TFTEI

Under the Convention on Long Range Transboundary Air Pollution

Review of the technical annexes IV, V and X of the Gothenburg Protocol

Large combustion plants

TFTEI technical secretariat
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Overview

- Annexes IV, V and X of Amended Gothenburg Protocol (AGP) for large combustion plants (LCP)

- NO_x - Best Available Techniques (BAT) and associated levels
- SO_2 - Best Available Techniques (BAT) and associated levels
- PM - Best Available Techniques (BAT) and associated levels

- Example of other regulations – US
- Example of other regulations – China

- Example of low NO_x-emission technologies
- Example of low SO_2 and PM-emission technologies

- Conclusions & next steps

Annexes IV, V and X of AGP for LCP

Combustion plants with a rated thermal input exceeding 50 MW_{th} for Parties other than Canada and the USA

Emission limit values (ELV) at O_2 reference contents: 6% for solid fuels (including biomass), 3% for liquid and gaseous fuels

Annex IV, Table 1 - Limit values for SO_2 emissions from combustion plants

Fuel type	Thermal power (in MWth)	SO_2 ELV (in mg/Nm^3) new	existing
Solid fuels	50-100	400	400
	100-300	200	250
	> 300	150*	150*
Liquid fuels	50-100	350	350
	100-300	200	250
	> 300	150	200
Gaseous fuels	> 50	35	35
Biomass	50-300	200	200
	> 300	150	200
Liquefied gas	> 50	5	5
Coke oven gas	> 50	400	400
Blast furnace gas	> 50	200	200
Refinery gas	> 50	35	800

* 200 mg/Nm3 if fluidized bed combustion

Annex V, Table 1 - Limit values for NO_x emissions from combustion plants

Fuel type	Thermal power (in MWth)	NO_x ELV (in mg/Nm^3) new	existing
Solid fuels	50-100	300*	300*
	100-300	200	200
	> 300	150**	200
Biomass, peat	50-100	250	300
	100-300	200	250
	> 300	150	200
Liquid fuels	50-100	300	450
	100-300	150	200
	> 300	100	150
Natural gas	> 50	100	100
Other gases	> 50	200	300

* 450 mg/Nm3 if pulverized lignite

** 200 mg/Nm3 if pulverized lignite

Fuel type	Thermal power (in MWth)	NO_x ELV (in mg/Nm^3) new	existing
Liquid fuels	Onshore turbines > 50	50	90
Natural gas		50	50
Other gases		50	120

Annex X, Table 1 - Limit values for PM emissions from combustion plants

Fuel type	Thermal power (in MWth)	Dust ELV (in mg/Nm^3) new	existing
Solid fuels	50-100	20	30
	100-300	20	25
	> 300	10	20
Biomass, peat	50-100	20	30
	100-300	20	20
	> 300	20	20
Liquid fuels	50-100	20	30
	100-300	20	25
	> 300	10	20
Natural gas	> 50	5	5
Other gases	> 50	10*	10*

* 30 mg/Nm3 for iron and steel gases

NO_x - Best Available Techniques and associated levels

Best available techniques (BAT):

- primary techniques: combustion optimisation, air or fuel staging, water/steam addition (by emulsion, for liquid fuels, or by injection), (ultra) low-NOx burners,

- secondary techniques/flue-gas treatment: flue/exhaust-gas recirculation (FGR/EGR), selective non catalytic or catalytic reduction (SNCR or SCR)

BAT associated environmental levels (BAT AELs):

Fuel type	Thermal power (in MWth)	NO_x ELV (in mg/Nm^3)		BAT AELs (in mg/Nm^3)	
		new	existing	new	existing
Solid fuels	50-100	300*	300*	155-200	165-300
	100-300	200	200	80-130	155-210
	> 300	150**	200	80-125	85-165
Biomass, peat	50-100	250	300	120-200	120-275
	100-300	200	250	100-200	100-220
	> 300	150	200	65-150	95-165
Liquid fuels	50-100	300	450	100-215	210-330
	100-300	150	200	85-100	85-145
	> 300	100	150	85-100	85-110
Natural gas	> 50	100	100	30-85	85-110
Other gases	> 50	200	300	22-100	22-110

* 450 mg/Nm3 if pulverized lignite

** 200 mg/Nm3 if pulverized lignite

SO_2 - Best Available Techniques and associated levels

Best available techniques (BAT):

- Dry flue-gas treatment: dry sorbent injection in boiler or in exhaust duct (DSI) (sorbent can be sodium bicarbonates or hydrated lime), spray dry absorber (SDA) with alkaline reagent, dry Venturi scrubber → all these techniques often combined with de-dust technologies

- Wet flue-gas treatment: wet scrubber of flue-gas desulphurisation (FGD) with flue gas flowing through column with water, seawater or alkaline solution to absorb acid compounds

BAT associated environmental levels (BAT AELs):

Fuel type	Thermal power (in MWth)	SO_2 ELV (in mg/Nm^3)		BAT AELs (in mg/Nm^3)	
		new	existing	new	existing
Solid fuels	50-100	400	400	170-220	170-400
	100-300	200	250	135-200	135-220
	> 300	150*	150*	25-110	25-165
Liquid fuels	50-100	350	350	150-200	150-200
	100-300	200	250	150-200	150-200
	> 300	150	200	50-120	150-165
Gaseous fuels	> 50	35	35	-	-
Biomass	50-100	200	200	30-175	30-215
	100-300	200	200	20-85	20-175
	> 300	150	200	20-70	20-85
Liquefied gas	> 50	5	5	-	-
Coke oven gas	> 50	400	400	50-200	50-200
Blast furnace gas	> 50	200	200	-	-
Refinery gas	> 50	35	800	-	-

* 200 mg/Nm3 if fluidized bed combustion

PM - Best Available Techniques and associated levels

Best available techniques (BAT):

- only PM reducing techniques: electrostatic precipitator (ESP), multicyclones, bag or fabric filters
- co-benefit SO_2-PM removal technologies: dry, semi-dry (usually combined with particle de-duster) or wet FGD/scrubber

BAT associated environmental levels (BAT AELs):

Fuel type	Thermal power (in MWth)	Dust ELV (in mg/Nm^3)		BAT AELs (in mg/Nm^3)	
		new	existing	new	existing
Solid fuels	50-100	20	30	4-16	4-22
	100-300	20	25	3-15	4-22
	> 300	10	20	3-10	3-11
Biomass, peat	50-100	20	30	2-10	2-22
	100-300	20	20	2-10	2-18
	> 300	20	20	2-10	2-16
Liquid fuels	50-100	20	30	7-18	7-22
	100-300	20	25	7-18	7-22
	> 300	10	20	7-10	7-11
Natural gas	> 50	5	5	-	-
Other gases	> 50	10*	10*	2-10	2-10

* 30 mg/Nm3 for iron and steel gases

Example of other regulations – US :

→ US regulation for electric and steam generating utilities (Subpart Da) > 73 MWth give rather low ELVs for combustion plants constructed or modified after 2005 for solid and liquid fuels

Hypotheses of conversion used to convert in mg/Nm^3 based on information collected in the US regulation and in the BREF (for standard flue-gas volumes)

SO_2

Fuel type	Thermal power (in MWth)	SO_2 ELV (in mg/Nm^3) new	SO_2 ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	US ELV (in mg/Nm^3)
Solid fuels	50-100	400	400	170-220	170-400	133-184
	100-300	200	250	135-200	135-220	
	> 300	150*	150*	25-110	25-165	
Liquid fuels	50-100	350	350	150-200	150-200	164-226
	100-300	200	250	150-200	150-200	
	> 300	150	200	50-120	150-165	

NO_x

Fuel type	Thermal power (in MWth)	NO_x ELV (in mg/Nm^3) new	NO_x ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	US ELV (in mg/Nm^3)
Solid fuels	50-100	300*	300*	155-200	165-300	90-143
	100-300	200	200	80-130	155-210	
	> 300	150**	200	80-125	85-165	
Liquid fuels	50-100	300	450	100-215	210-330	111-176
	100-300	150	200	85-100	85-145	
	> 300	100	150	85-100	85-110	

PM

Fuel type	Thermal power (in MWth)	Dust ELV (in mg/Nm^3) new	Dust ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	US ELV (in mg/Nm^3)
Solid fuels	50-100	20	30	4-16	4-22	11-18
	100-300	20	25	3-15	4-22	
	> 300	10	20	3-10	3-11	
Liquid fuels	50-100	20	30	7-18	7-22	14-22
	100-300	20	25	7-18	7-22	
	> 300	10	20	7-10	7-11	

Lowest range values for construction after 2011 and highest values for modification between 2005 and 2011

Example of other regulations – China :

→ Chinese regulation for thermal power plants (TPP) give stricter ELVs compared with AGP and SO_2 and NO_x BAT AELs

SO_2

Fuel type	Thermal power (in MWth)	SO_2 ELV (in mg/Nm^3) new	SO_2 ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	China ELV (in mg/Nm^3) new	China ELV (in mg/Nm^3) existing	China ELV (in mg/Nm^3) key area
Solid fuels	50-100	400	400	170-220	170-400	100	200	50
	100-300	200	250	135-200	135-220			
	> 300	150*	150*	25-110	25-165			
Liquid fuels	50-100	350	350	150-200	150-200	100	200	50
	100-300	200	250	150-200	150-200			
	> 300	150	200	50-120	150-165			
Gaseous fuel	> 50	35	35	-	-	35	35	35

NO_x

Fuel type	Thermal pow MWth)	NO_x ELV (in mg/Nm^3) new	NO_x ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	China ELV (in mg/Nm^3) new	China ELV (in mg/Nm^3) existing	China ELV (in mg/Nm^3) key area
Solid fuels	50-100	300*	300*	155-200	165-300	100	100	100
	100-300	200	200	80-130	155-210			
	> 300	150**	200	80-125	85-165			
Liquid fuels	50-100	300	450	100-215	210-330	100	200	100
	100-300	150	200	85-100	85-145			
	> 300	100	150	85-100	85-110			
Natural gas	> 50	100	100	30-85	85-110	100	100	100

PM

Fuel type	Thermal pov (in MWth)	Dust ELV (in mg/Nm^3) new	Dust ELV (in mg/Nm^3) existing	BAT AELs (in mg/Nm^3) new	BAT AELs (in mg/Nm^3) existing	China ELV (in mg/Nm^3) new	China ELV (in mg/Nm^3) existing	China ELV (in mg/Nm^3) key area
Solid fuels	50-100	20	30	4-16	4-22	30	30	20
	100-300	20	25	3-15	4-22			
	> 300	10	20	3-10	3-11			
Liquid fuels	50-100	20	30	7-18	7-22	30	30	20
	100-300	20	25	7-18	7-22			
	> 300	10	20	7-10	7-11			
Natural gas	> 50	5	5	-	-	5	5	5

Example of other regulations – China :

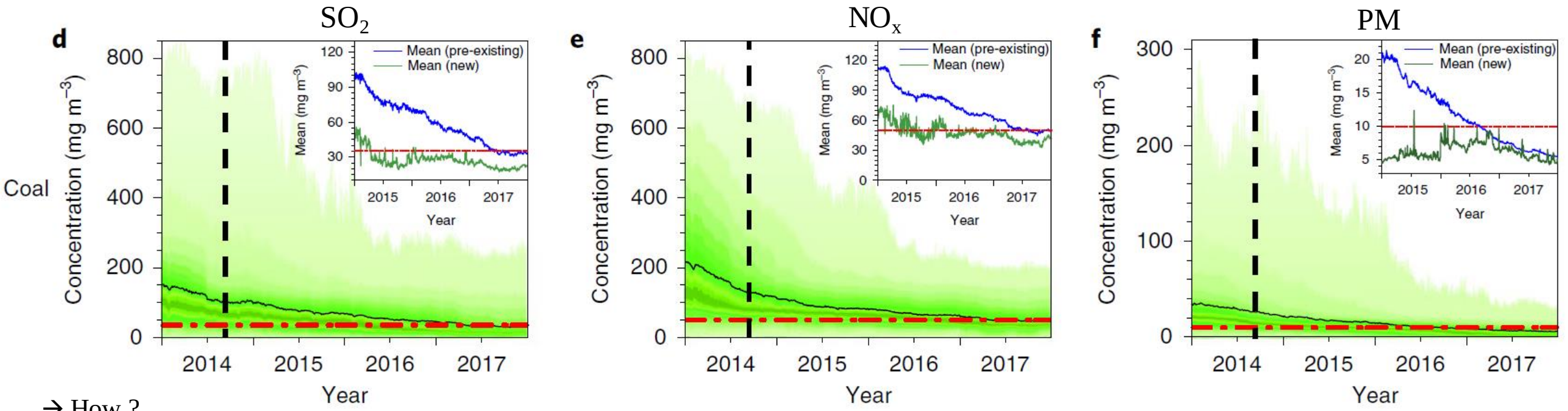
→ Chinese regulation for thermal power plants (TPP) give stricter ELVs compared with AGP and NOx BAT AELs

→ And an even stricter programme for **coal**-fired power plants with **ultra low-emission (ULE) standards** :
all **new units** must meet these standards **from 2015** onwards and **80%** of total coal-fired capacity must **comply with it by 2030**

Pollutant	Thermal power (in MWth)	AGP ELV (in mg/Nm^3)		BAT AELs (in mg/Nm^3)		China ELV (in mg/Nm^3)			
		new	existing	new	existing	new	existing	key area	ULE prog.
SO_2	50-100	400	400	170-220	170-400	100	200	50	35
	100-300	200	250	135-200	135-220				
	> 300	150	150	25-110	25-165				
NOx	50-100	300	300	155-200	165-300	100	100	100	50
	100-300	200	200	80-130	155-210				
	> 300	150	200	80-125	85-165				
PM	50-100	20	30	4-16	4-22	30	30	20	10
	100-300	20	25	3-15	4-22				
	> 300	10	20	3-10	3-11				

Example of other regulations – China :

→ Consequently, in Dec. 2017, mean concentrations for all coal PP capacity in China were of 35.3, 52.0 and 5.7 mg/Nm^3 for SO_2, NO_x and PM, respectively:



→ How ?

- shutdown of old and smaller PP for constructing new, larger ones
- almost all coal-fired capacity equipped with SO_2 removal (88% limestone wet FGD, 5% dry scrubber and 2.5% seawater scrubber, the rest being ammonia absorption)
- NO_x reduction techniques from 13% of total capacity in 2011 to 98.4% in 2017 (89% equipped with SCR, being active 94% of the time)
- PM: a lot of PP was already equipped before; 100% in 2017: 66% with ESP, 25% with ESP+bag filter, 9% with baghouse filters

Source: Tang et al. (2019) - Substantial emission reductions from Chinese power plants after the introduction of ultra low emission standards

Example of low NO_x-emission technologies

Several technologies have shown to achieve BAT AEL similar NO_x emission levels and even lower:

- OFA + low-NOx burners in combination with SNCR for solid fuel plants :

  - for > 300 MWth coal and oil shale power plants, NO_x concentrations < 180-190 mg/Nm^3 with OFA+ low-NOx burners and SNCR with urea injection [1][2] (for second project, only one SNCR necessary on 1 boiler out of 8)

  - similar NOx conc. achieved (< 180-190 mg/Nm^3) for coal plants of 70-165 MWth equipped with only SNCR or OFA + SNCR [2]

- SCR technologies for waste incineration plants:
  NO_x emission levels decreased from 300-500 to < 50-70 mg/Nm^3 at 11% O_2 (eq. 75-105 mg/Nm^3 at 6% O_2) for tail-end SCR systems [3]

- (Ultra) Low-NOx burners (U-LNB) for natural gas plants:

  - NO_x conc. < 30 mg/Nm^3 with reduced EGR and < 50 mg/Nm^3 without EGR for several projects for plants from 87-500 MW [4]

  - NO_x conc. of 14 mg/Nm^3 for natural gas and 96 mg/Nm^3 for diesel oil with 2 U-LNB combined with 20% EGR for one project and NO_x levels of 38-48 mg/Nm^3 with ultra low-NOx burners without EGR for various applications for three other projects [5]

Sources: [1] https://www.fortum.com/media/2016/11/jaworzno-iii-tauron-low-nox-combustion-project-poland-2010-2016 and https://www.fortum.com/media/2015/11/narva-power-plants-eesti-energia-estonia-nox-reduction-installations-2013-2015 ; [2] https://www.eescorp.com/wp-content/uploads/2017/10/SNCR-References.pdf ; [3] https://lab.fr/en/denox-system ; [4] Saacke 2019 Customer day meeting presentation ; [5] https://www.fivesgroup.com/energy-combustion/burners-systems/boiler-burners and TFTEI website

Example of low SO_2 and PM-emission technologies

Several technologies have shown to achieve BAT AEL similar SO_2 and PM emission levels and even lower :

- Semi-dry/dry sorbent injection combined with bag filters [1]; for 4 waste incineration plants of various power capacities, results were:

  - SO_2 concentrations decreased from 250-600 mg/Nm^3 to 50 and 20 mg/Nm^3 at 11% O_2 (eq. to 75 and 30 mg/Nm^3, resp., at 6% O_2)
  - PM levels from 2,000-6,000 mg/Nm^3 down to 3-10 mg/Nm^3 at 11% O_2 (eq. to 4.5-15 mg/Nm^3 at 6% O_2)

- Dry FGD system combined with fabric filter [2]:
  for a chemical plant, SO_2 concentrations decreased from 500-2,000 to 150 mg/Nm^3, and PM levels from 200 down to 10 mg/Nm^3

- Wet scrubber and FGD technologies (with injection of limestone, caustic soda or urea) combined with fabric filters [2, 3]:

  - for a 58 MWe coal and biomass plant, SO_2 concentrations from 600-2,000 down to 200 mg/Nm^3 achieved,
  - for a waste incineration plant, SO_2 and PM concentrations as low as 25 mg/Nm^3 and 2 mg/Nm^3 achieved

Sources: [1] https://lab.fr/systeme-sec# and https://lab.fr/en/semi-dry-system ; [2] https://lab.fr/en/fgd-system ; [3] https://lab.fr/en/wet-system

Conclusions & next steps

Conclusions :

- Since 2012, technologies were upgraded, leading to higher reduction efficiencies
- Some regulations and recent projects show that lower emission levels can be achieved with actual reduction techniques, at the power plant level but also at national levels

Next steps :

- Complete our literature review about recent low-emission technologies, and contact some manufacturers to learn more about last achievements
- Provide an assessment of AGP annexes (summary table, deadline : Dec. 10th)
- Develop informal background document on the revision of all AGP annexes (deadline : March 2022)

Thank you very much for your attention!

Questions?

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