO are considerably higher then those in the flue gases exhausted from the afterburner in Belišće.

Nevertheless, considering the low production intensity of the small scale producers and the intermittent production throughout the year, their air emissions do not contribute significantly to the total GHG emissions on the national level.

Finally, charcoal dust and debris, which present the generated waste, are used for briquettes production. The micro producers usually sell the dust and debris to a producer who owns the technology for the briquettes production.

5. Conclusions

Within the introduction of this report an overview of possible negative impacts on the environment originating from charcoal production has been given in order to provide a perspective for further analysis and evaluation of the environmental aspects of charcoal production in Croatia. From the available literature sources and the information on the world practice, it is evident that the significance and the level of environmental impacts highly depend on the feedstock supply systems and the management practice during the charcoal production.

During the research on charcoal production practice in Croatia, which encompassed both small and medium scale producers, as well as with the only large scale production company Belišće jsc. a number of field visits and interviews were conducted. According to the information gathered the majority of producers purchase the feedstock either from Hrvatske šume or from the wood processing industries, in the case of woody-residues. In both cases the feedstock supply can be considered as sustainable. Namely, Hrvatske šume as the state-owned company mandated for management of state-owned forests and the carrier of FSC Certificate, has the obligation to fulfil the requirements on the sustainable forest stewardship and utilisation prescribed by the national Law on forests and its by-laws, as well as those of the FSC Certificate. On the other hand, the usage of residues from wood processing industries contributes to the reduction of waste that needs to be landfilled. The importance of it is significant considering that organised composting of biodegradable waste is still not practiced in Croatia. The biodegradable waste is landfilled together with the municipal waste, which results with the methane, formed during the organic decomposition, being freely emitted into the atmosphere.

The practice of charcoal production is described in detail within the two case studies presented in this report. Due to different technology of production applied, the environmental aspects and efficiency of production differ to a certain extent. In the case of industrial production applied in Belišće, afterburning of the retort gases and utilisation of its energy contribute considerably to the mitigation of air pollutants emission. While on the other side, the emission of particulate matter and the dust concentration in the working areas are still to issues that should be addressed, in order to achieve better environmental performance. The environmental performance of the traditional charcoal production in Croatia could be evaluated only qualitatively, i.e. estimated, due to the fact that there are no data that would support detailed analysis. Based on the information gathered it can be concluded that the air emissions have the most important impact on the environment. Nevertheless, having in mind low intensity of the traditional charcoal production in Croatia, the air emissions originating from these activities are not significant on the national, in some cases not even regional, level. The impacts on the air quality in the vicinity of charcoal kilns are mitigated through the location of kilns on the outskirts of forests and relatively far away from the inhabited areas.

6. Recommendations

Better environmental performance of charcoal production in Croatia could be achieved with the application institutional and technical measures. Through introduction of medium and small scale producer into regional (or national) environmental monitoring system more information on environmental performance of these producers would be available, and thus the best, i.e. most cost-effective, technical and practical measures could be identified. On the other hand, to improve their environmental performance and secure better occupational conditions for their workers, both Belišće and the small and medium scale producers should primary improve the efficiency of production, mitigate emissions of greenhouse gases and particulate matter. For Belišće possible solutions for lowering of particulate matter emissions could be installation of bag filters, cyclones or similar equipment on the flue chimneys. Installation of this kind of equipment would also result in lower concentrations of dusts in the working areas. For reduction of the dust concentration in the working atmosphere and better working conditions, the best solution would be application of improved technology in the sieving and packaging processing, e.g. closed systems. In any case, health and working conditions should be improved through the supply and use of personal occupational safety equipment. This is a cheap and simple solution which can ensure fast and good result, until final solution is accomplished.

The recommendations can be summarised as presented in the table below:

Table 6.1 Recommendations for improvement of environmental performance of charcoal production in Croatia.

Implementer	Measure	Aim
Institutional-legal	Introduction of medium	Collection of data on

framework	and small producers into regional environmental monitoring system	environmental performance
All charcoal producers	Energy efficiency measures	Increase of production efficiency
Large scale producer “Belišće”	Installation of bag filters or cyclones or similar equipement	Reduction of particulate matter emission. Reduction of dust in the working environment.
All charcoal producers	Improvement of sieving and packaging technology – introduction of closed systems.	Reduction of dust in the working environment – protection of workers' health. Lower products losses during these production steps.
All charcoal producers	Supply, education and application of personal occupational safety equipment.	Increased occupational safety and health of the workers.

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8. Annex

Ten principles and their context of FSC International Standard. (Source: FCS Principles and Criteria for Forest Stewardship).

Principle		Context
#1	Compliance with laws and FSC Principles	Forest management shall respect all applicable laws of the country in which they occur, and international treaties and agreements to which the country is a signatory, and comply with all FSC Principles and Criteria.
#2	Tenure and use rights and responsibilities	Long-term tenure and use rights to the land and forest resources shall be clearly defined, documented and legally established.
#3	Indigenous peoples' rights	The legal and customary rights of indigenous peoples to own, use and manage their lands, territories, and resources shall be recognized and respected.
#4	Community relations and worker's rights	Forest management operations shall maintain or enhance the long-term social and economic well-being of forest workers and local communities.
#5	Benefits from the forest	Forest management operations shall encourage the efficient use of the forest's multiple products and services to ensure economic viability and a wide range of environmental and social benefits.
#6	Environmental impact	Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.
#7	Management plan	Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.
#8	Monitoring and assessment	Monitoring shall be conducted -- appropriate to the scale and intensity of forest management -- to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.
#9	Maintenance of high conservation value forests	Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach.

#10	Plantations	Plantations shall be planned and managed in accordance with Principles and Criteria 1 - 9, and Principle 10 and its Criteria. While plantations can provide an array of social and economic benefits, and can contribute to satisfying the world's needs for forest products, they should complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests.