BAT AND BEP IMPLEMENTATION TO REDUCE PCDD/PCDFs EMISSIONS IN ESEA COUNTRIES: MONITORING RESULTS, TECHNOLOGY SELECTION, EXPECTED OUTCOMES AND REPLICABILITY POTENTIALS

Centeno C[2], Gobbi M[1]*, Sbrilli A[1]

[1]UNIDO consultant, Italy; [2]UNIDO, Industrial Development Officer, Stockholm Convention Unit. Environmental Management Branch, Wagramerstrasse 5, A-1400 Vienna, Austria

Introduction

Formally launched on October 5, 2007, the ESEA (East-South East Asia) Forum is a programmatic regional initiative set up by UNIDO aimed to introduceBest Available Techniques and Best Environmental Practices(BAT/BEP) on priority sectors defined by participating countries, whichwere grouped based on country priority sectors of interest mentioned in annex C of article 5 of Stockholm Convention on POPs. The regional project "Demonstration of BAT & BEP in fossil fuel-fired utilities and industrial boilers in response to the Stockholm Convention on Persistent Organic Pollutants (POPs)"is the first integral sectorial project of the ESEA BAT/BEP Forumand is currently being carried out in Cambodia, Indonesia, Lao PDR, Mongolia, Philippines and Thailand.

Commonly, in the participating countries the baseline inventories of UP-POPs, namely Polychlorinated di-benzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), reported in the National Implementation Plans (NIPs)for the specific heat and power sectorwere estimated on the basis of the emission factors provided by the UNEP *Standardized Toolkit for identification and quantification of releases of dioxins and furans*, recently updated in 2013[1], and rarely on real measurements, due lack of national standards, adequate monitoring capacities andrelated high costs. However, the emission factors in the Toolkit are mainlybased on few measurements on large power plants and in industrialized countries, and do not discriminateon the basis of the presence of APCDs (Air Pollution Control devices) or of the age of the plants, so this can be a limiting factor when used for small and old boilers.Particularly, in the case of industrial boilers, literature reports a very wide range of emission factors (from sub-units to thousands µg TEQ/TJ), depending on type of fuel and age of the installation and especially for biomass fuelled facilities[2,3,4].Therefore the UNEP Toolkit must becontinuouslyupdated.The project foresees monitoring campaigns in selected pilot plants (both power plants and industrial boilers with different fuels and configuration) before and after the implementation of suitable BAT/BEP to evaluate the impact of intervention on the releases of PCDD/PCDF and of CO_2. Results of the first campaigns are presented in this paper. According to peculiar characteristics of boiler population in the six ESEA countries, BAT and BEP technologies on eight pilot facilities have been selected.Along with monitoring campaigns, the program envisages interventions on combustion optimization and efficiency improvement. For industrial boilers, replacement and retrofit interventions, with high replicability potentials have been selected, while for large power plants, due to high costs involved, only BEP will be implemented.

Materials and methods

Boilers selection

According to project budget, a maximum number of 12 pilot facilities (2 per country) had to be selected. Preliminary inventories of boiler population in the six country was carried out in order to identify the most representative plants, suitable to guarantee significant outcomes and high replicability for subsequent large scale interventions.The inventories were not exhaustive, due to the lack of organized structures in the countries, but gave enoughinformation to go forward with the identification of pilot boilers in each of the six countries.

Monitoring campaigns

Monitoring campaigns were contracted to internationally certified laboratories. Sampling campaigns were carried out in the selected facilities, after accurate tuning of the local conditions in order to conform to international standards. USEPA methods (EPA23A, EPA1613B and EPA 8290) and European methods (EN1948-1,2,3) were used by the laboratories for the sampling operations of PCDD/PCDF (samplings on three days of flue gases at the stacks, samplesof bottom ashesat boiler ash hopper, fly ash at dust filters hopper, boiler slags, slurry) and analysis of samples (filters, resins, solid and residues, etc), according to the Terms of

Reference signed with UNIDO. Besides PCDD/PCDF, ancillary parameters (particulate matter, Sox, NOx, mercury, chlorine content in fuels, etc) were also monitored.

PCDD/PCDF releases trends in ESEA Region

In order to include the project in the framework of the regional energy policy, the ASEAN energy outlooks for industrial and power sectors wereanalyzed, and the consequent PCDD/PCDF emissions trends were estimated,referring to UNEP Toolkit emission factors, in order to achievegeneral information on the trends of emission levels and of the ability of national energy planningpolicies to reduce the releases in compliance to the commitments of the Stockholm Convention.

Identification of emission factors for small industrial boilers

As the emission factors provided in UNEP Standardized Toolkit for the Heat and Power sectors are estimated with the limits explained in the introduction,new values, based on literature data,which takes into account the effect of advanced technologies on PCDD/PCDF releases, such as combustion optimization,were tentatively proposed to be used as reference for estimating the achievable reduction of releases from small industrial boilers, to be compared with the outcomes of sampling campaign carried out before and after implementation of selected interventions.

BAT/BEP selection

Research were carried out to identify the more suitable technologiesto produce a simultaneous reduction of PCDD/PCDF and CO_2, Additionally, for coal power plant, the interventions should also give benefits on mercury emissions. Efficiency improvement is one key factor to reduce the above said emissions. Among various available BAT/BEP, the following technologies have been selected:

for industrial boilers:

-Replacement of old boilers with new, technologically advanced ones

-Retrofit for efficiency improvement (addition of economizer, advanced control systems)

for power plants:

-Optimization of excess air

-Optimization of combustion

-Efficiency improvement by implementation of operation practices

Replicability and economic attractiveness

Special emphasis was given to the potential for replicability which is one of the aims of the project. The selected interventions have high replicability potential and are economically attractive for the boilers' owners.

Results and discussion

The outcomes from the inventories outlined the relevance of small and medium boilers in theESEAindustrial sector (66% of boilers are under 5 t/h steam and more than 80% are under 10 tons/hour steam production) as shown in Figure 1. The type of fuels burnt, in particular biomass, showed huge potentials for replacing fossil fuels, but is strongly affected by logistics. On the other hand, the use of oil products is still having an important share for industrial boilers as shown in Figure for Cambodia, which could limit the industrial growth in case of increase of oil price.Inventories have also given information on replicability potentials on the types of interventions identified for the selected pilot facilities.

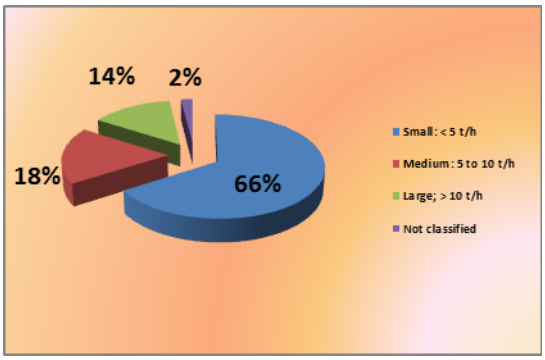

Figure 1 ESEA Region-Industrial Boilers by Type

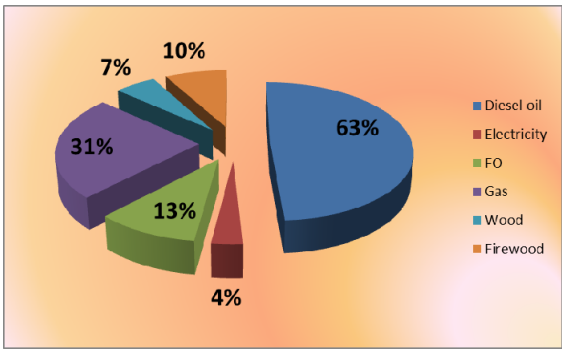

Figure 2 Cambodia-Industrial Boilers by Fuel

The need of setting up ad hoc bodies/agencies able to carry out periodic inventories of boiler population as basic for policies on reduction of emissions from boilers has also emerged.
Due to the expected growth of the economies, the study showed thatthe releases of PCDD/PCDF to air due tothe combustion of fossil fuels in the power and industrial sectors, projected to 2030, instead of being reduced, will rise by about 5 times for coal fired plants and about 2 times for oil fired plants, as shown in 오류! 참조 원본을 찾을 수 없습니다., highlighting the urgent need targeted policies at national/international levels on the region.

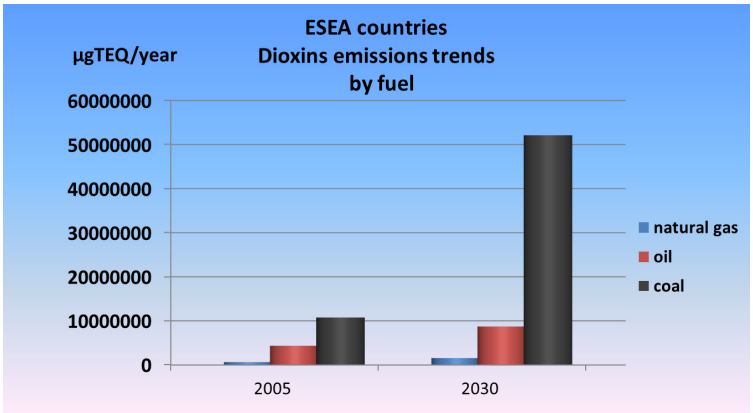

Figure 1ESEA Countries-PCDD/PCDF emission trends

In order to measure the virtuosity of a country energy policy for reducing PCDD/PCDF emissions, a specific index, called Country Emission Index (CEI), based on standardized PCDD/PCDF emission factors and fuel consumption has been introduced according to the following formula:

$$CEI = \frac{\sum EF_{fuel A} \times Energy_{fuel A} + \sum EF_{fuel B} \times Energy_{fuel B} + \cdots}{\text{Total Energy Consumptions}}$$

Where:
$EF_{fuelA,B...}$ is the PCDD/PCDF Emission Factor linked to the fuel(as in UNEP Toolkit), expressed in µgTEQ/TJ
$Energy_{fuelA,B...}$ is the energy consumption of the fuel(TJ):
Total Energy Consumptions is the Total energy consumption for power and industrial use (in TJ).

CEI takes into account the virtuosity of the Country regardless of its population and amount of consumptions, byhighlighting its technology standards referred to the intensity of PCDD/PCDF emissions per unit of energy consumed.
The proposed emission factors derived from literature andrelated to the effects of BAT/BEP implementation and toage of boilers are reportedin
Table 1;they were used to estimate the reductions of PCDD/PCDF achievable in case of implementation of BAT/BEP. The selected boilers and related interventions are illustrated in Table 2.

Table 1:Effect of BAT/BEP on PCDD/PCDF Emission Factors for Industrial Boilers

Fueltype	OldBoiler µgTEQ/TJ	Retrofittedboiler µgTEQ/TJ	BAT/BEPBoiler µgTEQ/TJ
Biomass	500	100	50
Coal	100	10	1
Fueloil	10	2.5	2.5

Table 2: Selected boilers and type of interventions

Country	Sector	Type of boiler selected	Replaced with	Type of intervention
Cambodia	Industry	Firetubes – wood logs 4 t/h	Watertubes-wood chips 4 t/h with APCD	Replacement

Indonesia	Power electric utility	Power boiler-coal 600 MW	-	BEP implementation-
	Industry	Firetubes -coal 40 t/h		Retrofit
Lao PDR	Industry	Firetubes- oil 4 t/h	Firetubes-coal 5 t/h with APCD	Replacement
Mongolia	Power electric utility	Power boiler-coal 100 MW		BEP implementation
Philippines	Power electric utility	Power Boiler-coal 300 MW		BEP implementation
Thailand	Industry	Firetubes- oil 10 t/h	-	Micro-emulsion technology test
	Industry	Watertubes-coal 16 t/h		Retrofit-efficiency improvement

Tables 3 and 4 shows the results of PCDD/PCDFs releases in the monitoring campaigns. It must be noted that very different national standards (if any) for normalization of emission data were found with respect to the international ones, therefore in order to present homogeneousconcentration values it was decided to refer as much as possible to European (0°C and 3%, 6% and 11% reference O_2) and United States standards (20°C 7% reference O_2) according to the type of fuel. Only in the case of Philippine the national standard of 10% O_2 at 0 °C was taken into consideration along with the 6%.Emission factors were mostly given as ranges to take in account the high variability of data.

The investigated coal fired power plants showed very low emission values. The relevant emission factors were calculated on the highest values for a conservative approach. As a reference, the UNEP Toolkit gives 10 µg TEQ/TJ for emissions to air and 14µg TEQ/TJ for residues.

The wood fired boiler in Cambodia, with no APCD, showsthe highest emission factor for this media (the range reported in the Toolkit for mixed biomass-clean wood fired boilers is 50-500 µg TEQ/TJto air). The coal industrial boiler and the two heavy fuel boilers generally show comparable emission factors.It must be noted that the boiler in Lao has no APCD, whereas the other two are equipped with APCDs. The UNEP Toolkit gives 2.5 µg TEQ/TJ for emissions to air foroil.

Table 3: Outcomes from PCD/PCDF campaigns in Power plants

Facility	Releases to air ng TEQ/Nm^3	Releases to fly ashes ng TEQ/kg	Releases to boiler bottom ashes/boiler slags ng TEQ/kg	Emission to air µg TEQ/TJ	Emissions to residues µg TEQ/TJ
Coal fired Boiler+ESP (Philippines)	**<0.0011-0.0434** *(10% O_2)* **<0.0011-0.0593** *(6% O_2)*	**0.646-2.7**	**0.0034-2.2**	**0.32-12.55**	**4.11-17.20** (Fly ashes) **0.01-3.51** (Bottom ashes)
Coal fired Boiler+ESP (Mongolia)	**0.0011-0.0030** *(EU 11%)* **0.0016-0.0044** *(EU 6%)* **0.0014-0.0039** *(US 7%)*	**2.3-4.8**	**2.2-2.7**	**0.7-2.0**	**10.5-22.0** (Fly ashes) **1.9-2.3** (Bottom ashes)

Table 4: Outcomes from PCDD/PCDF campaignsin Industrial boilers

Facility	Releases to air ng TEQ/Nm^3	Releases to flyashes/slurry ng TEQ/kg	Releases to boiler bottom ashes/boiler slags ng TEQ/kg	EF-Emission to air µg TEQ/TJ	EF-Emissions to residues µg TEQ/TJ
Wood firedBoiler No APCDs (Cambodia)	**0.30-0.67** *(EU 11%)* 039-0.87 *(US 7%)*	-	**7.5**	**51.5-184**	**1.41** (Wood bottom ashes)
Heavy oil Fired boiler No APCDs (Lao PDR)	**0.0001-0.0036** *(EU 11%)* **0.0002-0.0066** *(EU 3%)* **0.0002-0.0047** *(US 7%)*	-	**0.60-2.7 (slags)**	**0.07-1.48**	**0.003-0.013 (slags)**
Heavy oil fired boiler + Wet Cyclone (Thailand)	**0.0015-0.014** (EU 11%) **0.0027-0.0255** (EU 6%) **0.0019-0.0186** (US 7%)	**slurry n.d.**	**-**	**0.91-3.81**	-
Coal fired boiler+Wet cyclone+ scrubber (Thailand)	**0.006-0.009** *(EU 11%)* **0.009-0.013** *(EU 6%)* **0.0079-0.0116** *(US 7%)*	**0.021**	**0.9** (mean value)	**2.56-3.07**	**0.04** (cyclone ashes) **1.8** (bottom ashes)

It must be highlighted that difficulties in the sampling and analysis of PCDD/PCDFs in flue gases can negativelyaffect the evaluation of the results, that can be influencedby high uncertainties and variability in different samplings,especially in those cases where the content of PCDD/PCDF in flue gasis very low. Deployment of certified and skilled laboratories for sampling campaigns is therefore mandatory.
The ongoing activities are focusing on the implementation of the above mentioned typologies of interventions and on the selection of additional pilot facilities. Afterward, new monitoring campaigns will be carried out to register the impact on PCDD/PCDF releases

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