DNV·GL

HARD COAL/LIGNITE FIRED POWER PLANTS IN EU28

Fact-based scenario to meet commitments under the LCP BREF

European Climate Foundation

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Table of contents

EXECUTIVE SUMMARY

The European Climate Foundation (ECF) is looking for a fact-based scenario to identify technical requirements imposed on the hard coal/lignite fired large combustion plants (LCPs) by the Industrial Emission Directive (IED) and the revised Best Available Techniques (BAT) Reference Document for Large Combustion Plants (LCP BREF) and to estimate the investment costs of the required measures.

In 2017 an update of the LCP BREF will be issued. The BAT-conclusions of this LCP BREF have to be implemented in national regulations by 2021. This means that as of 2021 LCPs shall comply with the BAT-conclusions of the LCP BREF.

In this report DNV GL has assessed the emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust from the hard coal/lignite fired LCPs in EU28 and determined the required measures and costs per Member State to comply with the higher end of the yearly average BAT associated emission levels (BAT-AELs) as reported in the final draft of the LCP BREF issued June 2016.

The hard coal/lignite fired capacity per Member State is based on the Platts World Electric Power Plants Database, Europe, June 2016 and the European Environment Agency (EEA) 2014 database for large combustion plants, supplemented with information from utilities and DNV GL in-house knowledge.

The LCPs reporting emissions in 2014 in the EEA database have been taken as starting point. From this capacity the capacity taken out of operation is subtracted. This capacity consists of LCPs shut-down between 2014 and 2016, opted-out as derogation of the LCP Directive and announced to close (including LCPs in the Limited Lifetime Derogation regime of the IED). Capacity which became operational after 2014 and which is currently under construction or planned (under development) is added to result into the capacity expected to be in operation in 2021.

The check on compliance of the current emissions of the LCPs in operation as reported in the EEA database 2014 and the current emission limit values for the LCPs under construction with the BAT-AELs results in the compliance and non-compliance capacity per Member State as shown in table 1.

For the non-compliant capacity DNV GL has determined the required measures to reduce the current emissions below the relevant BAT-AELs. Based on multiple international reference databases for investments, supplemented with in-house knowledge DNV GL has estimated the capital expenditures (CapEx) and fixed and variable operational expenditures (OpEx). The annual capital costs are based on a linear depreciation of CapEx in 15 years and a WACC (weighted average cost of capital) of 5%/a. Since the future dispatch of the LCPs is unknown and uncertain, it is assumed that the number of operating hours will remain on 2014 level for all LCPs. These assumptions result in the CapEx and specific costs (weighted average of the annual costs per MWh for all LCPs with emission reduction measures for this flue gas component) per Member State and per flue gas component as shown in tables 2, 3 and 4.

The required measures to comply with BAT-AELs have to be implemented in the non-compliant LCPs within a timeframe of four years after publishing the LCP BREF, which is expected in 2017. The development and implementation of emission reduction measures takes typically 1.5 years. DNV GL expects that the total number of installations may lead to increase of CapEx levels, but will not lead to a shortage of engineering and construction capacity, as long as the activities are evenly spread over these four years. This is also expected for the catalyst for selective catalytic reduction (SCR) of NO_x emissions, since the current annual production capacity is much the same as the annual catalyst need for the determined measures.

Table 1 Compliant and non-compliant capacity of LCPs in operation in 2021

	Hard coal (MWe)			Lignite (MWe)		
	In operation 2021	Compliant	Non-compliant	In operation 2021	Compliant	Non-compliant
BG	530	-	530	3 646	670	2 976
CZ	1 971	-	1 971	8 549	275	8 274
DE	29 698	5 567	24 131	21 647	3 875	17 772
DK	2 803	2 025	778	-	-	-
ES	5 064	-	5 064	510	-	510
FI	1 885	-	1 885	-	-	-
FR	3 040	-	3 040	-	-	-
GR	-	-	-	3 187	630	2 557
HR	335	-	335	-	-	-
HU	-	-	-	1 086	-	1 086
IE	915	-	915	-	-	-
IT	7 751	4 285	3 466	-	-	-
NL	4 796	4 796	-	-	-	-
PL	13 940	82	13 858	9 664	-	9 664
PT	1 878	622	1 256	-	-	-
RO	1 115	-	1 115	4 120	500	3 620
SE	145	114	31	-	-	-
SI	124	-	124	725	-	725
SK	220	-	220	299	15	284
UK	8 614	1 500	7 114	-	-	-
EU28	**84 823**	**18 991**	**65 832**	**53 432**	**5 965**	**47 467**

Table 2 Cost and emission reduction of additional measures (NO_x)

	Hard coal				Lignite			
	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]
BG	3 629	2 867	74	7.71	21 484	7 997	191	1.99
CZ	9 906	4 242	186	4.39	44 136	12 646	561	2.76
DE	68 398	10 738	494	0.85	106 545	7 487	235	0.26
DK	1 367	-	-	-	-	-	-	-
ES	36 213	18 746	360	2.45	3 162	1 267	37	2.28
FI	10 468	5 637	141	3.07	-	-	-	-
FR	6 385	2 927	115	5.03	-	-	-	-
GR	-		-	-	16 757	7 828	179	1.83
HR	3 401	2 165	44	2.84	-	-	-	-
HU	-		-	-	7 389	2 032	78	1.77
IE	3 365	1 136	21	0.74	-	-	-	-
IT	18 956	1 440	45	0.55	-	-	-	-
NL	2 850	-	-	-	-	-	-	-
PL	64 806	38 312	1 094	3.25	54 028	20 454	595	1.46
PT	6 504	747	29	0.58	-	-	-	-
RO	7 458	5 795	147	7.65	25 530	14 456	459	5.16
SE	226	-	-	-	-	-	-	-
SI	688	315	11	3.65	284	182	22	1.02
SK	98	-	-	-	2 734	1 581	36	4.34
UK	72 002	44 722	613	2.46	-	-	-	-
EU28	**316 721**	**139 788**	**3 373**	**0.6-7.7**	**282 049**	**75 928**	**2 393**	**0.3-5.2**

Table 3 Cost and emission reduction of additional measures (SO_2)

	Hard coal				Lignite			
	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]
BG	2 982	2 322	208	22.14	95 187	70 724	679	7.17
CZ	14 972	9 213	372	8.16	66 696	29 158	1 054	9.77
DE	46 284	4 990	287	1.26	86 588	1 255	111	2.77
DK	709	31	2	7.51	-	-	-	-
ES	34 669	25 100	650	5.25	4 596	1 300	15	1.77
FI	5 517	2 282	134	4.83	-	-	-	-
FR	5 513	2 438	161	7.31	-	-	-	-
GR	-		-	-	19 015	3 555	76	1.29
HR	2 934	1 862	43	1.46	-	-	-	-
HU	-		-	-	7 689	1 377	15	2.81
IE	4 132	2 200	126	4.42	-	-	-	-
IT	16 051	2 477	78	1.01	-	-	-	-
NL	2 520	-	-	-	-	-	-	-
PL	103 470	77 363	1 829	3.69	92 309	35 247	598	1.91
PT	5 353	454	21	0.44	-	-	-	-
RO	31 252	29 754	492	19.92	72 293	57 849	480	20.95
SE	92	6	5	221.02	-	-	-	-
SI	364	41	45	14.42	312	126	6	7.24
SK	456	144	9	2.77	2 904	961	40	4.72
UK	43 243	20 565	405	1.60	-	-	-	-
EU28	**320 513**	**181 241**	**4 867**	**0.4-221**	**447 590**	**201 552**	**3 074**	**1.3-21**

Table 4 Cost and emission reduction of additional measures (dust)

	Hard coal				Lignite			
	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]	Actual emission [tonne/a]	Total reduction [tonne/a]	Total CapEx [MEUR]	Specific costs [EUR/MWh]
BG	305	244	6	0.57	2 241	1 791	75	0.92
CZ	434	109	26	0.87	2 521	1 281	150	0.58
DE	1 405	316	67	0.28	2 840	35	16	0.18
DK	258	12	10	0.54	-	-	-	-
ES	1 894	1 146	52	0.47	157	27	5	0.31
FI	194	45	11	0.82	-	-	-	-
FR	136	15	11	1.61	-	-	-	-
GR	-		-	-	886	470	39	0.39
HR	112	13	-	-	-	-	-	-
HU	-		-	-	243	22	17	0.41
IE	135	33	4	0.53	-	-	-	-
IT	671	-	-	-	-	-	-	-
NL	97	-	-	-	-	-	-	-
PL	4 654	3 725	139	0.32	2 702	1 536	60	0.37
PT	79	-	-	-	-	-	-	-
RO	3 504	3 399	75	3.29	2 371	1 807	61	0.65
SE	2	0	2	77.46	-	-	-	-
SI	12	-	-	-	11	108	12	0.42
SK	15	-	-	-	165	84	6	0.67
UK	1 408	297	41	0.36	-	-	-	-
EU28	**15 315**	**9 354**	**444**	**0.3-77**	**14 136**	**7 160**	**440**	**0.2-0.9**

1 INTRODUCTION

The European Climate Foundation (ECF) is looking for a fact-based scenario for the investment decisions in the hard coal/lignite fired large combustion plants (LCPs) in Europe. This should result in a point of reference to guide ECF's view, strategy and communication in further discussions on the on-going and perspective investment needs in the hard coal/lignite power generation sector and thus enable a wider perspective on the EU's future energy mix.

European regulations require that the emission limit values (ELVs) of the main air pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust do not exceed the emission levels associated with the Best Available Techniques (BAT) as described in the BAT reference document for Large Combustion Plants (LCP BREF).

In 2017 an update of the LCP BREF will be issued. The BAT-conclusions of this LCP BREF have to be implemented in national regulations by 2021. This means that as of 2021 LCPs shall comply with the BAT-conclusions of the LCP BREF.

In this report DNV GL has assessed the emissions from hard coal and lignite fired LCPs and determined the required measures (including costs per Member State) to comply with the BAT conclusions.

Section 2 of this report shows the workflow with the general approach for gathering the information from the hard coal/lignite fired LCPs in EU28, assessing the emissions and determining the required reduction measures and the associated cost.

In Section 3, LCP capacity information per Member State, aggregated for hard coal respectively lignite fired LCPs plants is provided:

- Capacity of all LCPs currently in operation, under construction or in development
- Capacity of LCPs to be shut-down (including derogation)
- Capacity of all LCPs expected to be in operation in 2021.

Section 4 describes how the BAT-conclusions are translated into the requirements for the LCPs expected to be in operation in 2021.

The emissions of the LCPs expected to be in operation in 2021 are described in Section 5. A distinction is made between the plants in operation and under construction in 2014.

In Section 6, LCP capacity information per Member State, aggregated for hard coal respectively lignite fired LCPs plants is provided:

- Capacity of compliant LCPs
- Capacity of non-compliant LCPs.

In Section 7 required emission reduction measures are determined for non-compliant LCPs. It provides per flue gas component information on costs and emission reduction potential per Member State, aggregated for hard coal respectively lignite fired LCPs plants:

- CapEx (EUR)
- Annual costs (EUR/a)
- Specific emission reduction costs per unit (EUR/MWh)
- Total emission reduction (tonne/a).

Possible supplier's constraints for implementation of measures are described in Section 8.

2 APPROACH

The general approach is presented in the workflow scheme of figure 2.1. In the next sections each step is elaborated in more detail.

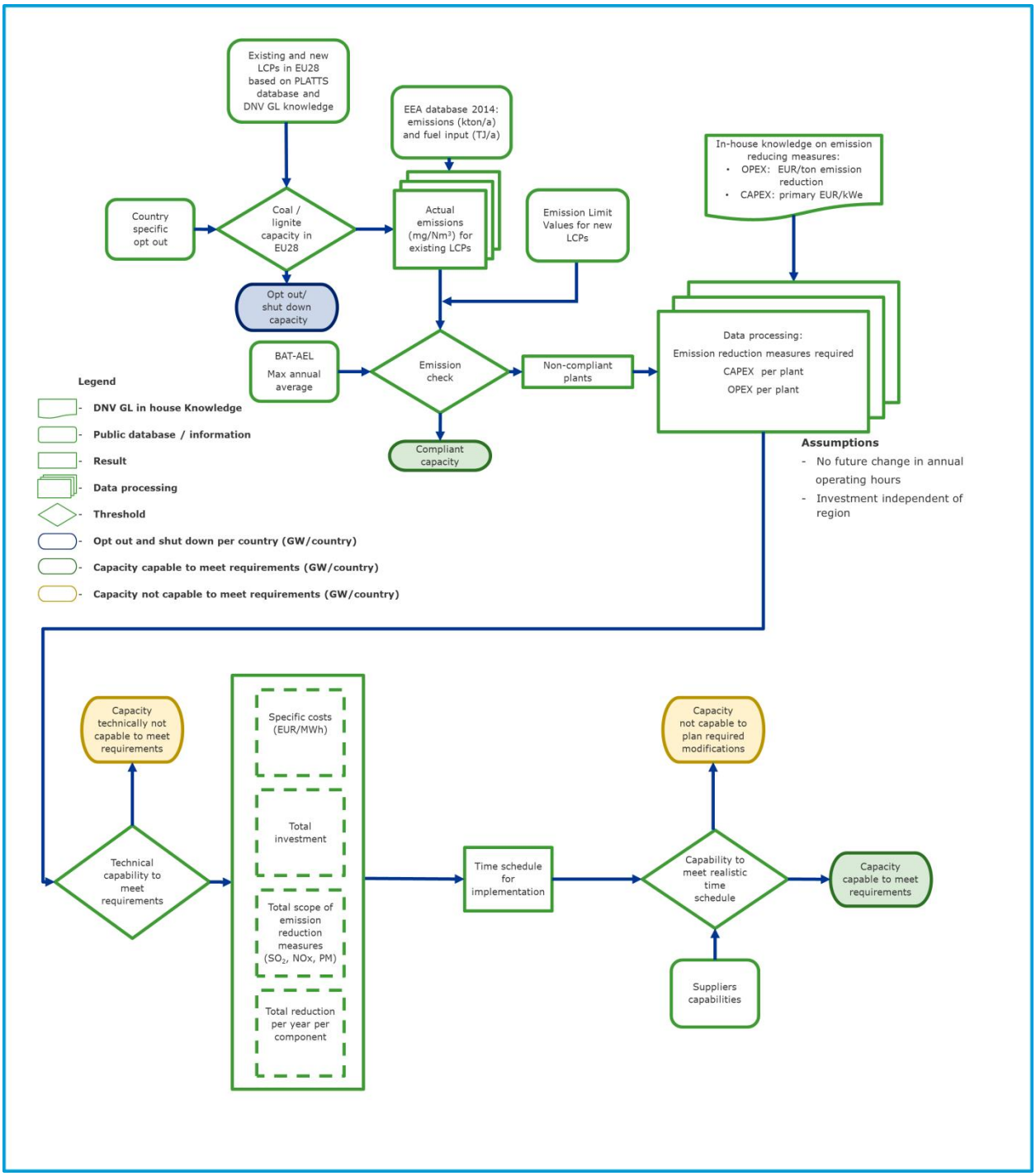

Figure 2.1 Workflow scheme for the assessment of LCPs

3 HARD COAL/LIGNITE FIRED LARGE COMBUSTION PLANTS IN EU28

The generation capacity of hard coal and lignite fired LCPs within the European Union is based on two public databases: Platts World Electric Power Plants Database, Europe, dated June 2016 [1] and the European Environment Agency (EEA) 2014 database for large combustion plants [2].

The first database, Platts, provides information per power generation unit in all Member States of the European Union (EU28, see table 3.1) such as electric capacity, status (e.g. retired, in operation, under construction, planned), fuel type (hard coal, lignite). The second database, EEA, provides information per reported LCP such as the thermal capacity, the annual thermal input, status (opt-out etc.). Inconsistencies between both databases have been assessed, based on DNV GL in-house knowledge or available public information. Incorrect reporting in Platts or EEA has been corrected, as far as observed; remaining mistakes may lead to deviations in the results of this report.

Table 3.1 Overview of present EU Member States (EU28)

Austria	AT	Estonia	EE	Ireland	IE	Poland	PL
Belgium	BE	Spain	ES	Italy	IT	Portugal	PT
Bulgaria	BG	Finland	FI	Lithuania	LT	Romania	RO
Cyprus	CY	France	FR	Luxembourg	LU	Sweden	SE
Czech Republic	CZ	Greece	GR	Latvia	LV	Slovenia	SI
Germany	DE	Croatia	HR	Malta	MT	Slovakia	SK
Denmark	DK	Hungary	HU	Netherlands	NL	United Kingdom	UK

Table 3.2 and 3.3 present an overview of the hard coal, respectively lignite capacity per Member State in operation in 2014, shut-down, derogations of the LCP Directive (opted-out) and the Industrial Emission Directive (Limited Lifetime Derogation; LLD), under construction and planned:

- The LCPs reporting emissions in 2014 in the EEA database have been taken as starting point. These LCPs are cross-linked with the hard coal and lignite fired units from the Platts database in order to determine the hard coal and lignite fired LCP capacity per Member State in operation in 2014
- The shut-down capacity per Member State is based on the units taken out of operation since 2014 (reported "not in operation" in 2016 in Platts)
- Per Member State the opted-out capacity (derogations of the LCP Directive, for plant with limited operating hours to be decommissioned in 2015 at the latest) has been determined based on the EEA database
- Units announced to close in 2023 at the latest (e.g. due to the Limited Lifetime Derogation regime in article 33 of the IED). It should be noted that ongoing governmental policy and political discussions with respect to future closures are not considered
- Under construction are those units not reporting emissions in 2014, plants which became operational after 2014, for which permits and ELVs are available, and units which are indicated as "CON" (under construction) in Platts
- The planned capacity per Member State is based on the units for which (building) plans are available or which are indicated as "PLN" (planned) in Platts.

This results in "LCPs in operation 2021": hard coal and lignite fired LCP capacities in the EU28 expected to be in operation by 2021, which have to comply with the BAT-conclusions.

Member States in the EU28 without hard coal or lignite fired LCPs and not having intentions for installing such plants (Cyprus, Estonia, Lithuania, Luxembourg, Latvia and Malta) are not included in the tables 3.2 and 3.3.

Table 3.2 Capacity of hard coal fired LCPs in EU28

	Hard coal (MWe)						
	In operation 2014	Shut-down	Opted-out	Announced to close	Under construction	Planned	In operation 2021
AT	1 229	983	-	246	-	-	-
BE	290	290	-	-	-	-	-
BG	1 790	1 260	-	-	-	-	530
CZ	2 042	28	-	68	25	-	1 971
DE	29 483	4 044	-	396	4 653	-	29 698
DK	3 428	470	-	155	-	-	2 803
ES	9 061	687	-	3 310	-	-	5 064
FI	2 664	274	242	263	-	-	1 885
FR	5 586	2 528	18	-	-	-	3 040
GR	-	-	-	-	-	-	-
HR	335	-	-	-	-	-	335
HU	-	-	-	-	-	-	-
IE	915	-	-	-	-	-	915
IT	9 776	1 720	-	305	-	-	7 751
NL	7 582	1 706	-	1 080	-	-	4 796
PL	20 225	200	283	9 722	3 920	-	13 940
PT	1 878	-	-	-	-	-	1 878
RO	1 425	100	210	-	-	-	1 115
SE	295	150	-	-	-	-	145
SI	124	-	-	-	-	-	124
SK	561	220	121	-	-	-	220
UK	21 579	8 845	-	4 120	-	-	8 614
EU28	**120 268**	**23 505**	**874**	**19 665**	**8 598**	**-**	**84 823**

Table 3.3 Capacity of lignite fired LCPs in EU28

	Lignite (MWe)						
	In operation 2014	Shut-down	Opted-out	Announced to close	Under construction	Planned	In operation 2021
AT	-	-	-	-	-	-	-
BE	-	-	-	-	-	-	-
BG	3 966	-	320	-	-	-	3 646
CZ	7 254	115	-	-	1 410	-	8 549
DE	21 658	476	-	635	-	1 100	21 647
DK	-	-	-	-	-	-	-
ES	1 720	160	-	1 050	-	-	510
FI	-	-	-	-	-	-	-
FR	-	-	-	-	-	-	-
GR	4 577	-	250	1 800	660	-	3 187
HR	-	-	-	-	-	-	-
HU	1 098	-	-	12	-	-	1 086
IE	-	-	-	-	-	-	-
IT	-	-	-	-	-	-	-
NL	-	-	-	-	-	-	-
PL	8 906	-	-	600	1 358	-	9 664
PT	-	-	-	-	-	-	-
RO	5 621	1 701	200	100	-	500	4 120
SE	-	-	-	-	-	-	-
SI	745	-	-	620	600	-	725
SK	647	348	-	-	-	-	299
UK	-	-	-	-	-	-	-
EU28	**56 192**	**2 800**	**770**	**4 817**	**4 028**	**1 600**	**53 432**

4 APPLICABLE BAT-CONCLUSIONS

The commitments under the LCP BREF are based on the BAT-conclusions as reported in the final draft of the LCP BREF issued June 2016. Although this is a working draft in progress, it is to be expected that the BAT-conclusions will not change in the final LCP BREF and this will apply from 2021 onwards.

The BAT-conclusions for the emissions of NO_x, SO_2 and dust to air from hard coal or lignite fired LCPs include a combination of best available techniques and BAT associated emission levels (BAT-AELs) based on a daily and yearly average. Since the emission of the LCPs in operation are reported as an annual value (see Section 5), the yearly average BAT-AELs for existing LCPs are taken into account in this report.

Complying with the BAT-conclusions means that the emissions shall not exceed the higher end of the range of the BAT-AELs. Local conditions may require emission limit values which are lower than the upper range of the BAT-AEL. As the assessment in this report is on Member State level, local conditions are not taken into account; compliance with the upper range of the annual average of the BAT AEL is considered as criterion in this report.

The BAT-AELs for NO_x, SO_2 and dust to air from hard coal or lignite fired LCPs are presented in the tables below.

Table 4.1 BAT-AELs for NO_x in mg/Nm^3

Thermal input MWth	New	Existing[4]
<100	150	270
100-300	100	180
>300 FBC	85	150[9]
>300 PC	85	150

Footnote 4: not applicable for operational hours <1500 per year
Footnote 9: The higher end of the range is 175 mg/Nm^3 for FBC boilers put into operation no later than 7 January 2014 and for lignite-fired PC boilers

Table 4.2 BAT-AELs SO_2 in mg/Nm^3

Thermal input MWth	New	Existing[3]
<100	200	360
100-300	150	200
>300 FBC	75	180
>300 PC	75	130

Footnote 3: not applicable for operational hours <1500 per year
For indigenous lignite fired LCPs with a capacity >300 MWth the maximum BAT-AEL is 200 mg/Nm^3 for new LCPs and 320 mg/Nm^3 for existing LCPs.

Table 4.3 BAT-AELs dust in mg/Nm^3

Thermal input MWth	New	Existing[1]
<100	5	18
100-300	5	14
300-1000	5	10[4]
>1000	5	8

Footnote 1: not applicable for operational hours <1500 per year
Footnote 4: The higher end of the BAT-AEL range is 12 mg/Nm^3 for plants put into operation no later than 7 January 2014

5 EMISSIONS OF LARGE COMBUSTION PLANTS

5.1 Methodology

5.1.1 Emissions of LCPs in operation

The assessed LCPs which are currently in operation are required to report yearly data such as energy input, thermal capacity and annual emissions of NO_x, SO_2 and dust. The annual emissions (tonne/year) during 2014 are reported in the EEA database [2].

5.1.2 Emission Limit Values LCPs in construction / under development

For units under construction or recently commissioned and units with no emissions reported in 2014, it is assumed that the emissions of these units (mg/Nm^3; dry, 6 % O_2) will be equal to the current ELVs of these units.

For planned units it is assumed that these units will be compliant with BAT-AELs for new LCPs. As a result, additional emission reduction measures will not be required.

5.2 Results

Table 5.1 Emissions reported by EEA (2014) for LCPs in operation in 2021

	Hard coal			Lignite		
	NO_x tonne/a	SO_2 tonne/a	Dust tonne/a	NO_x tonne/a	SO_2 tonne/a	Dust tonne/a
BG	3 629	2 982	305	21 484	95 187	2 241
CZ	9 906	14 972	434	44 136	66 696	2 521
DE	68 398	46 284	1 405	106 545	86 588	2 840
DK	1 367	709	258	-	-	-
ES	36 213	34 669	1 894	3 162	4 596	157
FI	10 468	5 517	194	-	-	-
FR	6 385	5 513	136	-	-	-
GR	-	-	-	16 757	19 015	886
HR	3 401	2 934	112	-	-	-
HU	-	-	-	7 389	7 689	243
IE	3 365	4 132	135	-	-	-
IT	18 956	16 051	671	-	-	-
NL	2 850	2 520	97	-	-	-
PL	64 806	103 470	4 654	54 028	92 309	2 702
PT	6 504	5 353	79	-	-	-
RO	7 458	31 252	3 504	25 530	72 293	2 371
SE	226	92	2	-	-	-
SI	688	364	12	284	312	11
SK	98	456	15	2 734	2 904	165
UK	72 002	43 243	1 408	-	-	-
EU28	**316 721**	**320 513**	**15 315**	**282 049**	**447 590**	**14 136**

Table 5.2 Assumed emission limit values for LCPs under construction

	Hard coal			Lignite		
	NO_x mg/Nm³	SO_2 mg/Nm³	Dust mg/Nm³	NO_x mg/Nm³	SO_2 mg/Nm³	Dust mg/Nm³
CZ	400	300	30	150	200	10 - 20
DE	100	70	10	-	-	-
GR	-	-	-	150	200	10
PL	100 – 250	80 - 200	10 - 30	200	200	10 - 30
SI	-	-	-	100	150	20

6 EMISSION COMPLIANCE CHECK

6.1 Methodology

In section 4, the BAT-AELs (mg/Nm^3; dry, 6 % O_2) for different types of power plants have been presented. These values are dependent on type of boiler, type of fuel, plant size and year of commissioning.

In section 5, the current (2014) annual emissions (tonnes/a) of these plants have been listed per Member State. These annual emissions are converted into annual average emission values (mg/Nm^3; dry, 6 % O_2).

In this section, the compliance of LCPs with respect to BAT-AELs is checked: if the actual emission for NO_x, SO_2 or dust is higher than BAT-AEL, the plant is qualified as non-compliant.

6.2 Results

Table 6.1 shows the results of the compliance check for LCPs expected to be in operation in 2021. The compliance per flue gas component (NO_x, SO_2 and dust) is presented in the tables 6.2, 6.3 and 6.4.

Table 6.1 Compliant and non-compliant capacity in 2021

	Hard coal (MWe)		Lignite (MWe)	
	Compliant	Non-compliant	Compliant	Non-compliant
BG	-	530	670	2 976
CZ	-	1 971	275	8 274
DE	5 567	24 131	3 875	17 772
DK	2 025	778	-	-
ES	-	5 064	-	510
FI	-	1 885	-	-
FR	-	3 040	-	-
GR	-	-	630	2 557
HR	-	335	-	-
HU	-	-	-	1 086
IE	-	915	-	-
IT	4 285	3 466	-	-
NL	4 796	-	-	-
PL	82	13 858	-	9 664
PT	622	1 256	-	-
RO	-	1 115	500	3 620
SE	114	31	-	-
SI	-	124	-	725
SK	-	220	15	284
UK	1 500	7 114	-	-
EU28	**18 991**	**65 832**	**5 965**	**47 467**

Table 6.2 Compliant and non-compliant capacity in 2021 (NO_x)

	Hard coal (MWe)		Lignite (MWe)	
	Compliant	Non-compliant	Compliant	Non-compliant
BG	-	530	725	2 921
CZ	170	1 802	1 445	7 103
DE	9 120	20 578	5 116	16 530
DK	2 803	-	-	-
ES	50	5 014	-	510
FI	-	1 885	-	-
FR	-	3 040	-	-
GR	-	-	630	2 557
HR	-	335	-	-
HU	-	-	-	1 086
IE	-	915	-	-
IT	5 525	2 226	-	-
NL	4 796	-	-	-
PL	1 932	12 008	-	9 664
PT	622	1 256	-	-
RO	150	965	500	3 620
SE	145	-	-	-
SI	-	124	-	725
SK	220	-	15	284
UK	1 500	7 114	-	-
EU28	**27 032**	**57 791**	**8 431**	**45 001**

Table 6.3 Compliant and non-compliant capacity in 2021 (SO_2)

	Hard coal (MWe)		Lignite (MWe)	
	Compliant	Non-compliant	Compliant	Non-compliant
BG	-	530	670	2 976
CZ	-	1 971	4 343	4 206
DE	21 207	8 491	20 371	1 276
DK	2 775	28	-	-
ES	556	4 508	250	260
FI	531	1 354	-	-
FR	-	3 040	-	-
GR	-	-	1 600	1 587
HR	-	335	-	-
HU	-	-	836	250
IE	-	915	-	-
IT	5 261	2 490	-	-
NL	4 796	-	-	-
PL	341	13 599	2 627	7 037
PT	622	1 256	-	-
RO	-	1 115	3 110	1 010
SE	114	31	-	-
SI	-	124	600	125
SK	-	220	15	284
UK	1 530	7 084	-	-
EU28	**37 733**	**47 090**	**34 422**	**19 010**

Table 6.4 Compliant and non-compliant capacity in 2021 (dust)

	Hard coal (MWe)		Lignite (MWe)	
	Compliant	Non-compliant	Compliant	Non-compliant
BG	-	530	1 633	2 013
CZ	661	1 310	1 059	7 490
DE	25 020	4 678	19 642	2 005
DK	2 053	750	-	-
ES	1 627	3 437	-	510
FI	1 261	624	-	-
FR	2 440	600	-	-
GR	-	-	940	2 247
HR	-	335	-	-
HU	-	-	250	836
IE	610	305	-	-
IT	7 751	-	-	-
NL	4 796	-	-	-
PL	1 646	12 294	5 298	4 366
PT	1 878	-	-	-
RO	100	1 015	500	3 620
SE	114	31	-	-
SI	124	-	-	725
SK	220	-	15	284
UK	5 974	2 640	-	-
EU28	**56 274**	**28 548**	**29 337**	**24 095**

7 REQUIRED EMISSION REDUCTION MEASURES

7.1 Methodology

In section 6, LCPs have been identified that are expected to be running in 2021, but being non-compliant with respect to the BAT-AELs for any of the flue gas components considered and thus will need (additional) emission reduction measures to enable future operation. For the flue gas components NO_x, SO_2 and dust, DNV GL determines per Member State:

- required (additional) emission reduction measures
- the costs of these measures (CapEx as well as annual costs)
- the specific costs of these measures (EUR/MWh)
- the total annual emission reduction (tonne/a).

7.1.1 Input data

The input data is based on information from the Platts [1] and EEA [2] databases:

- Fuel type (hard coal, lignite)
- Boiler type (pulverized, fluidized bed)
- Number of individual Units per Power Plant
- Year of commissioning
- Heat input (MWth)
- Net Power Output (MWe)
- Fuel consumption (TJ/a)
- Currently installed NO_x reduction measure (primary only, SCR, SNCR)
- Currently installed SO_2 reduction measure (wet, semi-dry, dry)
- Currently installed dust reduction measure (ESP or FF)
- Annual NO_x emission (tonnes/a)
- Annual SO_2 emission (tonnes/a)
- Annual dust emission (tonnes/a).

7.1.2 Assumptions and general technical data

DNV GL is using a number of general data and assumptions for its calculations, including:

- Specific flue gas volume per GJ of fuel: 360 Nm^3/GJ for hard coal [4] and 420 Nm^3/GJ for lignite; both based on dry flue gas with 6 % O_2
- Removal efficiencies (%) for NO_x, SO_2 and dust of newly installed emission reduction technologies, based on DNV GL in-house knowledge:
    - SNCR (incl. primary measures) 60 %
    - SCR (no primary measures) 85 %
    - Dry FGD (incl. fabric filter) 80 %
    - Semi-dry FGD (incl. fabric filter) 90 %
    - Wet FGD (incl. waste water treatment) 98 %
    - ESP or fabric filter 99.95 %
- Upgrades of currently installed emission reduction techniques result in an additional removal for NO_x, SO_2 and dust (percentages based on current emission; based on DNV GL in-house knowledge):
    - SNCR upgrade 30 %
    - SCR upgrade 65 %
    - Wet FGD upgrade 65 %
    - ESP upgrade 90 %

- Capital expenditures (CapEx) are determined for newly installed and upgrades of currently installed flue gas cleaning systems. A scale (sizing) factor is used to accommodate for different unit sizes, both for hard coal and lignite fired units, the latter being 20% more expensive. Applied investment figures (expressed in EUR/kWe installed) are based on multiple international reference databases for total investment costs of emission reduction equipment, including IECM [5], TFTEI [6], Powermag [7], EGTEI [8] and The Utility Air Regulation Group [9], supplemented with DNV GL in-house knowledge:
    - SNCR (incl. primary measures) 50 EUR/kWe
    - SCR (no primary measures) 120 EUR/kWe
    - Dry FGD (incl. fabric filter) 200 EUR/kWe
    - Semi-dry FGD (incl. fabric filter) 250 EUR/kWe
    - Wet FGD (incl. waste water treatment) 350 EUR/kWe
    - ESP or fabric filter 75 EUR/kWe
- CapEx for technology upgrades vary between 10% of new build costs for wet FGD up to 20% of new build costs for other SO_2, NO_x and dust reduction technologies. Based on DNV GL in-house knowledge
- Annual capital costs (EUR/a) are based on a linear depreciation of CapEx in 15 years; furthermore, a WACC (weighted average cost of capital) of 5%/a is taken into account
- Annual fixed operating costs (EUR/a) are determined for different types of flue gas cleaning systems (as a percentage of CapEx in EUR/a). Cost factors are based on DNV GL in-house knowledge, taking into account the complexity of the equipment and varying between 3 and 4% per annum
- Annual variable operating costs (EUR/a) are calculated for different emission reduction techniques for NO_x, SO_2 or dust removed from the flue gases. Most important parameter for the variable operating costs is the consumption of chemicals, e.g. limestone, hydrated lime or ammonia; data are based on DNV GL in-house knowledge. Values vary from 10 EUR/tonne for dust, 100-200 EUR/tonne for SO_2 and 200-400 EUR/tonne for NO_x
- Improvement of removal efficiencies with less than 10% can be achieved with operational measures only, without investments (no CapEx). Based on in-house knowledge
- Dust removal efficiency of new flue gas desulphurization, supporting dedicated dust removal equipment such as ESP or FF, are based on DNV GL in-house knowledge: 80% dust removal for wet FGD systems, 90% dust removal for dry and semi-dry systems
- It is assumed that the number of operating hours will not change in future, hence remain on 2014 level for all plants.

7.1.3 Technology selection methodology

The technology selection methodology is as follows:

- For each of the flue gas components (NO_x, SO_2 and dust) DNV GL has checked whether a unit is compliant or non-compliant (see Section 6)
- For each "non-compliant single flue gas component" the following is assessed:
    - If no flue gas cleaning system is currently in place, the most cost effective emission reduction technology that results in compliance is selected
    - If any flue gas cleaning system is currently in place, it is verified whether it can be upgraded to meet the BAT-AELs. In case the BAT-AELs cannot be met by upgrading this technology, the most cost effective new emission reduction technology that results in compliance is selected
    - For dust emissions the impact of a newly installed FGD technology is taken into account, as it will significantly support dust removal from the flue gases

- Power plants reporting emissions as one LCP but consisting of multiple units that have different emission reduction technologies installed, have been split in different units:
  - The unit(s) equipped with modern emission reduction technologies are assumed to meet IED emission limit values
  - The remaining units – not equipped with modern emission reduction equipment - are considered to be responsible for the remainder of the annual emissions, converted into emission values (mg/Nm^3).

  Subsequently, both categories of units are assessed independently for the necessity of additional emission reduction measures to meet BAT-AELs.

7.1.4 Units under construction and units planned for future construction

For units under construction, fuel input and emission data are not available in EEA [2]. The same holds for units that started operation after 2014. For these units the following (additional) assumptions apply:

- Annual operating hours are defined at a fixed value of 5,000 h/a
- Actual emission values are assumed to be equal to the ELVs of the unit (Section 5, table 5.2).

The "under construction" category is extended with units of which it is known that emission reduction technologies have been installed for either NO_x, SO_2 or dust removal after 2014. It is assumed that these units are currently capable of meeting IED emission limit values.

For units planned for future construction it is assumed that these units will be compliant with respect to BAT-AELs. Additional emission reduction measured and associated emission reduction and costs are therefore considered not to be relevant.

7.1.5 Final results

After selection of the most effective emission reduction measures per flue gas component for a unit, the following output is calculated:

- CapEx (EUR)
- Annual costs (EUR/a)
- Specific emission reduction costs per unit (EUR/MWh)
- Total emission reduction (tonne/a)

The specific emission reduction costs per Member State are the weighted average of the annual costs per MWh for all LCPs with emission reduction measures for this flue gas component (total annual cost per MWh electricity generated by all LCPs with emission reduction measures for this flue gas component).

7.2 Results

In the tables 7.1 – 7.3, CapEx, total annual costs, specific emission reduction costs and additional emission reduction (for NO_x, SO_2 and dust) are presented for "non-compliant" capacity in tables 6.2 - 6.4.

Table 7.1 Costs and emission reduction of additional measures (NO_x)

	Hard coal				Lignite			
	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]
BG	74	11.5	7.71	2 867	191	31.5	1.99	7 997
CZ	186	28.7	4.39	4 242	561	82.7	2.76	12 646
DE	494	71.6	0.85	10 738	235	36.4	0.26	7 487
DK	-	-	-	-	-	-	-	-
ES	360	58.5	2.45	18 746	37	5.9	2.28	1 267
FI	141	21.9	3.07	5 637	-	-	-	-
FR	115	17.5	5.03	2 927	-	-	-	-
GR	-	-	-		179	27.4	1.83	7 828
HR	44	6.9	2.84	2 165	-	-	-	-
HU	-	-	-		78	12.4	1.77	2 032
IE	21	3.3	0.74	1 136	-	-	-	-
IT	45	7.1	0.55	1 440	-	-	-	-
NL	-	-	-	-	-	-	-	-
PL	1 094	169.5	3.25	38 312	595	92.8	1.46	20 454
PT	29	4.4	0.58	747	-	-	-	-
RO	147	17.0	7.65	5 795	459	70.5	5.16	14 456
SE	-	-	-	-	-	-	-	-
SI	11	1.8	3.65	315	22	3.2	1.02	182
SK	-	-	-	-	36	6.0	4.34	1 581
UK	613	100.1	2.46	44 722	-	-	-	-
EU28	**3 373**	**519.8**	**0.6-7.7**	**139 788**	**2 393**	**368.8**	**0.3-5.2**	**75 928**

Table 7.2 Costs and emission reduction of additional measures (SO_2)

	Hard coal				Lignite			
	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]
BG	208	32.9	22.14	2 322	679	116.9	7.17	70 724
CZ	372	59.4	8.16	9 213	1 054	167.7	9.77	29 158
DE	287	43.6	1.26	4 990	111	17.5	2.77	1 255
DK	2	0.3	7.51	31	-	-	-	-
ES	650	105.8	5.25	25 100	15	2.6	1.77	1 300
FI	134	21.3	4.83	2 282	-	-	-	-
FR	161	25.5	7.31	2 438	-	-	-	-
GR	-	-	-		76	12.6	1.29	3 555
HR	43	7.1	1.46	1 862	-	-	-	-
HU	-	-	-		15	2.5	2.81	1 377
IE	126	20.1	4.42	2 200	-	-	-	-
IT	78	12.4	1.01	2 477	-	-	-	-
NL	-	-	-	-	-	-	-	-
PL	1 829	287.4	3.69	77 363	598	97.7	1.91	35 247
PT	21	3.3	0.44	454	-	-	-	-
RO	492	57.7	19.92	29 754	480	81.0	20.95	57 849
SE	5	0.8	221.02	6	-	-	-	-
SI	45	7.1	14.42	41	6	1.0	7.24	126
SK	9	1.4	2.77	144	40	6.5	4.72	961
UK	405	65.2	1.60	20 565	-	-	-	-
EU28	**4 867**	**751.5**	**0.4-221**	**181 241**	**3 074**	**506.0**	**1.3-21**	**201 552**

Table 7.3 Costs and emission reduction of additional measures (dust)

	Hard coal				Lignite			
	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]	Total CapEx [MEUR]	Annual costs [MEUR/a]	Specific costs [EUR/MWh]	Total reduction [tonne/a]
BG	6	0.9	0.57	244	75	11.0	0.92	1 791
CZ	26	3.7	0.87	109	150	20.8	0.58	1 281
DE	67	6.5	0.28	316	16	2.3	0.18	35
DK	10	1.5	0.54	12	-	-	-	-
ES	52	7.7	0.47	1 146	5	0.8	0.31	27
FI	11	1.6	0.82	45	-	-	-	-
FR	11	1.6	1.61	15	-	-	-	-
GR	-	-	-		39	5.1	0.39	470
HR	-	-	-	13	-	-	-	-
HU	-	-	-		17	2.5	0.41	22
IE	4	0.6	0.53	33	-	-	-	-
IT	-	-	-	-	-	-	-	-
NL	-	-	-	-	-	-	-	-
PL	139	17.6	0.32	3 725	60	7.7	0.37	1 536
PT	-	-	-	-	-	-	-	-
RO	75	9.0	3.29	3 399	61	9.0	0.65	1 807
SE	2	0.3	77.46	0	-	-	-	-
SI	-	-	-	-	12	1.3	0.42	108
SK	-	-	-	-	6	0.9	0.67	84
UK	41	6.0	0.36	297	-	-	-	-
EU28	**444**	**57.0**	**0.3-77**	**9 354**	**440**	**61.4**	**0.2-0.9**	**7 160**

8 SUPPLIERS' CONSTRAINTS FOR IMPLEMENTATION

8.1 Introduction

Flue gas cleaning systems for large power stations are generally supplied by major worldwide operating equipment manufacturers, including GE (including Alstom, 2015), MHI/Hitachi, Amec Foster Wheeler (including Siemens, 2014), Babcock Noell, Marsulex, Andritz (including Austrian Energy, 2011), Steinmüller Babcock, Balcke Dürr, Rafako, FLSmidt. These equipment manufacturers rely on numerous (partly international) suppliers for steel works, mills, pumps, fans, I&C systems, storage and handling equipment, (including e.g. conveyors and silos). Each of these suppliers is dependent on sub-suppliers for steel, smaller mechanical/electrical equipment, measuring equipment, etc.

As the number of equipment manufacturers as well as the number of (sub-)suppliers is very large, this is not expected to be limiting for installing a large number of emission reduction measures at LCPs in Europe. Most of the material required for flue gas cleaning systems is steel and synthetic materials and no limitation in supply has to be expected (at all). From the past (e.g. after the implementation of the Clean Air Acts in the USA) it is known that the costs of emission reduction equipment may rise, particularly due to commercial effects and not from scarcity of specific materials. This is why the higher end of current price levels for CapEx are taken into account.

It should be noted that the actual implementation time is less than four years, since utilities, owning non-compliant units, will not order at the date of publishing the LCP BREF. In paragraph 8.2 this is elaborated on.

Further, DNV GL is of the opinion that one particular component may be critical when a large number of flue gas cleaning systems has to be installed: the SCR catalyst material. In paragraph 8.3 this item is addressed.

8.2 Time schedule for implementation

Figure 8.1 shows a typical schedule for the development and implementation of emission reduction measures in an existing LCP.

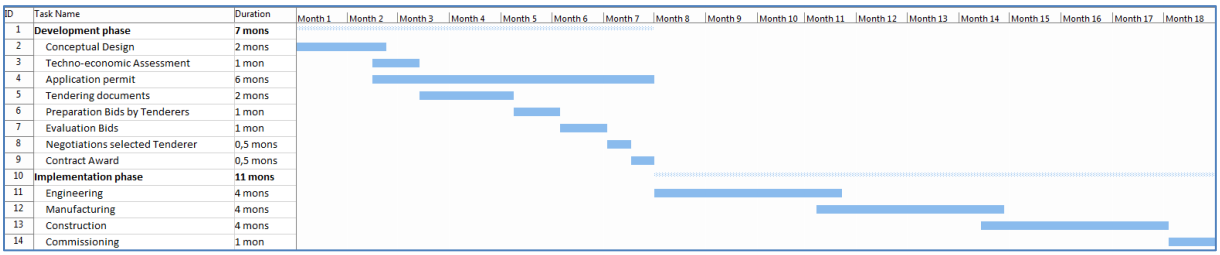

Figure 8.1 Typical schedule for development and implementation of upgrades in existing assets

After publishing of the final LCP BREF, operators will need approximately seven months to develop a project for reducing emissions. Based on a conceptual design a permit application procedure will be started and tendering documents will be prepared. The bids, received from tenderers will be evaluated and contract negotiation with the selected tenderer will result in awarding a contract.

After contract award, the suppliers start the detailed engineering resulting in specifications for new equipment. Manufacturing, based on these specifications, will start approximately ten months after project start and should be completed four months prior to the project finish, enabling a proper construction and commissioning of the new installation.

This means that, within the four years between publishing the LCP BREF and implementation of BAT-conclusions in the LCPs, LCP owners have 18 months for realizing the emission reduction measures. Furthermore, the timeframe for manufacturing equipment is only approximately 2.5 years (four years minus 14 months), since the manufacturing of the first project will not start earlier than ten months after publishing the LCP BREF and the manufacturing of the last project should end four months prior to LCP BREF implementation deadline.

A complicated situation may arise as utilities, owning non-compliant units, don't order equipment evenly spread over the timeline 2017-2020.

8.3 Catalyst production and installing capacity

8.3.1 Current capacity

Major SCR catalyst suppliers include:

- Cormetech: >1400 systems supplied at power plants (100,000 MWe) over the last 30 years
- Haldor Topsoe: >1000 systems supplied at power plants over the past 30 years
- Mitsubishi Hitachi Power Systems: >350 at power plants (and >1000 systems at stationary sources) in the last 40 years.
- Johnson Matthey: major supplier of SCR catalysts; no reference figures available from website. Probably similar production capabilities as Cormetech and Haldor Topsoe.

Summarizing, around 4,000 SCR catalyst systems have been installed during the last 30-40 years. The majority of these systems probably have been installed in the past 10 years, suggesting a total capacity of at around 200 catalyst systems per annum. Based on the figures of Cormetech, suggesting about 70 MWe per catalyst system, this equals approximately 14 GWe per annum installation capacity for SCR catalyst for the four largest SCR catalyst suppliers. Total production capacity may exceed this value as additional smaller suppliers are available in the market.

8.3.2 Required capacity

The required catalyst production and installing capacity is calculated from the number and power generation capacity of units that have to be equipped with a new SCR system or that need an upgrade of the existing SCR system. It is assumed that SCR upgrading - as an average - requires one third of the amount of catalyst when compared to a new SCR system. In other words: a 300 MWe units that needs an SCR upgrade is considered a 100 MWe equivalent unit with respect to the amount of catalyst required.

The assessment in section 7 results in the following requirements for the number of units to be covered:

- Number of new SCR systems: 101
- Number of updated SCR units: 77
- Total number of units to be covered: **178**

And for the equivalent GWe to be covered:

- Equivalent GWe for new SCR systems: 18
- Equivalent GWe for SCR upgrades: 10 (based on 30 GWe of units concerned)
- Total equivalent GWe to be covered: **28**

As can be derived from paragraph 8.2, only a period of 2.5 years is available for the production of catalyst. This means that in this period, catalyst for 11 GWe/a is required, which is much the same as the current annual production capacity (14 GWe/a; paragraph 8.3.1).

9 REFERENCES

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