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LEGAL LIMITS FOR NOx EMISSIONS RELATED TO BIOMASS IN EU COUNTRIES AND SERBIA

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Abstract. *In the last few years, the citizens of Serbia have witnessed great air pollution at the beginning of the heating season and the start of operation of small heating plants and individual combustion stoves, as well as due to relatively stable atmospheric conditions. Similarly, two-thirds of EU citizens live in cities constantly exposed to pollution, which often exceeds the limits recommended by laws. The use of biomass as RES somewhat alleviates this problem; however, biomass, like any other fuel, emits certain pollutants. The emission of nitrogen oxides (NOx) is one of the most important challenges in the field. The paper gives a review and analysis of the Serbian norms related to NOx emissions as well as the legal norms and the experiences of some of the selected European countries. As air pollution is among the ten most harmful phenomena for human health, it is important to know the limits of the emission as well as how to adapt to our circumstances the best solutions from the EU policy.*

Key words: *Biomass combustion, NOx emission limits, EU countries, Serbia.*

11. INTRODUCTION

Biomass is considered economically and environmentally friendly (as it is CO_2 neutral with less pronounced pollutant emissions in comparison with coal and oil). Nevertheless, the increasing use of biomass combustion for energy generation could even have adverse air quality impacts, especially considering the particulate matter (PM) and nitrogen oxides (NOx).

Knowing the proper formation/decomposition mechanisms of these individual hazardous compounds, their environmental and health effects as well as understanding how to minimize their emission is essential. The reduction of nitrogen oxide emissions (NOx) is one of the most important challenges in the field. NOx contributes to the formation of photochemical smog, ground-level ozone and acid rain. Acid deposition can lead to potential changes in soil and water quality, and consequently natural ecosystems and crops,

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followed by visibility impairment. In addition to all of the above, NOx emissions have adverse effects on human and animal health, as at high concentrations they can cause airways inflammation. Over 90% of NOx emitted due to the combustion process is NO, while the rest is NO_2. In the atmosphere NO is converted to NO_2, so the environmental protection regulations treat all nitrogen oxides as NO_2.

Table 1 Comparative emission factors for domestic consumption of fuels implied by the energy content of fuel [1]

	NOx (g/GJ)	$PM_{2.5}$ (g/GJ)
Wood	56.5	625
Coal	81.5	387
Burning oil	73.7	3.2
Gas	21.6	0.5

For any biomass combustion application, emission reduction is a major goal besides efficiency improvement. The selection of biomass combustion and NOx control systems is based on economic, technical and local considerations, and it also largely depends on the applicable legal restrictions concerning environmental protection. The emission limitations vary considerably from country to country, which has a significant influence on the choice of technology of biomass combustion for them. Legal restrictions on NOx emissions in the EU countries and Serbia will be discussed in what follows.

2. POLICY CONTEXT RELATED TO NO_X EMISSIONS

2.1 Legal framework of NOx emission limits in the EU

Europe applies several laws that directly or indirectly reduce NOx emissions. These include:

- The National Emission Ceilings Directive 2001/81/EC (NECD) [2], applied from 2001. The NECD sets emission ceilings for four important air pollutants (NOx, sulphur dioxide (SO_2), ammonia (NH_3) and non-methane volatile organic compounds (NMVOCs)) to be achieved from 2010 onwards for each Member State.
- The Gothenburg Protocol to the United Nations Economic Commission for Europe's (UNECE, 2012) Convention on Long-Range Transboundary Air Pollution (LRTAP Convention), which regulates emissions on a regional basis within Europe and protects ecosystems from transboundary pollution by setting emission reduction ceilings to be reached by 2010 for the same four pollutants as addressed in the NECD (EU, 2001b).
- The Large Combustion Plant Directive (2001/80/EC) [3] is important in reducing emissions of NOx, SO_2 and dust from combustion plants having a thermal capacity equal to or greater than 50 MW including power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid or gaseous fuels. New plants must meet the emission limit values (ELVs) given in the LCPD. However, the Member States can choose to meet the obligations for existing plants (i.e. those in operation pre-1987) by either complying with the ELVs or operating within a national emission reduction plan (NERP) that sets a ceiling for each pollutant.

- The Directive on Integrated Pollution Prevention and Control (96/61/EC) [4], IPPC, was brought in 1999 to prevent or minimize air, water, or land pollution from various industrial sources in the EU. Those installations covered by Annex I of the IPPC Directive are required to obtain authorization from the authorities to operate. New and existing installations, which are subject to 'substantial changes', have been required to meet the requirements of the IPPC Directive since 1999. Other existing installations had to be brought into compliance by 2007. The emission limit values outlined in the permit conditions must be based on the best available techniques (BAT).
- The Directive 96/62/EC [5] on ambient air quality assessment and management (Air Quality Framework Directive) and its first "Daughter" Directive 99/30/EC [6] from 1999 set limit values for hourly and annual average nitrogen dioxide concentrations to be achieved throughout the community by 1 January 2010.
- Since biomass can be classified as waste, regulations related to the emission of pollutants fall under the Waste Incineration Directive (WID) [7], which aims to prevent or limit the negative effects of waste incineration on the environment. If solid or liquid waste is combusted, then the WID is likely to apply to the plant.
- For large-scale installations using biomass (over 50 MWth capacity): Regulation through the Industrial Emissions Directive (IED, 2010/75/EU) [8].
- There are a few other directives that relate exclusively to NOx emissions caused by the transport sector, which we will not list here.

For the EU member states emission limits are established under the regulations arising from the Large Combustion Plants (LCP) Directive [3, 9], as well as the Waste Incineration Directive (WID) [7] (Table 2). In doing so, the LCP applies to biomass, which is defined as a product of agricultural production and forestry, waste from vegetable production, waste from wood processing and food industry, untreated wood waste and bark cork. Larger combustion plants are required to comply to both national and international legislation that imposes limits on emissions. As a result, such plants are expected to be well managed, often utilizing various emissions control technologies.

Emissions of pollutants from the combustion of fuel in medium combustion plants are generally not regulated at the EU level even though they contribute increasingly to air pollution, due to an increase in the use of biomass as a fuel, driven by climate and energy policy. The fuel combustion in certain small combustion plants and appliances is covered by implementing measures according to Directive 2009/125/EC [10].

Table 2 NOx emission limits under the LCP and WID for solid biomass [3,7,9]

	LCP (clean biomass)				Waste Incineration Directive				
	Co-combustion*	Stand-alone			Stand-alone		Co-combustion*		
$O_{2ref.}$	6%	6%			11%		6%		
MW_{th}	≥ 50	50-100	100-300	>300	<6t/h	≥6t/h	50-100	100-300	>300
NOx [mg/m^3]	200	400	300	200	200	400	350	300	350

Note: * Mixing rule applies for the composition of total flue gas.
$O_{2ref.}$ for the reference value of oxygen in flue gases

The EU environmental policy generally established by Directives imposes environmental objectives to be achieved by the Member States. EU Directives fix the

framework in which the Member States must create national legislation to attain the environmental quality objectives laid down in the Directives.

2.1.1 Austria

Table 3 Emission limits for residential heating boilers

Feeding system	Solid biomass	NOx [mg/MJNCV]
Manual / Automatic	Nominal heat output ≤ 300kW	150

Table 4 Emission limits for steam boilers (STB) and hot water boilers (HWB)

Nominal fuel capacity [MW]	NOx[mg/m^3_0,ref. 13% O_2]			
	STB	HWB		
		natural wood	wood residues	contaminated wood residues
0.15-5	-	250	300	500
5-10	-	250	300	350
10-50	-	200	200	350
50-300	300	200	200	350
>300	200	200	200	350

2.1.2 Denmark

Recommendations for emission limitations are given in national guidelines [11,12] and limits are adopted under the approval of local authorities/communities about the impact of the plant on the environment.

Table 5 NOx emission limits in Denmark

Fuel input [MW]	NOx [mg/ m^3_o,ref. 10% O_2]
Wood, like wood pellets, sawdust, woodchips, grain, straw	
>5	300

2.1.3 Finland

General emission limits for domestic biofuels (wood, wood waste, peat, straw) are shown in Table 6. Local authorities may set more stringent requirements for limiting emissions.

Table 6 NOx emission limits in Finland

Heat output[MW]	NOx [mg/ m^3_o, ref. 6%O_2]
50-300	400
100-300	300
>300	150

2.1.4 Germany

The legal framework represents the Federal Emission Control Act (BImSch G) specified by a list of national regulations (BImSch V) [13].

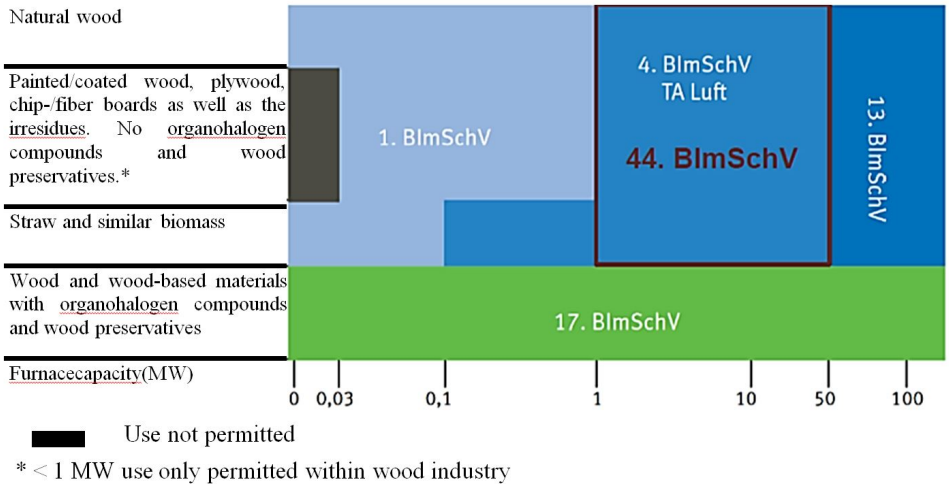

Fig. 1 Emission limits/approval procedure depending on the plant size and fuel

Limits on NOx emissions are shown in Table 7 below.

Table 7 NOx emission limits in Germany

Fuel input [MW]	NOx [mg/ m^3_o]	Ref
Straw and similar (ref.13%O2) 1.BImSchV		[13]
<0.1	-	
Straw and similar (ref.11%O2) TA-Luft 5.4.1.3		[14]
0.1-1	500	
1-50	400	
Clean wood (ref.11%O2) TA-Luft 5.4.1.2.1		[14]
1-2.5	250	
2.5-5	250	
5-50	250	
Clean wood (ref.13%O2) 1.BimSchV		[13]
0.015-1	-	
Used wood, low contamination (ref.13%O2) 1.BimSchV		[13]
0.05-1	-	
Used wood, low contamination (ref.11%O2) TA-Luft 5.4.1.2.1		[14]
1-50	400	
Used wood, high contamination (ref.11%O2) 17.BImSchV		[13]
All	200	

2.1.5 Netherlands

When defining emission limits, Dutch legislation made the difference between pure biomass (as defined in LCP) and all other types of biomass to be treated as waste (WID). General guidelines are:

- For combustion and co-combustion of clean solid biomass from agriculture, forestry and landscape maintenance operations as defined in the European LCP Directive (chaste tree, grass and remnants of composting, etc.), the so-called BEES-A applies.

- For all other solid fuels based on biomass, BVA applies (derived from WID). This refers to the vegetable, fruit and garden waste, slops, animal manure, mixed industrial waste, etc.
- BEES-B applies to gaseous fuels produced from anaerobic digestion or gasification of biomass which burns in a gas engine.
- An exception was made for the burning of waste in the form of pure wood in industrial installations of less than 5MWth owned by the manufacturer of timber. In such cases, applies NER-BR for waste clean wood.

Table 8 Defined NOx emission limits in the Netherlands [15]

	BEES-A Clean solidbiomass [mg/m^3_0, 6% O_{2dry}]	NER Clean waste wood [mg/m^3_0, 11% O_{2dry}]	BVA Stand-alone contaminated solid biomass [mg/m^3_0, 11% O_{2dry}]	BVA Co-firing contaminated solid biomass [mg/m^3_0, 11% O_{2dry}]
NOx	200 (>300MW_{th})	400(>250MW_{th})	130($\eta_{el.eq}$>40%,<20MW_{th}),	100 (<300MW_{th})
	100 (<300MW_{th})		70 (others)	200 (>300MW_{th})

2.1.6 Belgium

In the French-speaking part of Belgium, Wallonia, emission limits are defined by building permits as there are no official overall emission limits. The values in Table 9 are generally the ones to which local authorities granted building permits.

Table 9 Defined NOx emission limits in Belgium

Heat output [MW]	NOx [mg/ m^3_o, ref.11%O_2]	
Clean wood/plant	existing	new
0.5-1	500	500
1-5	500	250
5-50	400	250

2.1.7 Norway

For combustion installations with a capacity exceeding about 5 MW, individual licenses are issued. The degree of specified limits on emissions varies depending on the type of fuel, the plant size and the date of issue of the license. Thus, newer licenses that regulate emissions are more precise and more rigorous than older ones. Combustion installations covered by the Directive on Integrated Pollution Prevention and Control (IPPC) [16] are generally regulated based on the best available technology (BAT). Emission limits given in Table 10 are those for combustion installations smaller than 50MW burning biomass that are not covered by the IPPC Directive and which are following the Norwegian Pollution Control Authority (SFT) [17]. They guide bodies that issue licenses and, in certain cases, higher emission values are granted.

Table 10 Defined NOx emission limits in Norway

Capacity[MW]	NOx [mg/ m^3_o, ref.11%O_2]	
Biomass combustion installations	Existing	New
0.5-1	-	250
1-5	-	250
5-20	300	200
20-50	300	200

2.1.8 Sweden

Emission limits are generally determined by the approving authorities.

- For small-scale domestic appliances up to 300 kW, only the emission of organic gas compounds (OGC) and carbon monoxide (CO) are regulated.
- For plants between 300kW-50MW emissions of nitrogen oxides are limited by the system of NOx taxes and refer to plants that produce more than 25GWh annually.
- Plants with a capacity of over 50 MW.

Table 11 Defined NOx emission limits in Sweden

Capacity [MW]	NOx [mg/ m^3_o, ref. 6% O_2]	
Biomass combustion installations	Existing	New
50-100	600	400
100-300	600	300
300-350	600	200
350-500	600	200
> 500	500	200

2.1.9 Switzerland (not an EU member)

For installations of less than 70kW, the emission limit value refers to the type test only and it is not subjected to the control of emissions. Emission limit values for installations larger than 70 kW which should be guaranteed in practice and which are planned to be implemented are given in Table 12.

Table 12 Defined NOx emission limits in Switzerland [18]

Capacity[MW]	Ref. O_2 [$\%_{vol}$]	NOx [mg/ m^3_o]
0.07-1	13	250[1]
1-10	11	250[1]
>10	11	150

Note: [1] for a mass flow of more than 2.5kg

2.1.10 Spain

In Spain, there are no national emission limitations for small and medium-sized biomass combustion plants. Royal Decree 430/2004 [19] establishes emission limits for large biomass combustion plants (>50MW), under the LCP. The Ministry of Industry, Tourism and Trade has issued the document “The technical guide for biomass heating boilers installation in buildings”, which indicates that the combustion products in these installations must comply with the environmental requirements established by the national,

regional and local authority bodies, in line with EN 303-5 Standard for emission limits specification. The latter, however, does not define NOx emission limits, but emission limits for CO, OGC and particles.

2.2 Serbia

The values of permissible NOx emission limits for emissions from stationary combustion sources in the Republic of Serbia are given in Table 13.

Table 13 Emission limit values for nitrogen oxides (NOx) expressed as NO_2 under the Regulation on emission limit values of air pollutants [20]

Size	Capacity [MW_{th}]	Type of fuel	Ref. O_2 [$\%_{vol}$]	NO_x [mg/m^3_o]
large	50 -100			400
	100 - 300	solid biomass	6	300
	> 300			200
	50 -100			400
	100 - 300	liquid fuels	3	200
	> 300			200
	>50	gases other than natural gas	3	200
medium-	1-50	wood & wood residues	11	250/300[2]
sized	5-50	liquid fuels	3	350
	10-50	gases other than natural gas	3	200
small		other solid fuels different from	13	
	0.1-1	coal, briquettes from coal and coke		250
< 5 for facilities in which	the water temperature is lower than 110 °C and overpressure is not more than 0.05 MPa		3	100
	the water temperature in the boiler is more than 110°C and lower than 210°C and the overpressure is >0.05 MPa and less than 1.8 MPa	liquid fuels	3	200
	the water temperature is higher than 210°C, and the overpressure is greater than 1.8 MPa		3	250

[2]at the FB combustion

3. CONCLUSIONS

When a comparison is made across scales for NOx emissions limits, one can notice that the limits are stricter for smaller scale facilitates. This makes sense and is highly

recommended for the plants located in urban areas. Thus, it is recommended to centralize energy production in urban areas and use larger-scale plants that can more efficiently control combustion and possibly apply gas purification (FGT) systems, which are emitted through larger chimneys and at higher altitudes. However, localized sources of NOx could still have implications on air quality in cases where emissions sources shift substantially from large power or heat generation sources (usually situated away from densely populated areas and with tall chimneys) to smaller boilers (likely to be sited close to demand) and individual heating stoves. Therefore, if there is the introduction of significant biomass into the local urban infrastructure, impact case studies should be undertaken to determine the potential Air Quality impacts.

The Serbian Regulation on emission limit values of air pollutants which defines allowable emission values clearly regulates emission limits for solid biomass that is combusted, while this is not the case for liquid fuels. Namely, there is no categorical statement that liquid fuel may be of biomass origin, while biogas can be classified under the category of "gases other than natural gas". Allowable emission limits from large and medium-sized plants for biomass combustion are generally aligned with the regulatory standards of listed European countries. According to the values of this Regulation, Serbia is one of those countries with stricter restrictions on the NOx emissions at the combustion of biomass in small facilities. Restrictions related to the combustion of gaseous fuels in small installations apply only to natural gas. It should be noted in particular that the Regulation on limit values for emissions of air pollutants does not define the NOx emission limit for combustion of biomass that is not of wood nature, which can be considered as a failure, especially when taking into account that 63% of the available amount of biomass in Serbia is biomass from agricultural production. The crop biomass, which accounts for the largest part of agricultural biomass, is characterized by a very high N content due to its intensive fertilization. Due to the significant reserves of agricultural biomass and the fact that it, as a rule, emits higher amounts of nitrogen oxides, as well as because for small plants the introduction of an FGT system is usually not economically justified, it is necessary to define more lenient emission limits for combustion of this type of biomass. In this sense, it is useful to look upon the practice and experience of developed agrarian countries such as Denmark and Germany.

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