TAMPERE UNIVERSITY OF TECHNOLOGY

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EMISSION MONITORING AUTHORITY REQUIREMENTS AT POWER PLANTS IN EU

Master of Science Thesis

Examiner: professor Pentti Lautala
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ABSTRACT

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Protection of environment and human health is major concern for European Union. European Commission has established integrated pollution prevention and control directive and directives concerning large combustion plants (LCP) and waste incineration (WI) plants to prevent emissions from industrial installations. The LCP and WI directives set the lowest requirements such as emission limit values and monitoring requirements that the operators have to comply in EU. European Commission has also published best available technique (BAT) reference documents to help authorities determine the requirements in environmental permits for the installations.

This thesis is looking into the authority requirements for continuous emission monitoring systems (CEMS) that are set by the competent authorities in Spain, Estonia, France, Poland, Czech and UK. Power plants have to monitor and report air emissions with the help of CEMS. It consists of measurement equipment, analysers and sample conditioning systems as well as environmental data management solution. Directives and standards set the requirements for the CEMS, but still requirements differ between the target countries. For instance, according to the study only in UK certification (MCERTS) for the analyser is required and only in Spain plant owner is not allowed to perform the compliance reporting of the plants emissions. It is the responsibility of competent authority. Also the charging and trading emissions differ between the target countries.

The coming directive on industrial emissions will be possibly accepted in the end of 2010. It will unify and straiten the requirements. Emission limit values will lower and the emission monitoring requirements will be stricter. Due to the directive, the importance of the use of best available technique will be emphasized. BAT reference documents for large combustion plants and monitoring emissions are reviewed in 2010.

The subject of this thesis was wide and the special requirements are presented in general level. Further studies can use this thesis as a ground for more detailed research in monitoring and reporting emissions from power plants in EU. More research should be done because monitoring of local environmental legislation of Member States is ongoing process.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
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Ympäristön ja ihmisten terveyden suojeleminen ovat tärkeitä asioita Euroopan Unionille. Euroopan komissio säätelee päästöjen määrää voimalaitoksilta vesiin, ilmaan ja maaperään lainsäädännön ja standardien avulla. Direktiivi ympäristön pilaantumisen ehkäisemisen ja vähentämisen yhtenäistämiseksi (IPPC direktiivi) asettaa ehdot ympäristöluvan antamiselle muun muassa suurille polttolaitoksille ja jätteenpolttolaitoksille. IPPC direktiivi koskee yli 50 MW polttolaitoksia.

Suurten polttolaitosten päästöjä rajoitetaan direktiivillä 2001/80/EY (LCP direktiivi). LCP direktiivi koskee polttolaitoksia, joiden polttoteho on 50 MW tai enemmän. Se asettaa vähimmäisvaatimukset, joita suuret polttolaitokset joutuvat noudattamaan. Vaatimukset koskevat muun muassa päästöraja-arvoja, päästömittauksia ja raportointia. Päästöraja-arvot on määritelty LCP direktiivissä rikkidioksidille (SO_2), typpioksideille (NO_x) ja hiukkasille. Näiden päästökomponenttien lisäksi myös happipitoisuutta, vesihöyrypitoisuutta sekä savukaasun lämpötilaa ja painetta joudutaan mittaamaan jatkuva-aikaisesti.

Direktiivi 2000/76/EC (WI direktiivi) asettaa jätteenpolttolaitoksille tiukemmat vaatimukset kuin LCP direktiivi suurille polttolaitoksille. Polttotehorajaa ei ole, vaan direktiivi koskee kaikkia jätteenpolttolaitoksia. Direktiivi sisältää myös rajoituksia vesipäästöille.

Euroopan komissio on julkaissut ohjekirjoja muun muassa LCP- ja WI-laitoksille sekä parhaan mahdollisen tekniikan (BAT) käytöstä. Myös päästöjen tarkkailulle on oma BAT-ohje. Nämä BREF-asiakirjat ovat tarkoitettu lupaviranomaisten ohjeasiakirjoiksi arvioitaessa parhaan mahdollisen tekniikan käyttöä ympäristölupien myöntämisen yhteydessä.

Tämä diplomityö tutkii jatkuva-aikaisen päästövalvontajärjestelmän (CEMS) erityisiä viranomaisvaatimuksia sekä direktiivien ja standardien paikallisia tulkintoja seuraavissa maissa: Espanja, Viro, Tsekki, Puola, Iso-Britannia ja Ranska. CEMS koostuu mittalaitteista, näytteenottojärjestelmästä, analysaattorista sekä valvonta- ja raportointisovelluksesta. Analysaattorista saatu raakadata muutetaan vertailukelpoisiksi päästökeskiarvoiksi valvonta- ja raportointisovelluksessa tapahtuvassa päästölaskennassa.

Direktiivit ja standardit asettavat vaatimukset CEMS:lle. Tutkimuksen ja Metson aikaisemman kokemuksen perusteella vaatimusten tulkinnat eroavat niin EU:n jäsenmaiden kuin myös tämän diplomityön kohteena olevien maiden kesken. Tutkimuksen mukaan paikallisessa päästökaupassa ja -verotuksessa on eroja. Iso-Britanniassa voimalaitokset käyvät kauppaa SO_2:lla, NO_x:lla ja hiukkasilla, kun taas Viro verottaa voimalaitoksia samoista päästökomponenteista.

Metson Automaatioliiketoiminta oli muun muassa kiinnostunut siitä, rajoitetaanko jossain kohdemaassa CEMS:n integroimista automaatiojärjestelmään. Jos CEMS:iä ei voida integroida automaatiojärjestelmään, raportointi- ja valvontasovellus on täysin itsenäinen päästölaskenta yksikkö. Tällaista eristettyä mallia ei kuitenkaan mistään kohdemaasta löytynyt. CEMS:n ja automaatiojärjestelmän integroimisesta on paljon hyötyä. Automaatiojärjestelmä voi esimerkiksi päästötietojen avulla ajaa laitosta optimaalisella tavalla.

Tutkimuksessa parhaiten tietoa oli saatavilla Iso-Britanniasta. Ainoastaan UK:n alueella vaaditaan kahdennettu CEMS, mikä tarkoittaa käytännössä sitä, että jokaista päästökomponenttia kohden vaaditaan kahdennettu mittausjärjestelmä. Iso-Britannia on myös ainoa alue, missä vaaditaan MCERTS:n (Monitoring Certification Scheme) sertifikaatti analysaattorille. MCERTS on Iso-Britannian ympäristöviraston nimittämä sertifiointi toimielin. Missään muussa kohdemaassa ei tutkimuksen mukaan vaadita MCERTS:n tai vastaavanlaisen sertifiointiyrityksen sertifikaattia analysaattorille. Tutkimuksen mukaan valvonta- ja raportointisovelluksille sertifiointivaatimusta ei vielä Iso-Britanniassa ole, mutta se on suunnitteilla ja vaatimus saattaa tulla voimaan 1-2 vuoden kuluttua.

Espanjan osalta tuli esille vaatimus, jota ei missään muualla tullut vastaan. Tutkimuksen mukaan Espanjassa viranomaisraportointi tapahtuu pelkästään viranomaisten toimesta. He ottavat analysaattorista raa'an päästödatan ja tekevät itse vaadittavat päästölaskelmat.

Vaatimukset päästöjen valvonnalle ja raportoinnille asettaa tulevaisuudessa industrial emission directive (IED). IED kokoaa seitsemän olemassa olevaa direktiiviä mukaan lukien IPPC- , LCP- ja WI-direktiivit. IED hyväksytään mahdollisesti vuoden 2010 loppuun mennessä. IED tulee kiristämään nykyisiä vaatimuksia. Päästöraja-arvot alenevat ja valvontavaatimukset tiukkenevat, mikä näkyy muun muassa siinä, että LCP-laitokset joutuvat mittaamaan CO:a jatkuva-aikaisesti. CO-pitoisuudet pitää myös raportoida vironomaisille.

IED:n myötä parhaan mahdollisen tekniikan käyttö korostuu. BAT BREF-asiakirjojen käyttöä tullaan valvomaan aiempaa tarkemmin. BREF-asakirjat LCP-laitoksille ja valvonnalle ovat parhaillaan päivityksen alla. Myös niissä vaatimukset tiukkenevat. Uusien BREF-asiakirjojen päästötasojen odotetaan olevan alempana kuin IED:n päästöraja-arvot. Tämä saattaa koitua ongelmaksi, sillä IED:n mukaan BREF-asiakirjoja tulee pitää ensisijaisena lähestymistapana viranomaisten myöntämissä ympäristöluvissa. Tällä hetkellä ei ole tietoa kumpaa, IED:tä vai BAT BREF-asiakirjoja sovelletaan päätettäessä päästöraja-arvoja laitokselle.

Tämän diplomityön aihe oli laaja ja kohdemaita, joista tietoa kerättiin, oli paljon. Koska työn aikataulu oli tiukka, yksityiskohtaisempien tulosten hankkiminen ja etsiminen oli mahdotonta. Työn tulokset jäivät yleiselle tasolle, mutta tämän työn tuloksia on hyvä käyttää vahvana pohjana jatkotutkimuksille.

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Tampere, May 19, 2010

Matti Nikkola

CONTETS

ABBREVIATIONS

c	Concentration.
E	Extinction.
k	Extinction factor.
l	Measurement gap.
C	Total emission limit value for the pollutants and specific industrial sector in specific oxygen content determined according to which type of fuel is used.
C_{proc}	Emission limit value set for pollutants that are generated in combustion of other fuels (waste excluded). These emission limit values vary according to which type of fuel is used and what is the rated thermal input of the installation.
C_{waste}	Emission limit value set for incineration of waste for relevant pollutants and carbon monoxide.
V_{proc}	Flue gas volume caused by other fuels (waste excluded).
V_{waste}	Flue gas volume caused by the incinerated waste.

As	Arsenic.
Cd	Cadmium.
Cl	Chlorine.
Co	Cobalt.
Cr	Chromium.
Cu	Copper.
F	Fluorine.
Hg	Mercury.
Mn	Manganese.
N	Nitrogen.
Ni	Nickel.
P	Phosphorus.
Pb	Lead.
S	Sulphur.
Sb	Antimony.
Sn	Tin.
Tl	Thallium.
V	Vanadium.
Zn	Zinc.

CO	Carbon monoxide.
CO_2	Carbon dioxide.
H_2O	Hydrogen monoxide.
HCl	Hydrogen chloride.
HF	Hydrogen fluoride.
N_2	Nitrogen.
N_2O	Nitrous oxide.
NO	Nitrogen monoxide.
NO_2	Nitrogen dioxide.
NO_x	Nitrogen oxides.
$((NH_2)_2CO)$	Urea.
NH_3	Ammonia.
O_2	Oxygen.
SO_2	Sulphur dioxide.
SO_3	Sulphur trioxide.
TOC	Total organic carbon.

AEL	Associated Emission Level.
AMS	Automated Measuring System.
AST	Annual Surveillance Test.
BAT	Best Available Technique.
BOD	Biochemical Oxygen Demand.
BREF	Best Available Technique Reference .
BTEX	Benzene, Toluene, Ethyl benzene and Xylene.
CEMS	Continuous Emission Monitoring System.
CEN	European Committee of Standardization.
COD	Chemical Oxygen Demand.
CUSUM	Cumulative Sum chart.
DCS	Digital Control System, Distributed Control System.
EA	Environment Agency.
ELV	Emission Limit Value.
EMRS	Emission Monitoring and Reporting Solution.
EN	European Standard.
EOX	Extractable Organic Halogens.
E-PRTR	European Pollutant Release and Transfer Register.
EPER	European Pollutant Emission Register.
EST	Emission Trading Scheme.
EU	European Union.
FTIR	Fourier Transform Infrared Spectroscopy.
GHG	Greenhouse Gas.
IEC	International Electrotechnical Commission.

IED	Industrial Emission Directive.
IPPC	Integrated Pollution Prevention and Control.
ISO	International Organization for Standardization.
LCP	Large combustion plant.
MCERTS	Monitoring Certification Scheme.
MID	Method Implementation Document.
NDIR	Non-Dispersive Infra Red.
NDUV	Non Dispersive Ultraviolet.
NERP	National Emission Reduction Plan.
NIEA	Northern Ireland Environment Agency.
QAL1	Quality Assurance Level 1.
QAL2	Quality Assurance Level 2.
QAL3	Quality Assurance Level 3.
SCR	Selective Catalytic Reduction.
SEPA	Scottish Environment Protection Agency.
SNCR	Selective non-Catalytic Reduction.
SQP	Software Quality Plan.
SRM	Standard Reference Method.
Swedish EPA	Swedish Environmental Protection Agency.
TDS	Total Dissolved Solids.
TGN	Technical Guidance Note.
TSS	Total Suspended Solids.
TÜV	Technical Inspection Association (Technischer Überwachungs-Verein).
UK	United Kingdom.
UV	Ultra Violet Radiation.
WI	Waste incineration.

1. INTRODUCTION

This Master of Science Thesis was done for Metso Automation and Metso Power. Both of them are part of larger Energy and Environmental Technology segment of Metso Corporation. This thesis will look into matters which are concerning one of the product of Metso Automation, monitoring and reporting solution and continuous emission monitoring systems which are supplied by Metso Power alongside with the boiler plants.

For the protection of the environment and human health, European Commission has established Integrated Pollution Prevention and Control Directive and specifically for power plants, Large Combustion Plant and Waste Incineration Directives [1; 2; 3]. Directives define the lowest threshold that the power plants have to comply in restricting pollution.

Member States can tighten up the requirements stated in the directives and set other special requirements. Different interpretations of the EU requirements are causing conflicts. The primary goal of this thesis was to find out how the Member States has implemented the directives as well as find out possible special requirements for monitoring, controlling and preventing emissions at power plants. Also clarifying prospects for the developing requirements was one goal of the thesis. The target countries for this thesis were Estonia, UK, France, Poland, Czech and Spain. Portugal and Slovakia were dropped out from the list, because the information from those countries was not available.

Lot of the information in this thesis is based on the questionnaire. The questionnaire was developed in accordance with the experience of Metso and in such way that the answers would clarify the known issues concerning the interpretations. The questionnaire can be seen in appendix 1. Another information source of this thesis was the internet, specifically the web pages of the environmental agencies of the target countries and the web pages of the European Commission. Also the consultations with employees of Metso, clarified the environmental field through previous and ongoing projects.

According to the study the requirements differ between the target countries and are expected to differ in the future as well. New directive on industrial emissions will unify and straiten the present requirements and the use of best available technique in granting environmental permits for power plants, will be emphasized.

2. EU'S MEANS FOR POWER PLANTS TO PREVENT POLLUTION

By controlling and monitoring pollution in mobile sources and industrial- and energy businesses, we ensure for the future generations favorable living conditions. It is on our responsibility. Air quality has been great topic since the end of 1970s in European politics because it's one of the biggest concerns among European habitants [9]. European Union has developed many means to prevent pollutions. The focus in this thesis is on the means developed for power plants. In the figure 1 there is a pyramid which illustrates the whole implementation process of controlling and preventing emissions from power plants. In the first stage, directive concerning integrated pollution prevention and control (IPPC) contains widely the concept of preventing pollution in European countries. IPPC directive sets the large combustion plant (LCP) -and waste incineration (WI) directives. They concern controlling emissions in large combustion plants and waste incineration plants. Standards are set for plant owners, plant suppliers, certificated laboratories and measurement equipment (AMS) manufacturers to guide them comply with the EU directives. Although EU has set the directives, EU member states can interpret them on their own way. They might add some requirements or tighten those that are stated in LCP- or WI directive. In the pyramid four lowest stages builds the foundation for Emission monitoring and reporting as well as for emission measurement.

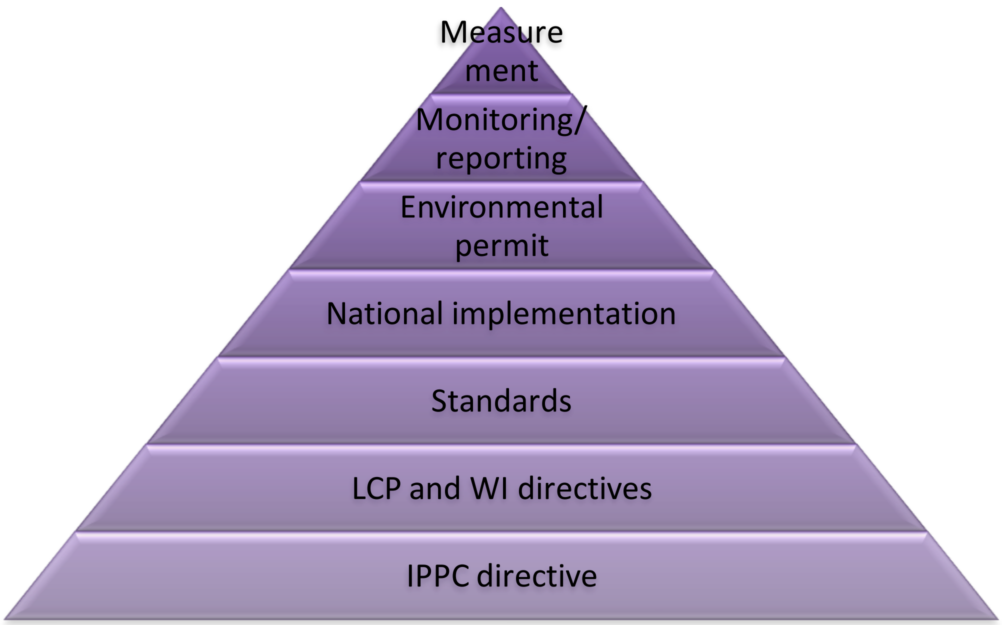

Figure 1. *European Union's process to control emissions from power plants.*

2.1. Causes to prevent pollution

The quality of air, water and soil is very important to humans well being in earth. Air quality has worsened since the industrial revolution mainly because of the great increase of traffic, industrial and energy production and fossil fuel incineration. Cities are enormous and still growing. In the big cities the impaired quality of air has increased the amount of people that suffer from lung diseases. Today there is twice as much asthmatics than 20 years ago. Fine particulate matter and ozone are considered as a significant reason of health issues. Fine particulate matter covers dust, soot, smoke and pollen. Although the fact that emissions of several pollutants have been decreased since 1990, concentration of particulate matter and ozone hasn't dropped. Many people living in cities have been exposed to a bigger concentration of particulate matter than the European Union's target value. [16]

Climate warming is a cause of increase of greenhouse gases. Aqueous steam of atmosphere and gases, such as carbon dioxide block the heat radiation leaving from earth. Blocked heat warms-up the atmosphere. Among other things, use of fossil fuels increases the amount of the greenhouse gases in atmosphere and thereby accelerates the greenhouse effect. [29]

Sulphur dioxide (SO_2) and nitrogen oxide (NO_x) are acidifying gases. Power production is one of the significant producers of SO_2 and NO_x emissions. After the emissions change to sulphate-, nitrate- and ammonium form, they descend to the ground. Our ecosystems has limit estimate for the fall-out after which in the long run the pollution will cause detrimental effects. The sulphur and the nitrogen of the emissions originate from the fuels that are incinerated. [24.] Significant source of nitrogen is also the combustion air. The sulphur and the nitrogen oxidize in the combustion process. Due to the acidification, forests might get damaged and in the water system species of plants can change and some species might even disappear for good. [43.]

Particulate emissions are almost purely ash from the fuels. It drifts to the air along with the flue gas. Unburned fuel might contain detrimental heavy metals, carcinogenic and other mutagenic compound. Heavy metals are emitted through two channels: Into the air through flue gas and into the water through fly ash. Heavy metals have characteristic that is hard to control. Many of the heavy metals associates with smallest components of fly ash and therefore it is hard for flue gas purificator to stop them getting into the atmosphere. [26.] For instance, mercury (Hg) is such metal element that can get through the flue gas purificators. That is not desirable because mercury is very harmful for the nature and for the humans. Mercury can be purified from the flue gases, but the reduction rate depends on the composition of the mercury. [13.]

2.2. Integrated Pollution Prevention and Control (IPPC) directive

Significant proportion of emissions is produced by industry. Due to the growing industry, emissions increases and thereby needs attention. Operators in different industry sectors have to cut down emissions to air and water due to the EU regulations. Investments for appropriate equipment to comply the regulations need lot of money. Today environmental matters are part of the performance for the organizations participating in the energy production

The image which the operators show to the customers is very important in the business. Customers see operators that care about the pollution prevention and the greener future of the earth in more positive light than those that does not take environment's wellbeing into account in their operations. Nowadays operators find controlling and cutting down emissions also as business opportunity than as coercive and money wasting measures. EU legislative regulations such as IPPC directive set the ground for the controlling and preventing pollution [1].

EU set in 1996 IPPC (Integrated pollution prevention and control) directive 1996/61/EC on preventing and cutting down pollutions to air, water as well as to ground from different sectors of industry. In 2008 IPPC directive got revised (2008/1/EC). In the energy industry, combustion plants which output are higher than 50 MW falls under the directive. The directive contains rules on permitting and controlling industrial installation. IPPC directive concerns the largest industrial plants, such as energy production plants, gas- and oil refineries, metal production and refining, mineral industry, chemical industry, paper- and board industry as well as waste management plants. Since 30 October 1999 new installations and existing plants which had been facing significant changes have been required to meet the IPPC requirements. Deadline for the other installations was in 30 October 2007. [11]

It is stated in the directive that every industrial plant that pollutes the environment significantly has to comply with the regulations of the local authority to be competent. Plant operators have to apply environmental permit from the competent authority of the member state in question. Operators falling under the IPPC directive have to comply with the conditions set in permit. [1]

2.2.1. Main principles of IPPC directive

First of the four principles is integrated approach. It looks the whole environmental performance in a wide perspective. Emissions to air, water and ground, energy efficiency, noise, waste generation, use of raw materials, prevention of accidents and restoration of the plant upon closure [11]. Integrated approach integrates the environmental way of thinking to every part of the plants performance.

Use of best available technique (BAT) is the second principle. Emission limit values set in environmental permits have to be based on best available technique. European IPPC Bureau organizes the change of information between industry, authorities, experts from EU countries and environmental organizations. [11.] It helps the authorities to determining BAT while licensing permits. The results of the change of information are published in BAT reference (BREF) documents. [13.] They are available to all people in the European IPPC Bureau web-site.

Flexibility is one of the principles. Authorities have some room in determining the permit conditions depending on the installation. They can take into account the technical characteristic of the installation, its geographical location and local environment condition. [11.] Installations differ from each other in many ways, such as which fuels are used and size of the plant. The permit conditions might be considered as tighter in locations where the nature is more vulnerable such as near settlement, near conservation area or near groundwater area.

The fourth principle states that public is allowed to participate in the decision making process. Public has access to permit applications, permits, results of the monitoring releases and The European Pollutant Emission Register (EPER). EPER is a public register that is meant to provide environmental information. It holds emission reports reported by EU Member States. EPER has been European Pollutant Release and Transfer Register (E-PRTR) since 2007. [11]

2.2.2. Applying environmental permit

Permit applications are delivered to competent authority of the member state. Applications must contain for example following information:

- General description of operations;
- Plant location and of the conditions of the environment at the site;
- Possible neighbors and concerned bodies;
- Products, processes, production, equipment and plant structures;
- Emissions, noise and trembling;
- Information on the waste generated and procedures to reduce waste generation;
- Estimated effects on the environment;
- Fuels, chemicals, water usage and storage;
- Water acquiring and sewerage;
- Risks, accidents and fault situation;
- Emission sources;
- Operations on the reduction and purification of the emissions;
- Information on the quality of the environment;
- Monitoring;
- Usage of the energy (energy efficiency);
- Best available technique (BAT). [4; 42]

2.3. Large Combustion Plant (LCP) directive

The aim of the directive is to restrict emissions to air generated by large combustion plants. Installations which rated thermal inputs are 50 MW or higher fall under the LCP directive excluding waste derived fuels and waste incineration [3]. The new version of the directive 2001/80/EC tightened the Community requirements from previous version 88/609/EEC (amended by 94/66/EC) from new installations because technical development had enabled the change to use more competent equipments and techniques to limit stack emissions.

2.3.1. Emission limit values

LCP directive sets air emission limit values for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and dust in the flue gas. Those pollutants cause acidification and eutrophication of the nature as they reach the ground. Such effects as well as ground-level ozone are major concerns. By establishing LCP directive European Commission wanted to take action against those undesirable effects on nature. Emission limit values for SO_2, NO_x and dust vary in accordance with which types of fuels are used. Also the rated thermal input (MW) of the plant is affecting on the emission limit values. Emission limit values are presented in dry flue gas as mg/Nm^3. NO_x emissions are also taken into account for gas turbines. In order that the measured emission values could be compared with emission limit values, the oxygen concentration has to be same as well as if the measurements are taken from wet flue gases the results have to be changed as they were measured from dry flue gases. For liquid and gaseous fuels the oxygen content by volume is 3%, for solid fuels 6% and for gas turbines it is 15%. The limit values are different for new and existing plants. Plants licensed before 27 November 2002 or plants that are put into operation after 27 November 2003 are stated as new plants. Existing plants are defined as those built before 1988 and those built from 1988 up to 2003. There are also other derogations that effects on the emission limit values. For instance, emission limit value for sulphur dioxide depends on the plant's operation hours per year. Derogations are also possible for plants which location is far away from settlement. [3]

2.3.2. Total annual emission

Since year 2004 the member states have had to report annually to the competent authority the total annual emissions of sulphur dioxide, nitrogen oxides and dust. The requirement concern all the combustion plants that has rated thermal input 50 MW or over. Report has to also include information on the plants total annual input energy. It shall be based on the net caloric value. Total annual emissions are classified based on the fuel types which are biomass, other solid fuels, liquid fuels, natural gas and other gases. [3]

2.3.3. Monitoring requirements

LCP directive requires continuous measurements of sulphur dioxide, nitrogen oxides and dust from installations which rated thermal input is 100 MW or over. Continuous measurements are not required for all installations even if the input is over 100 MW. The directive states in which situations installation does not have to measure the pollutants continuously. If the pollutants are not measured continuously periodic measurements at least in six months interval are required. [3]

Operators have to also measure continuously process parameters such as oxygen concentration, water vapor concentration as well as pressure and temperature of the flue gas. If the sample gas is dried before it is analyzed there is no need to measure the water vapor concentration continuously. [3]

The measurement methods have to be based on the CEN (European Committee of Standardization) standards. If CEN standards are not available ISO standards, international or national standards should be used. In order that the measurements would be representative and reliable the methods used for sampling and for sample gas analysis as well as the methods used for reference measurements to calibrate the continuous emission monitoring system (CEMS) have to be based also on the CEN standards. Operation of CEMS has to be checked by parallel measurement at least once in year. Parallel measurements are done with reference methods. [3]

According to the LCP directive the value of 95 % confidence interval of single measurement cannot exceed following percentages of the pollutants’ emission limit values. The 95 % confidence interval means that a single measurement value remains within the allowed maximum uncertainty limits with a probability of 95 %. Before the average values are compared to the emission limit values the confidential interval is subtracted. [3.]

Table 1. *Exceedance limits.*

Suphur dioxide	20%
Nitrogen oxide	20%
Dust	30%

The uncertainty of the emission measurements consist of systematic and stochastic errors. Systematic error remains constant in standard conditions and it cannot be eliminated by increasing measurements. For example, the systematic error of the flue gas volume measurement device can be determined by calibration. It can be fixed with correction factor. Stochastic errors are considered as unforeseeable changes in measurements. For instance, reading and registry errors are stochastic errors in emission measurements. Stochastic errors cannot be fixed by correction factors but it can be minimized by adding more parallel measurements. Total uncertainty of the emission measurement result consists of measurement devices and process condition and measurement event. [19]

LCP directive has set high availability criteria for CEMS. If three hours or more are discarded because of malfunction or maintenance of measurement system daily value is discarded. If more than 10 days are discarded in a one year competent authority has a responsibility to make sure that the operator does improvements to the emission monitoring system in order to gain better quality of the continuous measurements. [3]

2.4. Waste incineration directive

Incineration of waste can cause undesirable effects on soil, air, groundwater and surface water as well as on human health [5]. The directive 2000/76/EC was established to control and prevent the pollution from incineration and co-incineration plants concerning European Union member states. WI directive replaced two former directives: directive on incineration of hazardous waste (94/67/EC) and directive on household waste (89/369/EEC and 89/429/EEC). The directive consists of technical requirements, applications of operational conditions and emission limit values for specific pollutants into air and water. According to the WI directive operation of waste incineration plants is based on the thermal treatment of waste and sometimes the heat, generated in combustion is recovered. Co-incineration plant covers cement or lime kilns, steel plants and power plants. The main objectives of those plants are energy generation and production of material products. In co-incineration plants the waste is used as a fuel or the waste is just meant to be disposed. [8.]

2.4.1. Emission limit values

WI directive sets emission limit values for incineration and co-incineration plants. Emission limit values are set for pollutants into air: sulphur dioxide, nitrogen oxides and dust. In addition to the ELVs for the main three pollutants the directive sets emission limit values also for air pollutants carbon monoxide (CO), hydrogen chloride (HCl), total organic carbon (TOC), hydrogen fluoride (HF), heavy metals and dioxins and furans. WI directive sets also emission limit values for heavy metals and dioxins and furans in waste water from flue gas purification devices. Emission limit values vary according to the rated thermal input of the installation as well as according to the type of the fuel used. Fuels are classified as solid fuels, liquid fuels and biomass. [2]

Emission limit values for co-incineration of waste are determined by calculations and in relation to the flue gas volume. They are calculated with the formula underneath and the definition of the parameters in the formula can be seen from the table 2. All the emission limit values are presented in mg/Nm^3. [2]

$$C = \frac{V_{waste} \times C_{waste} + V_{proc} \times C_{proc}}{V_{waste} + V_{proc}} \quad (1)$$

Table 2. *Definition of the parameters in the above formula.*

V_{waste}	Flue gas volume caused by the incinerated waste
V_{proc}	Flue gas volume caused by other fuels (waste excluded).
C_{waste}	Emission limit value set for incineration of waste for relevant pollutants and carbon monoxide. Emission limit values can be seen in the annex V of the directive.
C_{proc}	Emission limit value set for pollutants that are generated in combustion of other fuels (waste excluded). These emission limit values vary according to which type of fuel is used and what is the rated thermal input of the installation. Annex II of the directive shows these emission limit values.
C	Total emission limit value for the pollutants and specific industrial sector in specific oxygen content determined according to which type of fuel is used.

Member States and local competent authorities can tighten the emission limit values that are stated in the WI directive. They can also set limit values for other pollutants than those stated in the directive.

In accordance to the WI directive there are provisions which operators have to meet to comply with the emission limit values. Limit values are set as half hourly and daily averages. The provisions vary according to which emission is monitored and whether the concern is on the half hourly or daily average value. [2]

2.4.2. Monitoring requirements

The requirements for emission measurement are tighter for incineration plants and co-incineration plants (WI directive) than for large combustion plants (LCP directive). Continuous measurements are required from all the installations despite the rated thermal input for sulphur dioxide, nitrogen oxides, dust, carbon dioxide, hydrogen fluoride, hydrogen chloride and total organic carbon. Also the process parameters oxygen concentration, water vapor concentration, flue gas pressure and flue gas temperature as well as the temperature near the inner wall of the combustion chamber have to be measured continuously. Heavy metals and dioxins and furans have to be measured periodically at least twice in a year. During the first 12 months of operation heavy metals and dioxins and furans shall be measured in periodic intervals of three months. The WI directive states that it is possible for competent authority to allow derogations in certain situation which are stated in the directive such as the continuous measurement of the water vapor content is not required if the sample gas is dried before analyzing the sample. [2]

Waste incineration plants and co-incineration plants report the air emissions as half hourly and daily averages. Like the LCP directive, WI directive states as well that before the average values are compared to the emission limit values the 95 % confidential interval is subtracted. The allowed maximum confidence intervals can be seen in the table 3. Measurement values during shut-downs and start-ups are excluded if waste is not incinerated. The daily averages are defined from the validated half hourly averages. [2]

Table 3. *The value of 95 % confidence interval of single measurement cannot exceed following percentages of the pollutants' emission limit values.*

Carbon dioxide	10%
Sulphur dioxide	20%
Nitrogen dioxide	20%
Dust	30%
Total organic carbon	30%
Hydrogen chloride	40%
Hydrogen fluoride	40%

2.5. Best Available Technique

European Commission established the European IPPC bureau. The main goal of the IPPC bureau is to assist the implementation of the IPPC directive and organize the exchange of information between experts from the EU Member States, industry and environmental organizations [15]. Best available technique reference documents (BREFs) are the outcome of the information exchange process [13]. The bureau has published many BREF documents for different industrial sector. There is BREF document for large combustion plants as well as for waste incineration plants. Also BREF document for monitoring is available. Current LCP and WI BREFs are from 2006 and the monitoring BREF is from 2003. Monitoring and WI BREF documents are under review which has started in 2010. [6.] During the review the BREFs are updated to cover the newest and best available techniques available today. Competent authorities are using these guidance documents in a situation where they are determining the content of the environmental permits (IPPC permits) for specific installation [13].

BREF document for large combustion plant concerns installation which rated thermal input is 50 MW or over. The document is used for industrial installations which use fuels such as peat, coal, lignite, biomass, liquid and gaseous fuels. In addition to the combustion process the document covers also fuel handling, flue gas treatment, handling of combustion residues and raw water treatment. The document covers information on the common techniques for energy generation and techniques which by using the operators can reduce emissions from large combustion plants. Techniques for efficient use of energy is also went through in the LCP BREF document. Energy efficiency is nowadays seen as an indicator of the industrial installations' effects on the environment. High efficiency in energy use is economically worthwhile and it indicates of the use of the environmentally right techniques in the processes. The techniques for reducing the emissions are presented separately for all the fuel types which can be seen in the figure 2. [13]

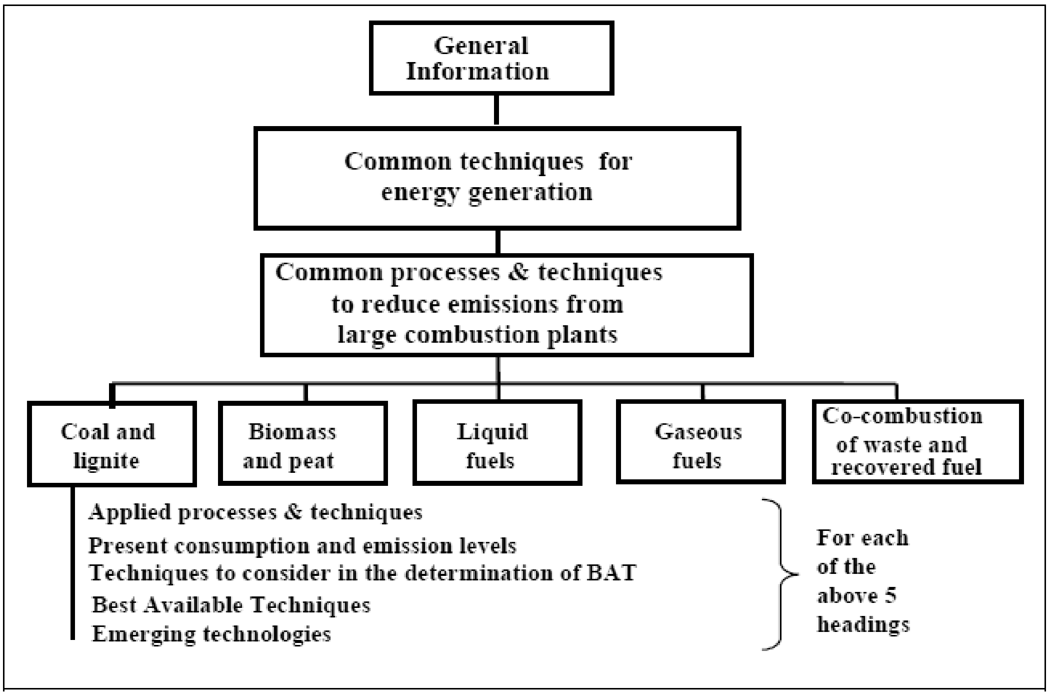

Figure 2. *Content of the BREF for large combustion plants. [13]*

Same kind of BREF document is published as well for waste incineration plants. The document covers installations that are specialized purely in incineration of waste. Other processes that thermally treat waste are not covered, for instance cement kilns and co-incineration processes (large combustion plants). In addition to the best available techniques for incineration processes general information on incineration of waste and on major environmental issues of incineration plants such as emissions to air and water, use and production of energy and noise are also presented in the waste incineration BREF. Other information on the best available technique e.g. achievable consumption and emission levels and idea of the costs are stated also. [12]

Monitoring BAT covers all the three LCP, WI and pulp and paper BATs. Monitoring BREF is a guide for the authorities that grants the IPPC permits and for the process operators for monitoring the emissions from installations operating in energy production and pulp and paper industry sectors. The process of the producing the monitoring data consist of many phases which have to be carried out as stated in standards or in method-specific guides The monitoring BREF states the phases which are presented in the figure 3 underneath. [14]

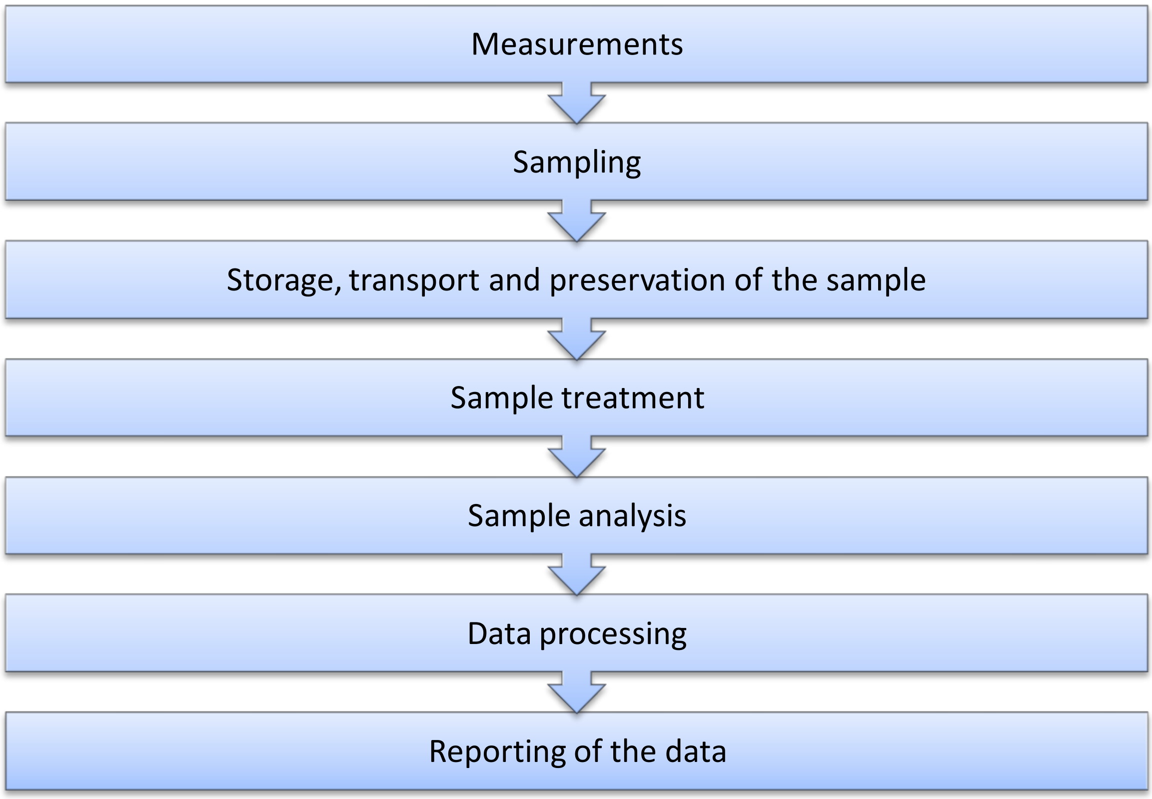

Figure 3. *The process of emission monitoring according to monitoring BREF document. [14]*

3. MEASUREMENT TECHNIQUES

From the performance of the measurement equipment is required a lot because of the strict requirements of the European Commission. Also the emission limit values are becoming lower which is in relation to the European Commission's requirements. Controlling and monitoring the quality of the performance of the measurement equipment is important part of the emissions monitoring process in EU.

There are many different measurement techniques which can be used for the measurement of the flue gas emissions from the power plant. This chapter focuses on couple of commonly used techniques which are used to measure sulphur dioxide, nitrogen oxides and dust which according to LCP directive are required to be measured continuously.

Continuous Emission Monitoring Systems are divided into two main categories that are following: sample taking measuring system and in-situ-technique. Sample taking measuring systems are based on the processing of the sample. Measuring probe takes the sample after which the heated sampling line transfers the sample to the cooler and finally to the gas analyzer. [19.] In-situ-technique is quite different than the sample taking technique. It doesn't have any detached sample processing operation. It analyzes the sample in the measuring device assembled in the stack [22].

3.1. Sulphur dioxide

SO_2 (sulphur dioxide) forms when the sulphur of the fuel reacts with oxygen during the combustion process. Almost all of the sulphur will oxidize to SO_2. 1-2% of the sulphur will oxidize to SO_3 (sulphur trioxide) but the concentration of SO_3 is very difficult to verify by measuring. SO_3 reacts with aqueous steam of the flue gas and forms little drops of sulphuric acid, which produces corrosion. The temperature of the flue gas has to be high enough because of the acid condensation point. Cold areas in the stack should be avoided, because then the acid drops will condensate and produce corrosion on the walls. [23]

It is important to take into account in sampling that the sulphur dioxide is very water dissoluble. Also the sampling line, valves and connectors have to be heated so that the corrosion can be avoided. [23]

SO_2 concentration can be measured with many different analysis techniques: FTIR, NDIR and UV-fluorescence techniques. In FTIR technique concentrations are measured directly from the wet gases without cooling the samples. Technique is suitable for minor concentration. [23.] FTIR is based on the absorption of the infrared light in different wavelengths. Infrared light is led through the sample gas but first the modulator cuts the infrared light into different wavelengths. Detector in the other end detects the infrared light that has passed through the sample gas. The absorption values are changed into concentrations with Fourier transformation mathematics. [17.]

NDIR (Non Dispersive Infrared) technique is based also on the absorption of the infrared light. It differs little bit of the FTIR technique: After the infrared light has passed the sample gas optical filter will determine the wavelength which is absorbed by the SO_2 particles and passes it through. The wavelength area of the NDIR technique is much narrower than in the FTIR technique. Narrow wavelength area prevents one device to measure many gas components at the same time. [17]

In UV-fluorescence technique the measurement is done with dilution probes and the temperature of the sample gas is kept above condensation point. Analysis is done with sensitive UV-fluorescence technique. Figure 4 shows the structure of the technique. SO_2 molecule is set to certain wavelength with the help of UV-lamp during the analysis. When the molecule returns to its normal energy state, it emits light in other wavelength which is measured with photomultiplier tube. [23]

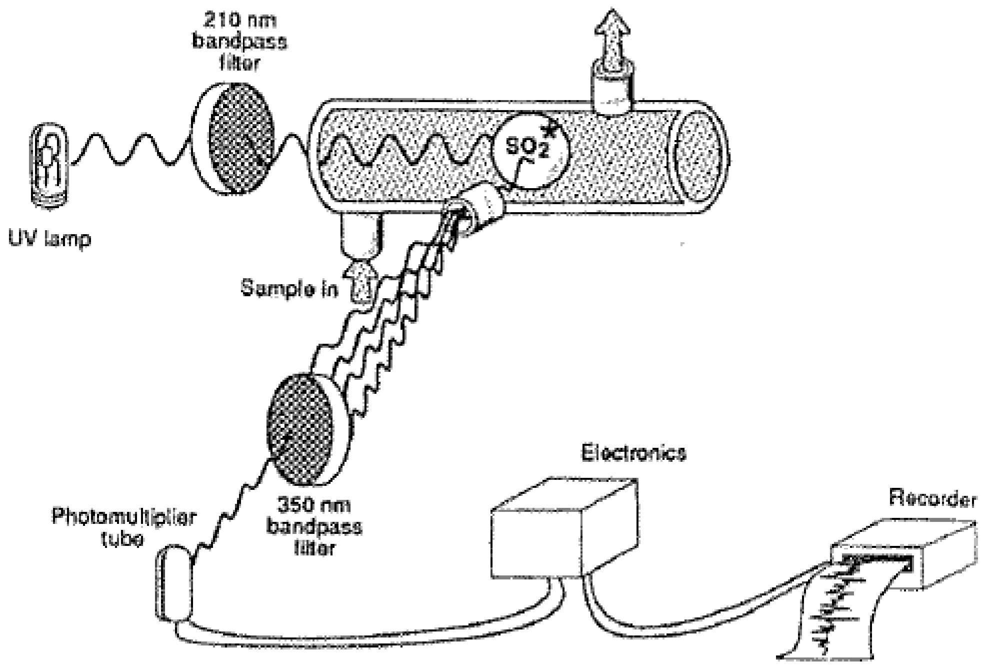

Figure 4. *Principle of the UV-fluorescence method. [21]*

3.2. Nitrogen oxides

Only a little part of the NO_x is NO_2. 95% of the NO_x is NO. Techniques that the analyzers use are based on the measurement of NO. NO_2 is converted to NO in detached converter. For the measurement of the NO there are analyzers that operate in infrared and analyzers that operate in ultraviolet. NDIR and FTIR analyzers operate in infrared and NDUV and UV-fluorescence analyzers operate in ultraviolet. The measurement principles of these techniques are defined in the chapter 2.5.1. [23]

Chemiluminescence technique is more commonly used method in measuring nitrogen oxides. It is based on the reaction between ozone and NO. Nitrogen monoxide contained by the sample gas reacts with the required amount of ozone produced by the analyzer. This reaction emits scintillation of light. It is measured with a scintillation indicator. Converter transforms NO_2 to NO. NO_2 is measured in turns with NO. Total amount is presented in NO_x and the other value that is presented is NO. Difference between the measurement signals is the amount of NO_2. The difference is very difficult to identify because the concentration of NO_2 is so low, only a few ppm (parts per million). Ppm is defined as the volume of gaseous pollutant per 10^6. If the NO_2 measurement is essential considering the NO_x emissions, it is important to minimize the sample loss in the sample cooler. Alternatively it is possible to use another drying method, such as permeation drier or completely another in-situ technique. [23.] Measurement devices which operation is based on the Chemiluminescence technique is more expensive than the FTIR, NDIR and UV-fluorescence devices [17].

3.3. Dust

Operation of dust measuring devices is typically based on optics. Measurement device has a light source that sends light across the stack and the light damps because of the absorption and scattering. The ratio of the intensity between sent and received light is called transmission. Extinction (optic density) can be calculated by using the law of Labert- Beer. Equation between dust concentration and extinction is

$$c = 2{,}3\frac{E}{l \cdot k}, \tag{2}$$

where c = dust concentration, E = extinction, l = measurement gap and k = extinction factor. Figure 5 shows the principle of the operation of a dust measurement device which is based on the scattering of the light. [23]

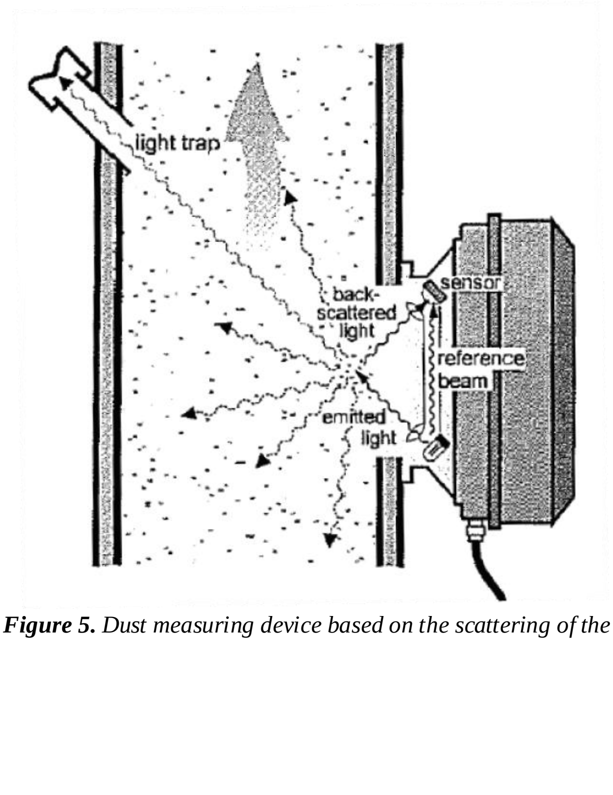

Figure 5. *Dust measuring device based on the scattering of the light. [37]*

Optical dust measurement devices measure the concentration through or partly through of the stack. Sender/receiver is assembled to the wall of the stack and the optics is placed on the other side of the wall. Optics turns the light beam back to the receiver and by doing so it increases the density of the measurement of minor concentrations. The newest dust measurement devices have measurement probes assembled into the stack. Operation of those devices is based on the scattering of the laser light in the probe. The advantages of this method are: it is easy to assemble and the equipment is not subject to the change of the alignment. [23.] The alignment does not change because the device consists of only one measurement probe. Other devices that has sender on the other side and receiver on the other side, are subject to change of alignment because the sender or receiver can move and change the alignment. Figure 6 shows the principles of the measurement device which performance is based on the scattering of laser light.

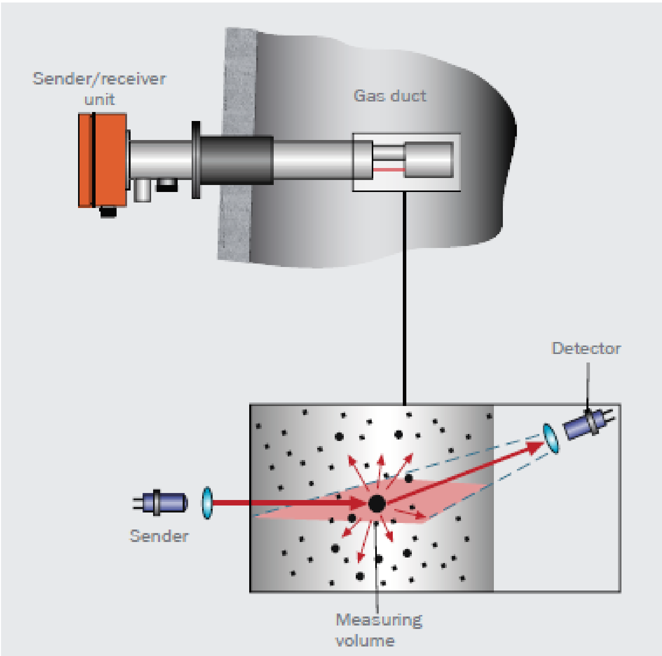

Figure 6. *Dust measurement device based on scattering the laser light.[37]*

Lately the principles of a triboelectricity have been applied to emission measurement. Triboelectricity is used in the particle separators. Operation of such emission measurement device is based on electric charge of the particles. Particles will donate their electric charge by colliding with the sensor probe when they are passing by. By measuring the electric charge it is possible to calculate the concentration of dust. Advantages of triboelectricity are cheap acquisition cost and ease of assembly. Size of the particles, electric charge, condensed water drops and velocity of running gas affects to the measurement. [23]

There is also measurement technique that is based on gravimetry. Gravimetric measurement technique is considered to be very accurate in dust measurements. The technique is used to measure under 50 mg/m^3 concentrations [33]. It is not usually used as continuous measurement in power plants, because it is expensive. Test laboratories use gravimetric technique as reference measurement in calibrating the dust measurement devices. The measurement procedure is simple. The dust particles are separated into weighted filter. The filter is dried and weighted again after the sampling. Dust concentration is determined from the weight increase of the filter in relation to the volume of the sample gas. [33.]

4. COMPARISON OF CEMS AUTHORITY REQUIREMENTS AT TARGET COUNTRIES IN EU

Main purpose of this thesis was to find special authority requirements of CEMS. The focus was on the large combustion plants and waste incineration plants. It is obvious that all the target countries are complying with the EU directives because they are in EU. Still it is possible for the EU countries to set special requirements and that is the reason why this thesis is been done. In the beginning of the thesis the target countries were Spain, Portugal, France, UK, Estonia, Poland Slovakia and Czech but Portugal and Slovakia dropped out due to the lack of information on them. Metso's interest was to gain knowledge about minimum requirements of CEMS in each target country. It is major advantage to be aware of the national requirements when approaching the market of a specific country. When all the needed information is available already in sales phase, lot of money and time is saved during the project implementation.

The situation is not always that simple. Each target country consists of different regional administrations concerning environmental matters. Each region has its own environmental department. The problem is that each region can interpret the environmental regulations in different way. Some requirements depend on what the local environmental department thinks is best for the region. Approaching the market of these kinds of countries it has to be done case by case. Of course some requirements are the same in each area. Good example is Spain. According to the questionnaire it has 17 different regional administration areas which interpret the environmental requirements in different way. The regions are shown in the figure 7 below. The study clarified also that Estonia is divided into 15 different counties. Each county has its own Environmental Department which operates as competent authority of the specific county. These Environmental Departments has power, inside the counties, to implement national environmental, nature protection, forest and fisheries legislation. County environmental department grants environmental permit to those plants that are located inside the county's borders. Figure 8 shows the 15 counties of Estonia.

Figure 7. *17 geographical areas of Spain.[24]*

Figure 8. *15 geographical ares of Estonia.[41]*

United Kingdom consists of four countries: England, Scotland, Wales and Northern Ireland. Environment Agency (EA) covers England and Wales, Scottish Environment Protection Agency (SEPA) covers Scotland and Northern Ireland

Environment Agency (NIEA) operates in Northern Ireland. All the three Agencies are responsible for their own country's pollution control.

The information gathered for the thesis is derived from internet, documents sent by local representatives (e.g. local environment agencies and equipment vendors) or questionnaire. Contact network was built and emission monitoring questionnaire was sent throughout the target countries. Metso was aware that some of the emission monitoring requirements are interpreted in a different way and wanted this thesis to clarify those interpretations. Questions in the questionnaire were planned according to Metso's experience and in such way that the answers would clarify the known issues concerning the interpretations. The questionnaire can be seen in appendix 1. Lot of the information is interpretation or opinions of individual people such as consultants, employees in local environment agency and employees in equipment vendor companies. Some information is not available from official documents. Only way of getting information from the existing methods is to interview people who have experience concerning those matters. These opinions can't be taken as official information.

The main interests of this thesis are: Requirements for the reporting solution, possibility of integration of CEMS to process automation system, continuous measurements, reported emissions and units, calculation of limit values for multi-fuel boilers as well as national emission trading (other than CO_2) and taxation.

4.1. Certification requirements for the system and reporting solution

From certification point of view, CEMS consist of two parts: continuous measurements devices and environmental data management solution as shown in figure 9. Metso Automation has developed Emission Monitoring and Reporting Solution (EMRS) to manage environmental data. Such data management application is usually mandatory, required by the local authorities. With environmental data management application operators shall be able to record required emission data. It takes the measurement data from the gas analyser. Data is manipulated and calculated into needed form and accumulated into reports. Then the emission reports are delivered to the local authorities.

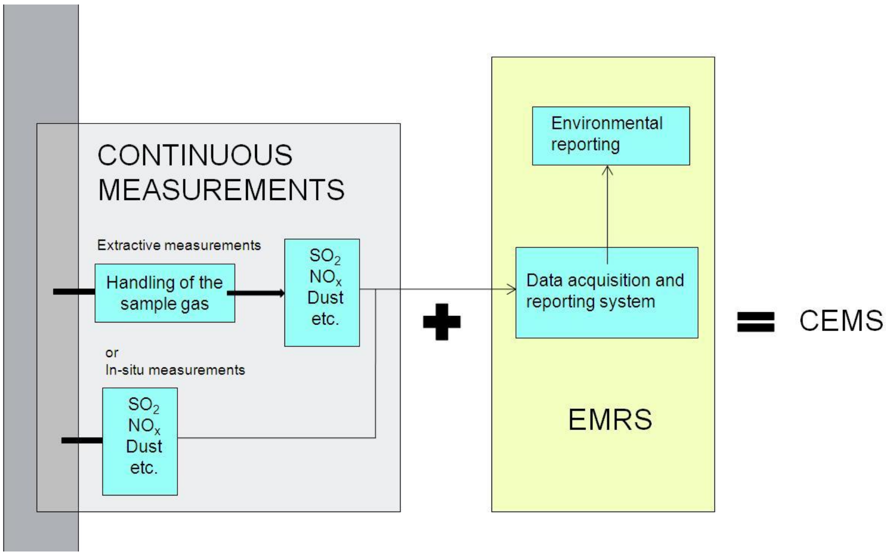

Figure 9. *Continuous measurements and EMRS together forms CEMS.*

Nowadays computers have big role as the environmental data is produced, manipulated, stored and reported. It is vital that the EMRS is secure and reliable. There are many things that companies which sell data management software need to take into account so they can cover the market demand and the requirements of LCP and WI directives, standards and local regulations. Underneath are listed examples of such things that software developer companies must keep attention to. It is important:

- to develop and maintain the software so that the quality of the measurements are not affected;
- to indentify corrupted data and discard it;
- to plan and develop cost-efficient solution;
- to have fast and fluent data management;
- to use known methods of data manipulation;
- that the handling and presenting of the data supports accurate and constructive decision- making. [28]

Continuous measurement devices are used in different conditions. Conditions vary country to country and site to site. They measure concentration of gases and particulate matter from e.g. power plants' stack. It is important to be sure that the devices are suitable for the specific installation and the analysers meet the needed requirements. By getting a certificate that is required or suggested in the specific country or area, CEMS suppliers and plant operators can be sure that their CEMS is suitable. Suitability of the analysers is assured by Quality Assurance Level 1 (QAL1) certificate [34]. Quality assurance of the CEMS is defined in the chapter five. In this chapter following requirements are clarified: Need of a certification for the CEMS and EMRS in target countries and the requirements that must be fulfilled to get the specific certificates.

According to the questionnaire in England and Wales certification of MCERTS (Monitoring Certification Scheme established by The Environment Agency) is not yet mandatory for the reporting software, but is expected to be in 1-2 years. In the upcoming version of Technical Guidance Note (TGN) M20 are expected to be a clause about the data management software. TGN M20 is guidance document for quality assurance of continuous emission monitoring systems published by Environment Agency in United Kingdom. For the continuous measurement equipment the certificate is mandatory. Certification of TÜV is also acceptable under some circumstances. This thesis does not focus on the requirements of TÜV. MCERTS has higher Operator Monitoring Assessment audit score because it has stricter requirements than TÜV. Such audits help Environment Agency to assess self-monitoring operators. Operator Monitoring Assessment audits are made to all operator sites in England and Wales. In Scotland and Northern-Ireland MCERTS isn't required for the data management software, but for the analysers MCERTS is mandatory. Derogation can be made if the equipment supplier can prove the suitability of their equipment in another way. This is also possible in England and Wales, but MCERTS is usually required by the local regulators. In a case of software in Scotland and Northern Ireland, authorities would like that the MCERTS is used if it is available.

In Scotland they are using the EN 15259 which is a standard for the requirements for measurement sections and sites and for the measurement objective, plan and report. EN 15259 is considered as the "European version" of MCERTS. EN 15259 relates to the Technical Guidance Note M1 which MCERTS applies under Environment Agency. Technical Guidance Note M1 is a guidance document for sampling requirements for stack emission monitoring. There is also a sister document for EN 15259 which is EN 15675. In 2009 and all the stack monitoring test laboratories had to get accreditation of both EN 15259 and EN 15675 standards. The certification requirements for analysers and softwares in target countries are presented in the table 4 and 5. As comparison the table shows also requirements of both Finland and Sweden.

Table 4. *Certification requirements for environmental data management software. Data based on questionnaire.*

Country/requirement	MCERTS	TUV	No certification
England and Wales	X		
Scotland	X		
Northern Ireland	X		
Spain			X
France			X
Poland			X
Czech	-	-	-
Estonia			X
Finland			X
Sweden			X

- No answer

Table 5. *Certification requirements for the automated measuring system (AMS). Data based on questionnaire.*

Country/requirement	MCERTS	TUV	No certification
England and Wales	X	X*	
Scotland	X		
Northern Ireland	X		
Spain			X
France	X*	X*	
Poland			X**
Czech	-	-	-
Estonia			X
Finland			X
Sweden			X

** Not mandatory, but preferred.*
*** No certification required, but operators usually demand certificate for the analyser.*
- No answer

4.1.1. MCERTS for environmental data management software

MCERTS defines the requirements for the data management software in the document Performance standards and Test procedures for the Environmental Data Management Software. EMRS supplier has to comply it, if they want the MCERTS certificate for their data management software. Sira Certification Service make to software evaluations whether the suppliers application complies with the standards. Sira has been appointed as MCERTS's certification body by Environment Agency. [28.]

The standard is divided in three parts. Part A specifies the generic quality requirements of the software. It also defines a standard for the lifecycle used to develop and maintain the data management application. Performance requirements for the data management application are stated in part B. Part C is divided in different sectors C1 - Cn that defines specific sub-areas of the application. [28.] Figure 10 shows the alignment of the three parts.

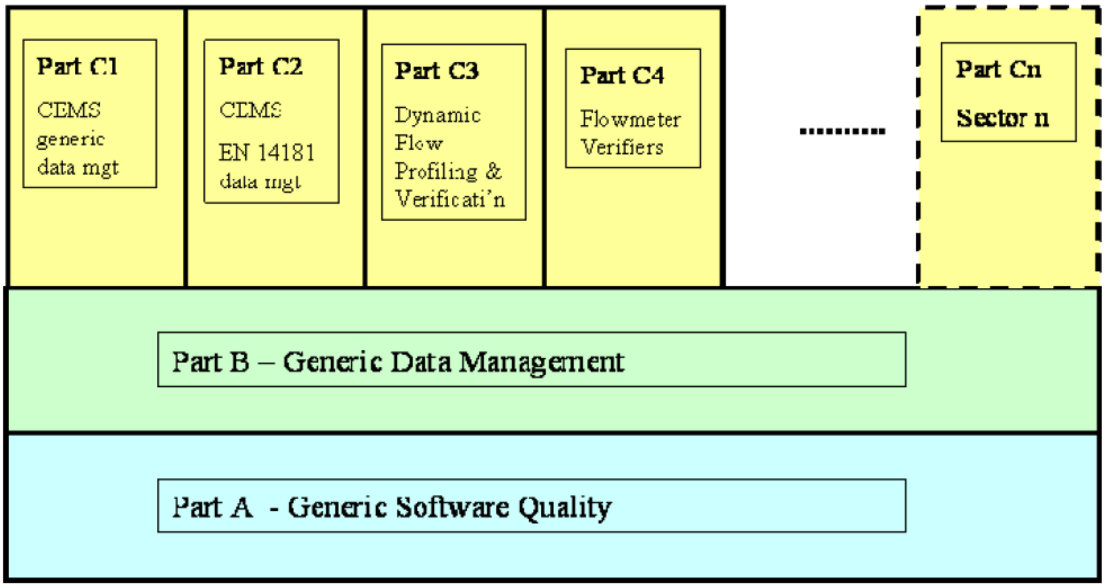

Figure 10. *Standard is divided into three parts. [28]*

EMRS supplier has a Software Quality Plan (SQP) which covers all the information how the quality of the software has been achieved and maintained. EMRS supplier's SQP has to contain a decision whether the part A standard is appropriate for the application. There might be more rigorous norms that the application must comply. E.g. standard IEC 61508 is for the applications that are related to safety. It is more rigorous than Part A. EMRS supplier has to define the software lifecycle and gather a list of documents that are produced or used in the application software development. Software tools, software components and hardware used through the software lifecycle must be listed in the Quality Plan. EMRS's behavior in normal and faulty operation of every communication interface has to be defined. Design information of the EMRS has to be available for the assessor, because EMRS supplier has to show the used methods that prove the software can be maintained. [28]

In addition to handling the part A EMRS supplier's software has to comply with the part B as well. Integrity of the measurement data has to be proven. It can be done by complying requirements in Part B. Part B defines general aspects concerning managing the measurement data. [28.] Such aspects are listed on the next page.

Aspects defined in Part B:

- Application documentation;
- Mathematical specification and processing of measurement data;
- Traceability and auditability of data;
- The storage and security of data;
- Interfaces to measurement devices;
- Report generation and the display and presentation of data;
- Certification of new installation;
- Software installation and acceptance;
- Commercial status of the supplier. [28]

The part C of the standard defines the MCERTS performance standards for environmental data management software (EMRS). EMRS gather measurement data from automated measuring system. MCERTS performance standards meet the LCP- and WI directives as well as the IPPC directive. [28]

It has to be ensured that the software is able to gather, handle and report the data in the formats that the WI Directive, LCP Directive and Environmental Permitting Regulations, 2007 require. EMRS has to be able to produce needed (LCP- , WI- , IPPC directives) averages (e.g. half hourly- , hourly- , weekly averages) of the emissions. EMRS needs to gather data within the entire ranges used in the CEMS. [28]

EN 14181 must be complied by the environmental data management software within specific requirements. EMRS must be capable to operate according to the EN 14181 QAL 3 requirements concerning zero and span checks. [28]

4.1.2. MCERTS for analysers/CEMS

Environment Agency has published document Performance standards and Test procedures for Continuous Emission Monitoring System for certification of analysers. It sets requirements the equipment must meet to gain MCERTS certificate. European and international standards are used to monitor sites and accept laboratories. MCERTS complies with EN 15267-3 standard which sets EN 14181 standard’s QAL 1 and QAL 3 requirements. EN 15267-3 standard states also the uncertainty requirements that automated measuring system have to meet. [27.] Metso Power can be sure that if their provided automated measuring system is MCERTS certified, equipment does comply with all the required standards. MCERTS is recognized in UK and accepted internationally

Testing laboratories that test the equipment must meet the requirements of internationally recognized ISO/IEC 17025 standard, EN 15267-3 as well as MCERTS requirements. The ISO/IEC 17025 standard sets requirements for carrying out tests, calibrations and samplings. [27]

These are the test made to assess the CEMS:

- lack of fit;
- response time;
- detection limit (repeatability at zero);
- repeatability at span;
- influence of ambient conditions on zero and span readings;
- performance and accuracy under field conditions;
- cross-sensitivity to likely components of the stack gas other than the determinant;
- influence of sample pressure and sample temperature;
- susceptibility to physical disturbances;
- time-dependent zero and span drift under field conditions;
- availability and maintenance interval under field conditions;
- reproducibility under field conditions;
- design features. [27]

The document holds requirements for three different particulate monitors. Plants that fall under the LCP- or WI directive, uses Class 1 particulate monitors. Class 1 monitors are the monitors that Metso Power is delivering to their customers. Class 1 monitors have to comply EN 14181 standard. Class 2 monitors also measures emissions in mg/m^3. These monitors are said to be *filter dust monitors*. Class 2 monitors are been used in PPC installations which have emission values less than 50% of the emission limit values. Class 3 monitors are said to be *filter leakage monitors*. Class 1 particulate monitors must be able to measure and record zero and span drifts as it is stated in EN 14181 QAL 3 requirements. Classes 2 and 3 don’t have to comply with QAL 3 in EN 14181. [27]

4.2. CEMS integration to automation system

Metso classifies the integration of CEMS and automation system into three different categories. Variations of these three options are possible. Option one in figure 11 presents emission monitoring system fully detached from automation system and it is called a stand-alone system. Data from CEMS goes straight to the emission server, where all the calculation and manipulation of the data are done. By choosing this option, plant can’t use calculated emission data, for process controlling. [37] Benefits of the integration of the CEMS and automation system are defined in the next page.

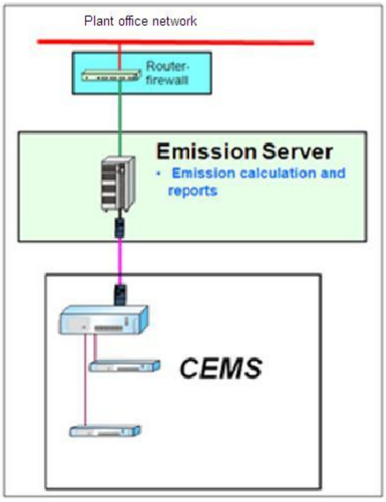

Figure 11. *Detached emission monitoring system.*

Option two is full integration of CEMS and automation system. All the data goes through automation system. Emission data calculation and reports are made in information server, where all the other process data is located as well. Figure 12 shows how the system equipment are linked together.

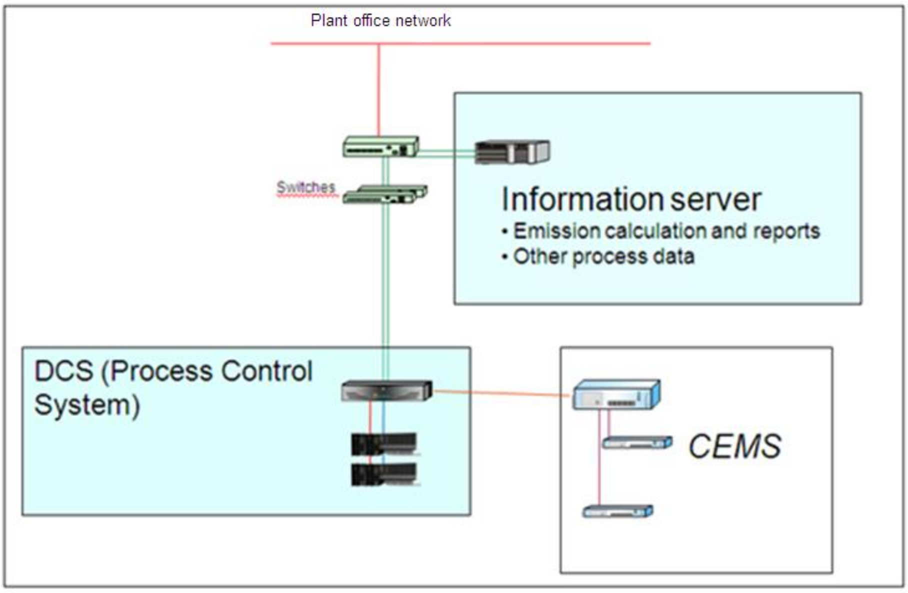

Figure 12. *CEMS integrated to automation system.*

Automation system can use the emission data to find the optimal way of running the plant. For example in MetsoDNA advanced emission reporting solution is able to send the relevant information to automation system. It will also generate alarms to the automation system which brings the possibility to respond quickly to emergencies and fault situations. [38.] Also the alarms from the exceeding of the CEMS calibration function are sent to the automation system [18]. From the emission and process data it is possible to efficiently analyse the problem situations and their causes. All the most important monitored pollutants are shown on the screen of an operating station. Access rights for the emission information are allocated to different user groups. For instance, from MetsoDNA emission information is easily available for the different users via browser based user interface. Users can monitor relevant information of the permit conditions and emission limit values. [37.] Figure 13 presents example of daily report and measurement equipment down time report of LCP-plant.

LCP DAILY REPORT

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	Operating Times			Disturbance Times						
	Boiler in Operation	Normal Operation	Cleaning Equipment	NOx	SO2	Dust	CO	O2	H2O	Pressure
Time	h	h	h	h	h	h	h	h	h	h
00:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
01:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
02:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
03:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
04:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
05:00	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
06:00	1,0	1,0	0,0	0,0	0,0	0,0				
07:00	1,0	1,0	0,0	0,0	0,0	0,0				
08:00	1,0	1,0	0,0	0,0	0,0	0,0				
09:00	1,0	1,0	0,0	0,0	0,0	0,0				
10:00	1,0	1,0	0,0	0,0	0,0	0,0				
11:00	1,0	1,0	0,0	0,0	0,0	0,0				
12:00	1,0	1,0	0,0	0,0	0,0	0,0				
13:00	1,0	1,0	0,0	0,0	0,0	0,0				
14:00	1,0	1,0	0,0	0,0	0,0	0,0				
15:00	1,0	1,0	0,0	0,0	0,0	0,0				
16:00	1,0	1,0	0,0	0,0	0,0	0,0				
17:00	1,0	1,0	0,0	0,0	0,0	0,0				
18:00	1,0	1,0	0,0	0,0	0,0	0,0				
19:00	1,0	1,0	0,0	0,0	0,0	0,0				
20:00	1,0	1,0	0,0	0,0	0,0	0,0				
21:00	1,0	1,0	0,0	0,0	0,0	0,0				
22:00	1,0	1,0	0,0	0,0	0,0	0,0				
23:00	1,0	1,0	0,0	0,0	0,0	0,0				
Average	1,0	1,0	0,0	0,0	0,0	0,0				
Sum	24,0	24,0	0,0	0,0	0,0	0,0				
Minimum	1,0	1,0	0,0	0,0	0,0	0,0				
Maximum	1,0	1,0	0,0	0,0	0,0	0,0				

!	Concentration value exceeds the emission limit value
0,0	Concentration value exceeds the upper limit of calibration function
0,0'	Negative concentration value is set at zero
*	Disturbance time of measuring device exceeds 20 minutes
INVALID	Not enough valid data for calculating the concentration mean value

LCP DAILY REPORT metso

02.02.2010 Printing time: 3.2.2010 12:55

	NOx					SO2				
	Daily limit value 600 mg/m³(n)		Hourly limit value 1200 mg/m³(n)			Daily limit value 400 mg/m³(n)		Hourly limit value 800 mg/m³(n)		
		Normal operation	Start-up/ Shutdown	Cleaning Equipment Malfunction	Measuring System Malfunction		Normal operation	Start-up/ Shutdown	Cleaning Equipment Malfunction	Measuring System Malfunction
Time	mg/m³(n)	kg	kg	kg	kg	mg/m³(n)	kg	kg	kg	kg
00:00	224,3	40,3	0,0	0,0	0,0	0,0'	8,8	0,0	0,0	0,0
01:00	244,1	44,1	0,0	0,0	0,0	0,0'	7,3	0,0	0,0	0,0
02:00	237,5	43,5	0,0	0,0	0,0	0,0'	5,5	0,0	0,0	0,0
03:00	232,5	45,2	0,0	0,0	0,0	0,0'	8,5	0,0	0,0	0,0
04:00	238,9	38,3	0,0	0,0	0,0	9,4	9,5	0,0	0,0	0,0
05:00	233,2	41,5	0,0	0,0	0,0	0,0'	8,5	0,0	0,0	0,0
06:00	231,4	43,1	0,0	0,0	0,0	0,0'	8,2	0,0	0,0	0,0
07:00	226,9	41,0	0,0	0,0	0,0	4,4	9,7	0,0	0,0	0,0
08:00	219,1	44,6	0,0	0,0	0,0	0,0'	8,9	0,0	0,0	0,0
09:00	235,1	43,3	0,0	0,0	0,0	0,0'	6,8	0,0	0,0	0,0
10:00	202,1	27,6	0,0	0,0	0,0	8,3	7,4	0,0	0,0	0,0
11:00	146,2	24,3	0,0	0,0	0,0	45,8	11,6	0,0	0,0	0,0
12:00	154,1	26,0	0,0	0,0	0,0	49,9	12,4	0,0	0,0	0,0
13:00	133,9	21,4	0,0	0,0	0,0	0,0'	6,1	0,0	0,0	0,0
14:00	109,0	20,2	0,0	0,0	0,0	0,0'	3,9	0,0	0,0	0,0
15:00	149,9	28,4	0,0	0,0	0,0	0,0'	3,4	0,0	0,0	0,0
16:00	186,6	39,8	0,0	0,0	0,0	0,0'	3,9	0,0	0,0	0,0
17:00	163,5	30,0	0,0	0,0	0,0	0,0'	3,4	0,0	0,0	0,0
18:00	168,2	28,0	0,0	0,0	0,0	0,0'	4,3	0,0	0,0	0,0
19:00	151,1	26,0	0,0	0,0	0,0	31,4	10,6	0,0	0,0	0,0
20:00	203,0	44,3	0,0	0,0	0,0	154,4	31,3	0,0	0,0	0,0
21:00	150,2	29,9	0,0	0,0	0,0	69,0	16,4	0,0	0,0	0,0
22:00	122,3	24,7	0,0	0,0	0,0	0,0'	5,2	0,0	0,0	0,0
23:00	106,3	27,7	0,0	0,0	0,0	0,0'	3,5	0,0	0,0	0,0
Average	157,2	34,3	0,0	0,0	0,0	0,0'	8,6	0,0	0,0	0,0
Sum		823,3	0,0	0,0	0,0		205,3	0,0	0,0	0,0
Minimum	106,3	20,2	0,0	0,0	0,0	0,0	3,4	0,0	0,0	0,0
Maximum	244,1	45,2	0,0	0,0	0,0	154,4	31,3	0,0	0,0	0,0

Figure 13. *Daily and equipment down time reports.*

In option three CEMS is semi-integrated to automation system. Data goes through automation system, but there is still detached emission server which does all the manipulating and calculations of the measurement data. All the reports as well are produced in the server. The principle of the option three is shown in the figure 14.

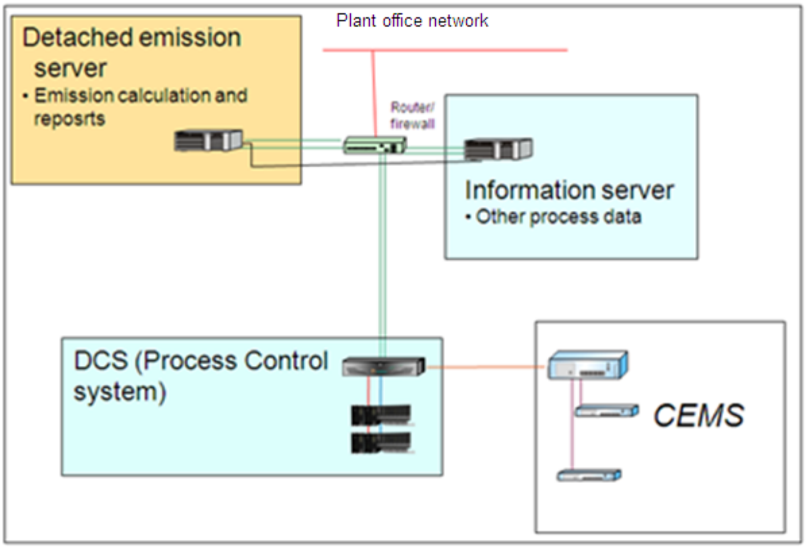

Figure 14. *CEMS semi-integrated to automation system.*

Interpretations of integration levels at target countries are defined in this chapter. In the table 6 is shown each country's way to regulate the integration of the automation system to the CEMS. All this information is based on the questionnaire. In many countries it is not very clear what is allowed and what is not. In Estonia the regulations to this whole concept is under development, so there is not much information available. Only choice is to find it out case by case.

Situation in Spain is different. According to the questionnaire operators purchase environmental data management softwares for process monitoring. Authorities take the emission data straight out of the analyser and manipulate the data and calculate the emissions using their own protocols and softwares. This is completely different way of reporting than in many other EU countries. The study clarified that when the environmental data management software is used for own use, all the automation system integration options are possible. It is still determined case by case by local authorities.

In Spain authorities have more responsibility in the reporting of emissions. Because the authorities perform the compliance reporting, environmental data management software doesn't have to have authority reporting part. Operators still needs environmental data management software for their own use. If there are no strict requirements for the solution, it might be possible to customize the solution for each customer.

In UK regulation of CEMS integration to automation system is clear. According to mail conversation with contact in UK, all the options are possible in UK as long as the data is secure and verifiable, but in the end the local Environment Agency person decides which option is suitable for the installation. Though, the full and semi integration of CEMS are likely options to be used.

The questionnaire clarified that in France and Poland there is no specific regulation on integration of the CEMS to automation system, as long as the software complies with all the calculation rules stated in the LCP- and WI directives. Also the form of the reports has to be as local authorities define. According to the questionnaire all the existing plants in Poland have separate emission server that does the emission manipulation and calculations. It is possible to have either option one, fully separate emission monitoring system or option 3, semi-integrated emission monitoring system.

Table 6. *Automation system integration possibilities in EU countries. Data based on questionnaire.*

Country/integration level	Stand-alone	Integrated to automation system	Semi-integrated to automation system	Not clear
UK	X	X	X	
Spain	X	X	X	
Estonia				X
Czech			X	X
France	X	X	X	
Poland	X		X	
Finland		X	X	
Sweden		X	X	

From Estonia and Czech it was difficult to find exact information on this subject. One of the answers to the questionnaire claimed that this matter, concerning CEMS integration level is under development in Estonia. It is new subject to Estonia and it is advised to follow the development of the matter.

4.3. Continuous measurements

Emissions are measured continuously or periodically. Periodic measurements are taken in certain intervals if continuous measurements are not required. Interval could be for instance six or twelve months. [19.] In the case of waste incineration plant, more pollutants have to be measured continuously than in the case of large combustion plant. This thesis concentrates on continuous measurements.

Continuous measurement system consists of many parts. In the figure 15 you can see simplified extractive sampling line. In many cases the sampling gas is moist and hot. To prevent condensation in sampling lines, heated filter boxes and heated sampling lines are used. One method of handling the sample is to lead the sample gas to the analyser as hot and moist. That is a simple and suggested way of handling the sample, because there is no condensation lost of the examined components. Calibration gas is fed from the start of the sampling line. Some analysers require the sample gas to be dried before it enters the analyser. Calibration gas goes through the whole sampling line as the real gas sample. [19]

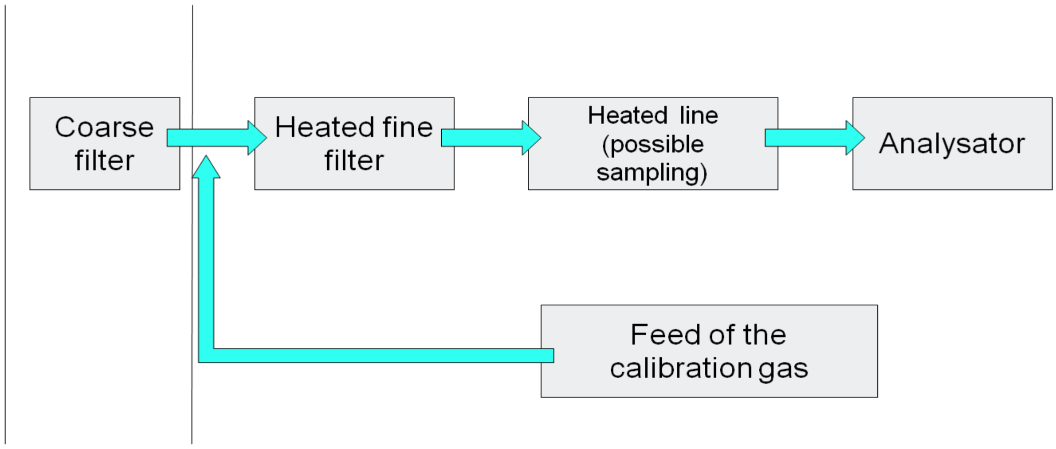

Figure 15. *Extractive sampling line.*

In situ is an alternative method to carry out the measurements. The operation of in situ measurement devices does not based on sampling. Flue gas is analyzed inside the measurement devices inside the stack. [23.] Investment cost of in situ measurement device is more expensive than extractive sampling device [31].

4.3.1. Criteria for continuous measurement system in target countries

Large Combustion Plant directive states that continuous measurement system is required when the rated thermal input of the plant is 100 MW or more. There are some derogations for special conditions. Continuous measurements are not required e.g., if the service life of the plant is 10000 operational hours or lower. Also if the operator can prove that sulphur dioxide emissions cannot exceed the limit value under any circumstances, continuous measurement of SO_2 is not required. [3.] In the table 7 below is presented each countries limit which they comply.

The threshold is not always the same as stated in LCP directive. The threshold can be lower, but not higher. For instance, Spain has tightened up the limit from the LCP directive's 100 MW to 50 MW. According to the study in UK they comply with the LCP directive, but in some cases the CEMS requirement limit can be under the 100 MW. If the plant is located near populated area, the threshold can be lower. The rated thermal input limit after which the continuous measurements are required is always derived from the IPPC license under which the plant runs. Table 7 shows the threshold of each target country.

Table 7. *Rated thermal input limit after which CEMS is required. Data based on questionnaire.*

Country/requirement	Rated thermal input limit (MW)
UK	100
Spain	50
Estonia	100
Czech	100
France	20
Poland	100
Finland	100
Sweden	100

The study revealed that in France the rated thermal input limit after which continuous measurement system is 20 MW. It is the lowest among the target countries. Plant which rated thermal input is 20 – 50 MW, continuous measurement are required only in specific condition and some pollutants do not have to be measured continuously in any conditions. Plant (20 – 50 MW) has to have continuous measurement for sulphur dioxide (SO_2) if the plant has desulphurization device installed. If there is no desulphurization device, periodic measurement has to be taken quarterly and daily estimates of the sulphur content of the fuel and of the plant's operating parameters. Continuous measurement or regular quarterly measurements are required for nitrogen oxides (NO_x) and oxygen (O_2), if plant (20 – 50 MW) has flue gas treatment system (e.g. Selective Catalytic Reduction or Selective non-Catalytic Reduction) installed. Dust and carbon monoxide (CO) have to be measured only annually.

In France in the case of plant which rated thermal input is 50 – 100 MW, the measurement of sulphur dioxide, nitrogen oxide and oxygen are regulated in the same way as in the case of a 20 – 50 MW plant. Carbon monoxide has to be measured continuously and dust has to be under continuing assessment. Plants which have rated thermal input of 100 MW or over are required to have continuous measurements for all the main pollutants (sulphur dioxide, nitrogen oxides, dust, and carbon monoxide) and oxygen as it is stated in the Large Combustion Plant Directive.

4.3.2. Required continuous measurements in target countries

In the table 8 it is presented the pollutants and process parameters that are required to be measured continuously in each target country concerning large combustion plants. The information is based on the questionnaire which was made during the study. Some can be determined by calculations. SO_2 and dust measurements don't concern gas turbines. There isn't much fluctuation with the continuous measurement requirements. Continuous measurement of carbon oxide (CO) is required at large combustion plants in UK, Spain, Estonia, Czech, France, Poland, but in UK whether it is required, depends on what is stated in the environmental permit. LCP directive states that SO_2, NO_x and dust have to be measured continuously as well as all the peripherals, but no CO.

Table 8. *Parameters that are required to be measured continuously in Large Combustion Plants (LCP). Data based on questionnaire.*

Measured parameters	UK	Spain	Estonia	Czech	France	Poland	Finland	Sweden
NO_x	X	X	X	X	X	X	X	X
SO_2	X	X	X	X	X	X	X	X
Dust	X	X	X	X	X	X	X	X
CO	X	X	X	X	X	X	X	X
TOC								
HCl								
HF								
N_2O	X							
NH_2								
NH_3								X
CO_2				X				
Flue gas flow (wet)	X	X	X			X	X	X
Flue gas flow (dry)	X		X				X	X
Flue gas pressure	X	X	X		X	X	X	X
Flue gas temperature	X	X	X	X	X	X	X	X
O_2 concentration	X	X	X	X	X	X	X	X
H_2O concentration	X	X	X		X	X	X	X

It seems that it is quite common to measure CO continuously, though it is not required by the European Union. By measuring emissions of carbon monoxide, operators gain important knowledge of combustion process. It is then possible to gain efficient combustion, reduction of pollutant emissions and safe operation. With the knowledge of CO concentration in the flue gas, it is possible to fine tune the air to fuel ratio so that the efficiency of the combustion process is optimal. Possible unburned combustibles are detected as well from the concentration of carbon monoxide. That is important because too high amount of unburned combustibles causes unsafe situation in the process. In combustion process there is always excess air. If the amount of the excess air is too low, generation of unburned combustibles (e.g. carbon monoxide, coal) in the flue gas will increase. That is called “fuel rich” situation. It is not safe because the unburned fuel might fire up afterwards. Another situation is called “air rich“ situation which means there is too much excess air. That is not desirable, because efficiency of the combustion suffers and concentration of nitrogen increases in the flue gas, because air comprises lot of nitrogen. Though, in air rich situation the combustion is complete and does not cause any dangerous situations. [44.]

In the case of a large combustion plant continuous measurement of N_2O is required in UK, but not always. According to the questionnaire, in other countries it is not required in any conditions. The reason why it is sometimes required in UK is explained underneath the table 9 where the continuous measurement requirements of waste incineration plant are explained. Czech is the only target country that continuously measure carbon dioxide (CO_2), but not all the plants have continuous measurement of CO_2. It is required because operators have to report the emission as well. They also calculate the amount of CO_2 emission for verification.

Measurement of flue gas flow, flue gas pressure, flue gas temperature, O_2 concentration and H_2O concentration are considered as peripheral measurements. Almost all target countries require measuring them all continuously. Czech distinguishes little bit from the others. Czech requires only continuous measurements of flue gas temperature and O_2 concentration.

Table 9. *Parameters that are required to be measured continuously in waste incineration plants (WI). Data based on questionnaire.*

Measured parameters	UK	Spain	Estonia	Czech	France	Poland	Finland	Sweden
NO_x	X	X		X	X	X	X	X
SO_2	X	X		X	X	X	X	X
Dust	X	X		X	X	X	X	X
CO	X	X		X	X	X	X	X
TOC	X	X		X	X	X	X	X
HCl	X	X		X	X	X	X	X
HF	X	X		X	X	X	X	X
N_2O	X							
NH_3	X				X			X
CO_2				X				
Flue gas flow (wet)	X	X				X	X	X
Flue gas flow (dry)	X						X	X
Flue gas pressure	X	X		X	X	X	X	X
Flue gas temperature	X	X		X	X	X	X	X
O_2 concentration	X	X		X	X	X	X	X
H_2O concentration	X	X		X	X	X	X	X

In the table 9 above presents the requirements for continuous measurements in the case of a waste incineration plant. Requirements are tighter than in large combustion plants. In UK new plants tend to have the continuous measurement of hydrogen fluoride (HF), but it is still dependant of the environmental permit as well as the continuous measurement of ammonia (NH_3) and nitrous oxide (N_2O). Monitoring of NH_3 and N_2O are required when the plant is running NO_x reduction system that is using ammonia. Such methods are selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR). These methods are called secondary methods, because the nitrogen oxide has already reached the flue gas. Primary methods are used to prevent the generation of the nitrogen oxides in the combustion process. [13; 30]

In SCR system fed NH_3 reacts with oxygen (O_2) and nitrogen oxides (NO and NO_2). Urea ($(NH_2)_2CO$) is also used instead of ammonia. Catalyst, such as base metal oxides, zeolites, iron oxides or activated carbon is used to advance the reaction. Emissions of NO_x can be reduced by 90% or over. [13.] Underneath is presented the reaction where ammonia is used as reaction agent.

$$\mathbf{4\,NO + 4\,NH_3 + O_2 \leftrightarrow 4\,N_2 + 6\,H_2O}$$
$$\mathbf{6\,NO_2 + 8\,NH_3 \leftrightarrow 7\,N_2 + 12\,H_2O}$$

As the NH_3/NO_x ratio increases, the NH_3-slip will also increase. NH_3 slip is the amount of unused ammonia. With higher NH_3/NO_x ratio better removal of NO_x is achieved, but then it is possible that the threshold set for the NH_3 slip is exceeded. This kind of situation can be avoided by continuous measurement of ammonia in the flue gas. It is important to maintain the NH_3 slip as low as possible because the ammonia can react with sulphur trioxide (SO_3) and cause corrosion and fouling of the heating surfaces. [13.]

SNCR method differ little bit from the SCR method. SNCR does not use catalyst. With SNCR is possible to achieve 30–50% reduction of the NO_x emissions in the flue gas. It can be used together with the primary reduction methods. It very important to monitor the temperature of the flue gas, because the reagent (ammonia, urea, caustic ammonia) used is decided according to the temperature of the flue gas. If the temperature is too low, the conversion rate decreases and the NH_3 slip will increase. Secondly if the temperature is too high, ammonia will oxidize and more NO_x is produced. [13.] Underneath is presented the equations of the wanted reaction and un-wanted reaction.

Wanted reaction:

$$\mathbf{4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O}$$

Unwanted reaction:

$$\mathbf{4\,NH_3 + 5\,O_2 \rightarrow 4\,NO + 6\,H_2O}$$

Primary methods are based on the control of the combustion conditions. It is advised to use primary methods before secondary methods. If burners are used in the combustion, the LowNO_x-burners can be used to prevent the generation of the NO_x emissions. LowNO_x-burners phase the feed of the combustion air to the combustion zone. In a situation of fluidized bed combustion, NO_x emissions can be reduced with well controlled partitioning of the primary- , secondary- and possible tertiary air and recycling of the flue gas back to the combustion zone. [13.] With primary reduction methods it is possible to attain 10-50% reduction of the NO_x emissions depending on the separation process and combustion method as well as fuel [31].

4.3.3. Supplying process of CEMS

Metso Power is supplying continuous emission monitoring systems alongside with boilers, when it is part of the contract. Plant owner might require that the CEMS has to be supplied from a specific manufacturer. The CEMS supplying process begins as Metso Power receives the boiler enquiry and the material and the type of boiler is decided. Also reporting solution can be part of the contract. The CEMS and reporting solution manufacturers are preliminary defined according to process and technical requirement. The final selection will be made based on the best price-quality ratio. Information of the previous CEMS projects is sometimes used for helping the decision making. After the appropriate vendor has been chosen the next step is to start engineering. The needed assemblies and location of the analysers are defined as well. [39.] Also possible double measurements of the pollutants and double analysers have to be taken into account at this point. At the moment, in UK this kind of double CEMS is required. [38.]

The delivery cover information on the following requirements: Training of the end users, definition of the guaranty measurements, maintenance of the equipment and delivery time as well as the definitions of the assembly and commissioning. The quality of the CEMS deliver is ensured together with the CEMS supplier and needed final reports are given to customer before taking over the delivery. Customer has responsibility to maintain and test the CEMS after the takeover. [38; 39]

4.4. Reported emissions and units

Large Combustion Plant (LCP) directive requires monitoring and reporting of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust. Waste Incineration directive requires also reporting of carbon monoxide (CO), total organic carbon (TOC), hydrogen chloride (HCl) and hydrogen fluoride (HF) in addition to previous LCP requirements. All the installations in Europe falling under the LCP directive or WI directive has to report these pollutants to the local authorities. These directives set the foundation of the reporting in EU area. [2; 3] In addition to the requirements of the directives there are the local environmental permits that usually sets more pollutants that has to be reported to local authorities. In the case of a LCP plant, CO is one of the most common amendments to the reporting scheme. Below the tables 10 and 11 shows the emissions that are required to be reported in each country, including units they are reported in. Table 10 covers LCP plants and table 11 covers WI plants.

4.4.1. Large combustion plants

Of the table 10 it is possible to see some variety between the target countries, but some requirements seems to be quite standard. For instance UK and Spain has almost same requirements between themselves, but comparing to other countries you begin to notice more variation. According to the questionnaire only UK reports N_2O to the authorities, but it is not always required. Reporting of the N_2O in UK is done in the same format as all the other pollutants (SO_2, NO_x, Dust). LCP directive is partly applied: LCP plants in UK report nitrous oxides as hourly averages and 48 hourly averages rather than daily averages. LCP directive states that the main pollutants sulphur dioxide, nitrogen oxides and dust are reported as hourly and daily averages.

Table 10. *LCP-plants: emissions that are reported to authorities in each target country. Data based on questionnaire.*

Pollutant/country	UK	Spain	Estonia	Czech	France	Poland
NO_x	X	X	X	X	X	X
SO_2	X	X	X	X	X	X
Dust	X	X	X	X	X	X
CO	X	X	X	X	X	X
TOC				X		
HCl			X	X		
HF				X		
N_2O	X					
CO_2				X		

All the pollutants are reported in mg/Nm^3 and in specific oxygen content.

Peripherals, such as flue gas flow, temperature, pressure, oxygen content and moisture content are used to correct the raw values of the measured parameters. Measured oxygen content is used to calculate specific oxygen content for reported pollutants and measured moisture content is used to calculate emission concentrations in a dry content, if the emission concentrations are measured from moist flue gas. Answers to the questionnaire from Czech and France claimed, that they don't report flue gas flow to the authorities. It could be misunderstanding, because measurement results of flue gas flow is used to calculate e.g. total annual emissions.

Reporting of carbon monoxide (CO) seems to be required in all countries though it is not required by the LCP directive. It is dependent on the plant's environmental permit. Carbon monoxide is an indicator of the combustion efficiency. Nowadays emission limit value for carbon monoxide is around 75 – 250 mg/Nm^3 (6% oxygen content) depending on local requirements and conditions [31].

Requirements in Czech vary the most compared to the other target countries. According to the questionnaire it is the only country that requires reporting of total organic carbon (TOC), hydrogen chloride (HCl) and hydrogen fluoride (HF) which are required in the WI directive. Measurements of those pollutants are taken periodically in three years intervals. Authorities in Czech might require also the reporting of carbon dioxide (CO_2). The amount of CO_2 can be determined by calculation or it can be measured continuously.

4.4.2. Waste incineration plants

In the table 11 emissions starting from NO_x and ending to HF is required in each target country as it is required in WI directive, except HF. If plant in UK is running some kind of NO_x reduction system, such as Selective Catalytic Reduction or Selective non-Catalytic Reduction, the operator is required to report emissions from N_2O and NH_3 pollutants and that is why they are measured continuously as well. The reporting of nitrous oxide and ammonia in UK is still dependent on the local environmental permit, but it is clear case when the plant is running NO_x reduction system. Waste incineration plants in UK report nitrous oxides (N_2O) and ammonia (NH_3) as half hourly averages throughout the day and as daily averages. Although the questionnaire answers from other target countries did not state the reporting requirement of ammonia, it is common in all over the Europe that ammonia is reported to authorities when such NO_x reduction system is used that uses ammonia in the reduction process.

Table 11. *WI-plants: emissions (mg/Nm3) that are reported to authorities in each target country. Data based on the questionnaire.*

Pollutant/country	UK	Spain	Estonia	Czech	France	Poland
NO_x	X	X	X	X	X	X
SO_2	X	X	X	X	X	X
Dust	X	X	X	X	X	X
CO	X	X	X	X	X	X
TOC	X	X	X	X	X	X
HCl	X	X	X	X	X	X
HF	X	X	X	X	X	X
N_2O	X					
NH_3	X					

4.4.3. EU regulations of the emissions to water

In this thesis water emissions are mentioned only in general level. Waste water from large combustion plants and waste incineration plants is remarkable pollution source. WI directive states monitoring requirements for waste incineration plants. The level of emissions to water depends on the fuel used, the amount of water used for cooling, the used flue gas cleaning system, the abatements method used. The water pollutants from large combustion plants are presented in appendix 2. Although, LCP directive does not say anything about the emissions to water, large combustion plants can monitor following effluents:

- suspended solids;
- heavy metals (e.g. Cu, Zn, Cr, Cd);
- salts (chloride and sulphate);
- organic halides;
- biocides;
- phosphate;
- pH. [13]

The quality of the incineration process has effect on the formation of emissions to water. Flue gas and fly ash composition will worsen if the incineration process is incomplete. Waste incineration directive has regulations on the measuring and monitoring emissions to water. Waste incineration or co-incineration plant operators have to apply a permit for waste water discharges from cleaning of exhaust gases. Waste incineration directive states emission limit values for water discharges from flue gas cleaning devices. Those emission limit values are presented in appendix 4. Underneath is a list of the requirements that waste incineration directive states of the measurement of the pollutants into waste water. The measurements are taken out in a spot where the waste water is discharged into the environment. [2]

- Continuous measurement is required for pH, temperature and flow of the discharges.
- Suspended solids have to be measured daily by spot sample measurement.
- Flow proportional representative sample over 24 hours period can be required by the regulators
- At least monthly measurements of a flow proportional representative sample of the discharge over a period of 24 hours of the heavy metals.
- At least every six months measurements of dioxins and furans; for the first 12 months of operation, measurements have to be taken at least every three months.
- If regulators have set emission limit values for polycyclic aromatic hydrocarbons or for other pollutants, they can define the measurement periods for them self. [2]

4.5. Calculation of limit values for multi-firing unit

Multi-firing unit is described as a plant which uses two different fuels or more. Emission limit values are determined in a different way than in the case of plant using only one fuel. LCP directive has stated how the emission limit values are calculated. First the emission limit values are listed for every fuel type. Then the fuel-weighted limit values are determined. That is done by multiplying individual emission limit values with each fuels' thermal input and dividing the result with the total thermal input of the plant. Lastly the fuel-weighted limit values are aggregated. [3]

LCP directive states that the local authorities calculate these limit values. If the used fuel-mix is changing during operation, the limit values are changing also. They have to be calculated again. That can be done by the authorities or by the operator. The goal was to collect information from each target country about how they are calculating emission limit values for multi-firing units. If it is done online the limit values are calculated instantly as the fuel-mix changes by calculating application.

Table 12. *Calculation of emission limit values for multi-firing units. Data based on questionnaire.*

Country/requirement	Allowed to calculate online by the operator	Determined only by authorities	No information
UK			X
Spain		X	
Estonia	X		
Czech	X		
France	X		
Poland	X		
Finland	X		
Sweden	X		

Above table 12 shows that it is quite common to let the operator calculate the emission limit values online in the case of changing fuel mix during operation. In Czech operator is allowed to calculate the emission limits, but the calculation has to be verified by the authorities. The calculating application calculates, complying with the calculation rules stated in the LCP directive and sets the new emission limit values for the pollutants as the fuel-mix changes. According to the questionnaire only in Spain the limit values are set by competent authority. Spain is stricter on things concerning generally monitoring emissions than many other target countries. For example emission reports and reporting is done entirely by the authorities. From UK the information was not very clear. The emission limit values are calculated with the calculation methods of the local competent authority and the calculations are same that LCP directive states. The problem was that it is not clear whether the operator is allowed to calculate the emission limit values online as the fuel-mix changes or does only the authority representative have the power to set the changing limit values for the plant.

4.6. National emission trading/taxation

European Union Emission Trading Scheme (EU ETS) has been established by the European Commission to reduce greenhouse gases and to protect the earth from harmful effects. The Trading Scheme is based on Emission Trading Directive 2003/87/EC. The Emission trading Scheme is on phase two which covers 2008-2012. First phase (2005-2007) was a pilot phase. It prepared the scheme for the phase 2. Phase two is the first phase where the member states have to comply with the emission targets. The targets are based on the information learned in the phase one. Those emission targets are set in the Kyoto Protocol. Every member state had to prepare a National Allocation Plan. The plan has to contain information on the emission allowances that the member has planned to allocate to the installations. The National Allocation Plans covers the means and progress how the member state will meet its own targets set in the Kyoto Protocol.

Each country has their own cap for the emission allowances they are planned to allocate. Phase two covered the trading of carbon dioxide (CO_2) emissions from combustion plants, from oil refineries, from coke ovens, from iron and steel plants and from cement-, glass-, lime-, brick-, ceramics-, pulp and paper factories. Also nitrous oxides (N_2O) emissions from the production of nitric acid are included.[10]

Upcoming phase three lasts 7 years (2013-2020). Phase three will contain some changes and amendments to the phase two. EU ETS will have one EU-wide cap for the allocated emission allowances. It will replace all the national caps which are used in the phase two. Phase three will also cover more sources of emissions. From 2012 CO_2 emissions from civil aviation will be included to the EU Emission Trading Scheme. From 2013 installations that capture, transport, geologically store the greenhouse gases. CO_2 emission sources will be extended to include petrochemicals, ammonia and aluminium sectors. Also the emissions of nitrous oxides from the production of adipic and glyoxylic acid will be included as well as perfluorocarbon emissions from production of aluminium. [10]

In addition to the greenhouse gas (GHG) emission trading scheme, it is possible that EU member countries trade nationally with other pollutants than CO_2. Also taxation on some pollutants is possible. For instance, trading of emissions such as sulphur dioxide, nitrogen oxides and dust is defined as national trading. Those pollutants are not included to the EU Emission Trading Scheme.

Sweden has been set up charge on nitrogen oxides (NO_x) as well as on sulphur dioxide. The charge on NO_x emissions was set up in the beginning of 1992 and it concerned combustion plants and energy production installations which output is 25 GWh in a year or over. Swedish Environmental Protection Agency (Swedish EPA) collects the charges. The collected money is returned back to the participating operators. Only 0,7% of the money is used for the administration costs. Amount of the money that plant is getting back depends on the emitted NO_x emission in relation to the power output (GWh) of the plant. For plant owners it is cost-effective to invest on reducing NO_x emissions. At the same time NO_x emissions are reduced. One emitted kg of NO_x costs approximately 5,3 € and refund is about 0,9 € per one MWh. Every participating plant has to measure continuously the NO_x or they can use presumptive emission levels which are 250 mg/MJ for boilers and 600 mg/MJ for gas turbines. Direct measurement is preferred because presumptive emission levels are higher than the true emissions. Hourly averages of NO_x emissions are added up and reported to Swedish EPA as total annual emissions. [26]

One of the objectives of this thesis was to find out if the target countries have any national taxation or trading system of pollutants, such as Swedish charge on nitrogen oxides. With the help of the questionnaire, it was possible to acquire some information about national emission plans of some of the countries. The table 13 below shows in which countries following pollutants are traded or taxed. This level of trading and taxation is purely national and does not include to the EU Emission Trading Scheme. Results concerns energy generation and combustion plants.

Table 13. *Taxation/trading of pollutants in each target country. Data based on questionnaire.*

Country/pollutant	NO_x	SO_2	Dust	N_2O
UK	Trade	Trade	Trade	
Spain	-	-	-	-
Estonia	Tax	Tax	Tax	
Czech	Tax	Tax		
France	-	-	-	-
Poland	Trade*	Trade*		Trade
Suomi	-	-	-	-
Sweden		Tax		Tax

** Plans for emission trading.*
- No answer

UK has National Emission Reduction Plan (NERP), where UK's implementation of LCP directive is defined. LCP plants running under the NERP can trade/transfer annual emission allowances of sulphur dioxide, nitrous oxides and dust with other LCP plants. NERP applies to the whole UK: England, Wales, Scotland and Northern Ireland. NERP has set annual allowance limits for SO_2, NO_x and dust. LCP plants are not allowed to exceed those limits. If some LCPs cannot operate within the annual allowances or if operator doesn't want to install emission abatement equipment, they can buy more emission allowances from other LCPs. In other words, if operators have substantially lower annual emissions than the allowances states, it is profitable for the operators to sell the surplus emission allowances.

Poland is not yet trading with nitrogen oxides or sulphur dioxides, but it is planning to do so in the future. N_2O is traded among some nitrogen plants in Poland. Poland has also charges on emissions discharged into air. According to EU, emission reports for authorities are for monitoring the compliance of emission limit values. In Poland the purpose of authority emission reports is more multidimensional. According to the study report includes also information on emission charges that plant has paid. Emission charge report has to include monthly, quarter, half annual and annual payment calculations. In reports also total emissions have to be presented. They are reported in kilograms. One kilogram of emitted emission has specific charge. Authority emission report exclude the shut-down -and start-up periods as stated in LCP –and WI directive but in emission charge report the start-ups and shut-downs are included.

5. IMPLEMENTATION OF EN 14181 STANDARD

There are two kinds of continuous emission monitoring systems: extractive and in-situ. Extractive CEMS consists of gas analyzer itself, sample probe, flow meters, delivery pumps, sampling line and measurement equipment. Dust filters, devices that remove moisture, converters and diluters which are used for sample conditioning are also part of the CEMS. In order to get reliable and accurate emission data it is required that all the parts work properly as independent unit. To assure the quality of the CEMS European Commission and European Free Trade Association have authorized European Committee of Standardization (CEN) to establish the standard EN 14181. This standard fulfills the requirements of LCP and WI directives. [34]

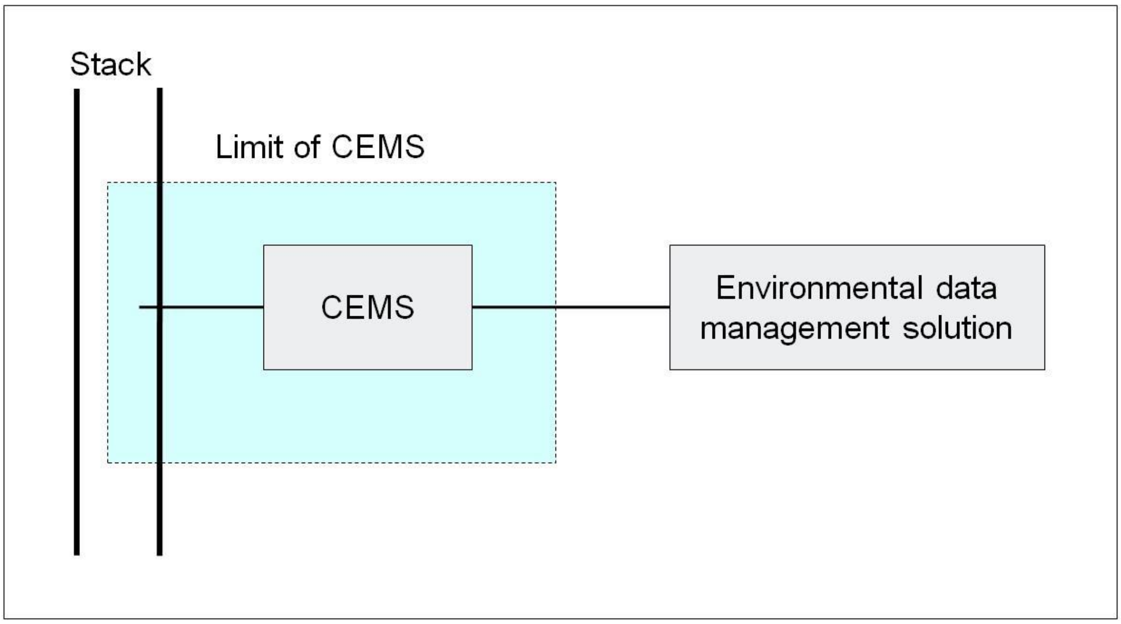

Figure 16. *Limits of the CEMS that the EN 14181 standard covers.*

Above figure 16 shows the parts that the EN 14181 standard covers. Standard does not cover environmental data management solution which function is to handle the data and calculate the emissions as well as record the emission data. Environmental data management solution can also affect the quality of the emission data as the quality of the results are analyzed from the whole measurement system. [34.] Quality requirements for environmental data management solution vary between different countries. Standard for the environmental data management solution is under development [37].

In 2010 CEN published Technical Report EN 15983:2010 to guide the implementation of the EN 14181:2004 standard. The Technical Report explains the requirements stated in the EN 14181:2004 concerning the procedures of the three quality assurance levels (QAL 1-3) as well as the Annual Surveillance Test. [35]

5.1. Quality Assurance Levels

The quality assurance process is classified into three different Quality Assurance Levels: QAL1, QAL2 and QAL3. They present the quality assurance before and during the purchase process as well as the quality assurance during the ongoing operation of the CEMS. In addition to the QAL1-3 there is Annual Surveillance Test (AST). AST can be considered as minor scale of the QAL2 tests. The EN 14181 standard consists of QAL1, QAL2, QAL3 and AST definitions. Underneath the figure 15 presents the concept of the quality assurance process of the EN 14181 standard. [34]

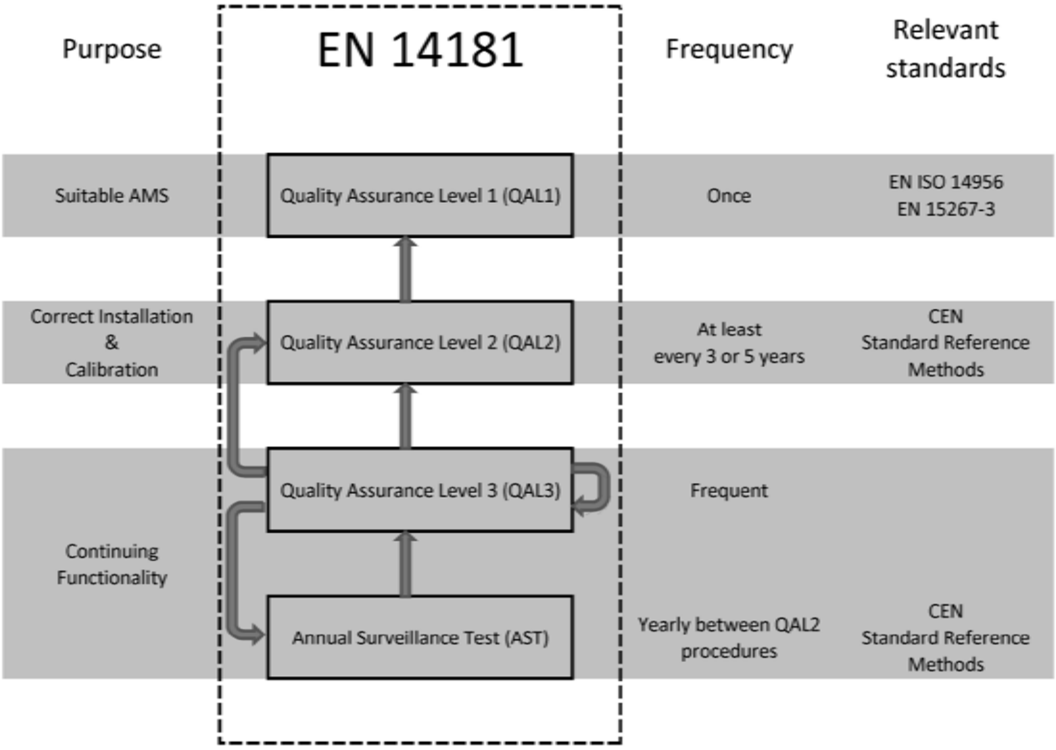

Figure 17. *Quality Assurance Levels. [35]*

5.1.1. QAL 1

The EN 14181 standard states specifically the procedures that the CEMS has to pass to comply with the uncertainty requirements on the measured values. Requirements can be set by LCP or WI directive, national legislation or local competent authority. In the first level QAL1, the suitability of the CEMS is valuated. The total uncertainty of CEMS has to be smaller than the requirements of the authorities. [19] Total uncertainty consists of all possible uncertainty components of the CEMS. QAL1 procedures are performed according to the EN 14956 standard. It covers specifically the suitability evaluation procedures and the methods to calculate the total uncertainty of the measured values of the CEMS. [34.] The equipment vendor is responsible for assuring the QAL1 requirements are complied.

QAL1 compliance is usually proved by certificate of competent certification body such as MCERTS or TÜV. [19.] All the analysers have to have own QAL1 certificates. Also the sample conditioning system has to be QAL1 certified. Due to the EN 14181 standard, it was unclear if the QAL1 certificate is required for the independent analysers and also for whole the measurement system. [38.] The study clarified that in UK such QAL1 certificate for the whole measurement system covering all the analysers and sample conditioning system is not required at the moment. It is enough to have separate certificates for the measuring devices and sample conditioning system.

5.1.2. QAL 2

QAL2 consists of three parts: Functional test, determination of the calibration function with parallel measurement and testing of the variability of the measurement devices. Functional tests are performed first. Functional tests cover the tests shown in the table 14 below.

Table 14. *Functional tests.*

Operation	**QAL2**	
	Extractive CEMS	In-situ CEMS
Cleanliness and Alignment of the measurement device		X
Sample handling	X	
Documentation	X	X
Serviceability	X	X
Leak test	X	
Zero and span check	X	X
Linearity		
Interferences		
Zero and span drift (audit)		
Response time	X	X
Report	X	X

After functional tests calibration and validation of the CEMS are done. After the installation of the CEMS the calibration is carried out with parallel measurements. Measurements are based on the standard reference method (SRM). Then the variability and the uncertainty compliance of the CEMS are determined. Parallel measurements have to be taken at least period of five years interval or more often if required by local legislation or competent authority. Underneath the figure 18 shows the flow diagram of the QAL2 test procedures. [34]

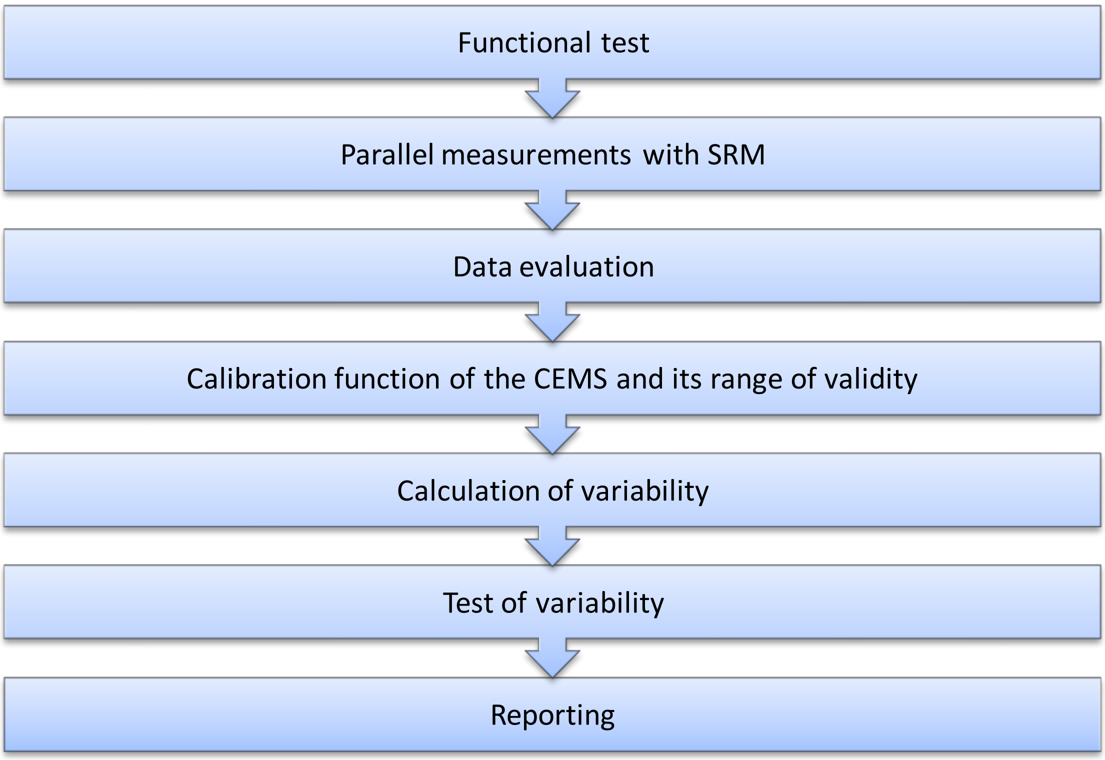

Figure 18. *Flow diagram of the QAL2 process.*

After the functional test parallel measurements are performed. SRM acts as a reference for the measurements from the CEMS. At least 15 measurement pairs have to be taken. The measurement process should last three days in order to avoid autocorrelation between the SRM and CEMS. Calibration function is calculated by comparing the measurements from the CEMS and SRM after which the variability for the CEMS is calculated. Calibration function defines the linear relationship between CEMS values and values from reference measurements during QAL2 tests. Then the variability is tested: Standard deviation between the values of CEMS and SRM are compared to the requirements. Reports of the QAL2 have to be reported to the competent authority in six months from the tests. [34]

5.1.3. QAL 3

During the operation the quality of the CEMS has to be assured by the operator. With the help of QAL3 monitoring operators can identify when maintenance of the equipment is needed. In order to assure the quality, drift and precision of zero and span readings are monitored with the help of CUSUM or Shewart control charts. Precision and drift can be determined as combined together (e.g. Shewart) or separately (CUSUM). Results are compared to the values determined in QAL1 and checked whether the equipment is working under the stated requirements. CUSUM is more sophisticated method than Shewart, because it is more flexible and it shows whether the span and zero need adjustment. Some QAL3 applications provide also the appropriate adjustment value. [34]

EN 14181 standard defines what should the QAL3 application do. It does not define how to do it [37]. Metso has its own QAL3 application, which can be used for different types of analysers. The analysers can be classified into three categories according to their different testing and adjusting. The first option in the table 15 analyser performs the span and zero checks automatically. The test results are transferred automatically into the QAL3 application. QAL3 application executes automatically all the calculations and provides the adjustment values. The analyzer adjustment procedure is performed manually using the adjustment values from the QAL3 application. [32.]

In the second option the span and zero check has to be performed manually and the results are entered manually into the QAL3 application. The adjustment is performed manually, in the same way as in the option one. [32]

Third option is the easiest for the user. The QAL3 procedure of the analyser is completely automatic. The analyser performs automatically the span and zero checks. The analyser itself also performs the adjustments if necessary. The test results are automatically transferred to the QAL3 application. The application just provides the test history in a report. [32]

Table 15. *Analyzers categorized according to QAL3.*

QAL3	Span and zero check of analyzer	Adjustment of analyzer
1	Automatic	Manual
2	Manual	Manual
3	Automatic	Automatic

In the case of a CUSUM chart, QAL3 monitoring is based on the standard deviation s_{AMS}. The calculation of the standard deviation is done under the plant conditions not. Formula 3 is used to calculate the s_{AMS}. [34]

$$s_{AMS} = \sqrt{u_{inst}^2 + u_{temp}^2 + u_{volt}^2 + u_{pres}^2 + u_{others}^2} \tag{3}$$

where

u_{inst}^2	is the uncertainty of the instability;
u_{temp}^2	is the uncertainty which is caused by the variation in the air temperature;
u_{volt}^2	is the uncertainty which is caused by the variation in voltage;
u_{pres}^2	is the uncertainty which is caused by the variation in ambient pressure;
u_{others}^2	covers all the other uncertainties that might effect to the span and zero readings. [34]

5.1.4. Annual Surveillance Test

Annual Surveillance Test (AST) is carried out once a year. AST is a similar procedure as the QAL2 tests but in minor scale. It consists of functional test and parallel measurements with SRM. AST is performed only for checking whether the calibration function determined in the previous QAL2 test is still valid. New parallel measurements according to QAL2 are required if the AST is not passed. At least five measurement pairs are required (15 measurement pairs in QAL2). [34]

5.2. QAL 1-3 responsibilities

One of the goals of this thesis was to find out and clarify the responsibilities relating to the three quality assurance levels. Many parties that are operating under the EN 14181 quality assurance standard are involved in verifying the quality of the CEMS such as plant owner, boiler supplier, CEMS manufacturers, CEMS suppliers, test laboratories and regulators. There are clear regulations about the QAL responsibilities in the EN 14181 standard. For example, in UK the responsibilities and roles of the participating organizations, concerning MCERTS QAL1 certification of the CEMS and QAL2 and QAL3 procedures are as it is stated in the table 16 on next page.

Table 16. *Quality assurance responsibilities and roles in implementing EN 14181.*

	CEMS manufacturer and supplier	Plant owners	Test laboratories	Regulators
Obtain QAL1 MCERTS certificate for the CEMS	X			
Supplying and commissioning of proper CEMS	X			
CEMS installation	X			
Acquire ISO 17025 and MCERTS performance standard accreditations for SRMs			X	
QAL2 and AST parallel measurements			X	
Assessing or performing the QAL2/AST functional tests			X	
QAL3 procedures		X		
QAL2, QAL3, and AST reports		X		
Operator compliance assessment				X
Definition of the EN 14181 requirements				X

The plant owner has the overall responsibility for complying with EN 14181 standard. Competent authority assesses only the plant owner's operation on the quality assurance. The requirements of the EN 14181 standard can be complicated to implement. Every organization plays its own part in the implementation. For example, UK's Environment Agency has stated that there is a need of a co-operation between the different organizations involved in the implementation process. [40]

5.2.1. Specific QAL2 responsibilities

Information on the quality assurance of the CEMS from other target countries than UK could not be found during the study. This subject was a little obscure for the involved organizations. The answers to the questions about QAL 1-3 in the questionnaire were all quite superficial. As a summary of the answers it can be said that the plant owner has the overall responsibility of the compliance with the QAL2 procedures.

Test laboratories are required to perform the QAL2 and AST procedures, but sometimes it can be difficult for them to perform for instance the functional tests because the operation of the different CEMS varies. Environment Agency has allowed some derogation in order to help the implementation of the EN 14181. QAL2 and AST functional tests can be carried out by either operator or CEMS supplier but the test laboratory is required to audit these tests according to the requirements in Annex A of the EN 14181 standard. If the test laboratory representative is not able to audit the tests there have to be some kind of proof that the tests have being carried out. [40]

When boiler supplier is delivering new plant, sometimes the boiler deliverer is required to supply the CEMS for the plant depending of the contract. The boiler owner sometimes wants the boiler deliverer to carry out or manage also the first QAL2 tests. In UK QAL2 tests have to be carried out after the QAL3 has been running successfully at least three months. In practice it means that the plant is running in normal operating conditions. Although the boiler supplier is managing the QAL2 tests, the overall responsibility is on the plant owner according to the questionnaire. QAL2 covers tests from all the determinants that are required to be measured continuously. Next list shows more specifically the responsibilities of the QAL2 procedures that Environment Agency has established for the CEMS in UK plants. [25]

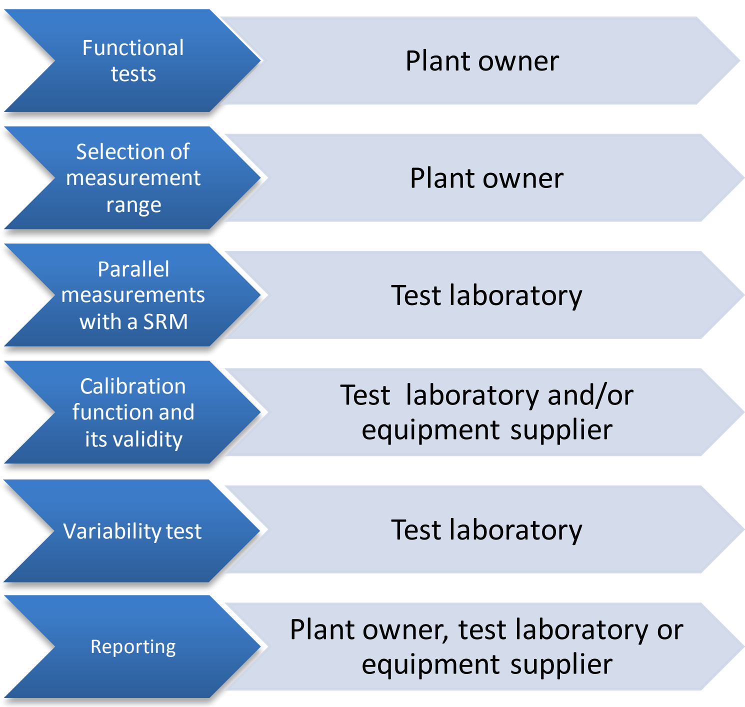

Figure 19. *Responsibilities for QAL2 and AST procedures.*

6. OUTLOOK FOR THE FUTURE

EU has made future plans in reducing and monitoring emissions from power plants. New proposed industrial emission directive (IED) will come into force. IED will be possibly accepted by the end of 2010. [20.] The proposal recasts seven existing directive related to industrial emissions into single, clear and coherent legislative instrument. The recast includes in particular the IPPC, LCP and WI Directives. The main goal of the industrial emission directive is to achieve higher level of the protection of the environment and human health. It will simplify the legislation and also the unnecessary administrative costs will be cut down by the directive. [7.]

6.1. Industrial emission directive

In the directive there is a general part which is to be applied for all the operations the IED affects on. Such operations are: combustion plants, chemical industry and other industrial operations and waste incineration and co-incineration plants. Next chapters will define the special requirements for each industry.

Requirements for LCP plants in the proposed directive will apply for the plants which rated thermal input is 50 MW or over. The changes to the existing legislation in the IED will concern mostly the large combustion plants. Changes are more moderate on the operations using solvents. [20]

The proposal includes aggregation rules for the combustion plants. For the existing combustion plants, if flue gases of two or more separate plants are discharged through one stack, the combination of those plants is considered as a single combustion plant and the rated thermal inputs of units are calculated together. Same aggregation rule is applied for the new plants if the plant is installed in such way that, taking into account technical and economical matters, the flue gases of two or more combustion plants could be discharged through one stack. The decision is under consideration of the competent authority.

6.1.1. Emission limit values

As the IED will come into force the emission limit values of power plant shall be determined according to the BAT. Generally the emission limit values shall be stricter than present emission limit values. The difference between the proposed emission limit values for the old and the new plants is small. Emission limit values for sulphur dioxide and nitrogen dioxide in LCP plants will be stricter for almost all sizes of plants. Dust emission limit values will be stricter despite the size of the LCP plant. In the case of combustion of peat separate emission limit values are set for sulphur dioxide. Today the sulphur dioxide emission limit value for the combustion of peat is considered as emission limit value for solid fuels. The proposal will set emission limit value for carbon monoxide for combustion plants. There is no emission limit value for carbon monoxide in present LCP Directive. Underneath there is table 17 where is the difference between the existent emission limits compared to the emission limit values proposed by the IED for the old plants. The emission limit values in BAT BREF documents can also be seen from the table. BAT BREF documents work as guides for applying the Best Available Technique. The emission limit values for combustion of coal will lower 17-40% depending of the rated thermal input of the plant. [20]

Table 17. *Proposed emission limit values for dust emissions in IED and BAT BREF compared to existent limits in LCP directive.*

	Emission limit values (mg/Nm^3)	
	Coal	**Liquid fuels**
50-100 MW		
IED	30	30
LCP directive	50	50
BAT BREF	5-30	5-30
100-300 MW		
IED	25	25
LCP directive	30	30
BAT BREF	5-25	5-25
>300 MW		
IED	20	20
LCP directive	30	30
BAT BREF	5-20	5-20

6.1.2. Emission monitoring requirements

The existent continuous measurement requirements for large combustion plants will be valid also in the directive on industrial emissions but the coming directive includes also monitoring requirements for the carbon monoxide emissions to air. Also the plants that use coal or lignite in the combustion the total emissions of mercury (Hg) have to be determined once a year. [20]

Validated monthly and daily averages are determined in the same way as they are determined today. The confidence interval can be subtracted before the averages are compared to the emission limit values as stated in chapter 2.3.3. [20]

Importance of best available technique will be emphasized and the use of the BREF documents will be controlled more strictly. In the process of restricting emissions in EU the best available technique will be the primary method of approach. Though, the emission limit values are based on the BAT there is no requirement for specific technique or technology to be used to comply with the emission limit values. [20]

Best available technique BREF document for LCP plants will apply for plants which rated thermal input is 50 MW or over. The LCP BREF covers traditional fuels: Coal, lignite, biomass, peat , liquid fuels and gaseous fuels as well as co-combustion of waste derived fuels. Emission levels are stated in the BREF for the pollutants in LCP plants as well as definition of techniques how to reach the emission levels. Specific emission limit values are not stated. The emission levels are based on the daily average values, standard conditions and in specific oxygen content. Oxygen contents are the same as in the LCP directive and coming industrial emission directive. [20]

The means how the best available technique is applied for the specific plant have to be considered in the IPPC permit procedure. With the help of BAT BREF document the operator has to define in the permit application the means how the plant is going to apply best available technique. [20]

Emission levels in the BREF documents are called BAT AEL (Associated Emission Level). Emission limit values which differ from the BAT emission levels can be granted in environmental permits on special occasion. Despite of that the emission limit values cannot exceed the final emission levels stated in the industrial emission directive. Competent authorities shall have the responsibility to confirm that the emission limit values determined for the IPPC permit of the plant will comply with the IED requirements. [20]

7. CONCLUSION

Important source of information for this thesis was the questionnaire that was sent to the representatives of the target countries. There is a histogram in the appendix 3 which shows the number of sent questionnaires to each target country and the number of received answers. Information of the local implementation of environmental matters is difficult to get which can also be seen from the histogram. These matters are complicated for the participating organizations such as authorities, operators, boiler and CEMS suppliers and test laboratories. In some cases the culture or simply the language barrier can block the communication.

This thesis answered to the need of Metso Automation and Metso Power which concerned the level of communication between automation system and emission monitoring system, emission reporting, emission measurement, national emission trading/taxation and determination of emission limit values as well as certification of emission monitoring and reporting solution and continuous emission monitoring system. This thesis built up the knowledge level of Metso Automation and Metso Power on the target countries. This information helps when approaching the market of specific country.

Almost all of the contacts in UK answered to questionnaire. That indicates that they are aware of their own environmental requirements and how they are implemented. The communication language was not an obstacle due to the questionnaire which was in English.

The information gathered by this thesis did not found such information that would block Metso Automation from approaching any of the target country. For instance, according to the study competent authorities in the target countries do not require emission monitoring system to be fully detached from the automation system. Many of the countries allow the full integration of the CEMS and automation system and all of them allow also the semi-integration option

At the moment it is considered that redundant CEMS is required only in UK. It is relevant information to Metso Power, because they often have to manage continuous emission monitoring systems for the customer alongside with the boilers. It means that redundant analysers have to be installed.

In UK MCERTS certification is required for analysers and highly preferred for monitoring and reporting solution. According to the study, no other Member State requires any kind of certification for instance from MCERTS or TÜV. MCERTS certification is planned to be mandatory for the monitoring and reporting solution in one or two years. Though, it is not required yet it is worthwhile to acquire the MCERTS certification now. Communication with the authorities can be easier with the certificate and monitoring and reporting solution suppliers have to acquire it afterwards anyhow.

The study reviled that in Spain authorities perform the emission reporting of the plants. They take the emission data straight out from the analyser and perform needed calculations. Plant owner can use the emission monitoring and reporting solution for process monitoring. The study should be taken further because many things have to be clarified. For example, what are the specific responsibilities of each participating organization? Before Metso Automation can supply EMRS to a plant in Spain, the requirements of competent authority have to be clarified.

Metso Power is supplying continuous emission monitoring systems alongside with boilers. Depending on the contract, Metso Power has to manage sometimes the first QAL2 test. The plant owner has the overall responsibility, but it can share the responsibility with CEMS supplier through the contract.

According to the study and the experience of Metso the requirements differ between the Member States and are expected to differ in the future as well. For instance, many countries tax or trade nationally other pollutants than CO_2 (GHG) and the taxed/traded pollutants differ between countries. Due to the charges, there can be special requirements for the emission calculations. Further studies should be performed to get more detailed information on the effects of national taxation or trading to the CEMS.

In the future the requirements will become stricter due to the industrial emission directive and by the growing importance of best available technique. The emission limit values will lower and the monitoring requirements will be stricter. Emission limit values shall be based on the emission levels stated in the best available technique reference document. It is interesting to see how the IED directive will be implemented by the Member States and does it resolve the problems of today such as the variation in the environmental permit requirements. The Best Available Technique BREF documents are under review at the moment. IED will come into force before the reviewed LCP and Monitoring BAT BREF documents. The emission levels in BAT documents are expected to be stricter than the IED requirements. It is conflicting because the idea of today is that the emission limit values granted in the environmental permits can exceed neither the BAT emission levels nor the IED emission limit values. It is unclear which requirement should be applied. That problem has not been solved yet.

The subject of this thesis was very wide and there was many target countries from which the information was gathered. The results were partly superficial and more detailed information was difficult to find. The schedule of the study was too tight for more detailed investigations, because of the wide subject of the thesis. The results can be still considered as a strong ground for further studies. It covers information on wide perspective from six Member States of EU.

Monitoring of the local environmental legislation is ongoing process. Requirements change and become stricter. Metso's products and services have to adapt with them. Research has to be done continuously. The study on this subject should be done with narrower perspective. For example, it is better to take only one country at a time under examination. Another option could be to look into single area of information and find out how it is interpreted in specific countries. The contact network gathered by this thesis will help in this process.

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APPENDIX 1

Appendix 1. Emission monitoring questionnaire.

Emission monitoring questionnaire

1. **Are there any special requirements for the equipment and monitoring that differ from regulations stated in LCP- and WI directives?**
   e.g. do you require some kind of certification for the equipment or reporting solutions, such as MCERTS or TÜV?

2. **Which emissions should be monitored/reported?**
   Answer yes if reporting is needed for the emission component. Put a mark (X) if the component is measured or calculated. In which unit the emission component is reported? Put a mark if the component has to be measured continuously. There is empty rows, where you can add components if needed.

Large Combustion Plants (LCP)

Pollutant/other data	Reporting needed		Meas. / Calc.		Unit	Continuous meas.
	Yes	No	Measured	Calculated		
NOx						
SO_2						
Dust						
CO						
TOC						
HCl						
HF						
N_2O						
NH_2						
Flue gas flow (wet)						
Flue gas flow (dry)						
Flue gas pressure						
Flue gas temperature						
O_2 concentration						
H_2O concentration						

Waste incineration (WI)

Pollutant/other data	Reporting needed		Meas. / Calc.		Unit	Continuous meas.
	Yes	No	Measured	Calculated		
NOx						
SO_2						
Dust						
CO						
TOC						
HCl						
HF						
N_2O						
NH_2						
Flue gas flow (wet)						
Flue gas flow (dry)						
Flue gas pressure						
Flue gas temperature						
O_2 concentration						
H_2O concentration						

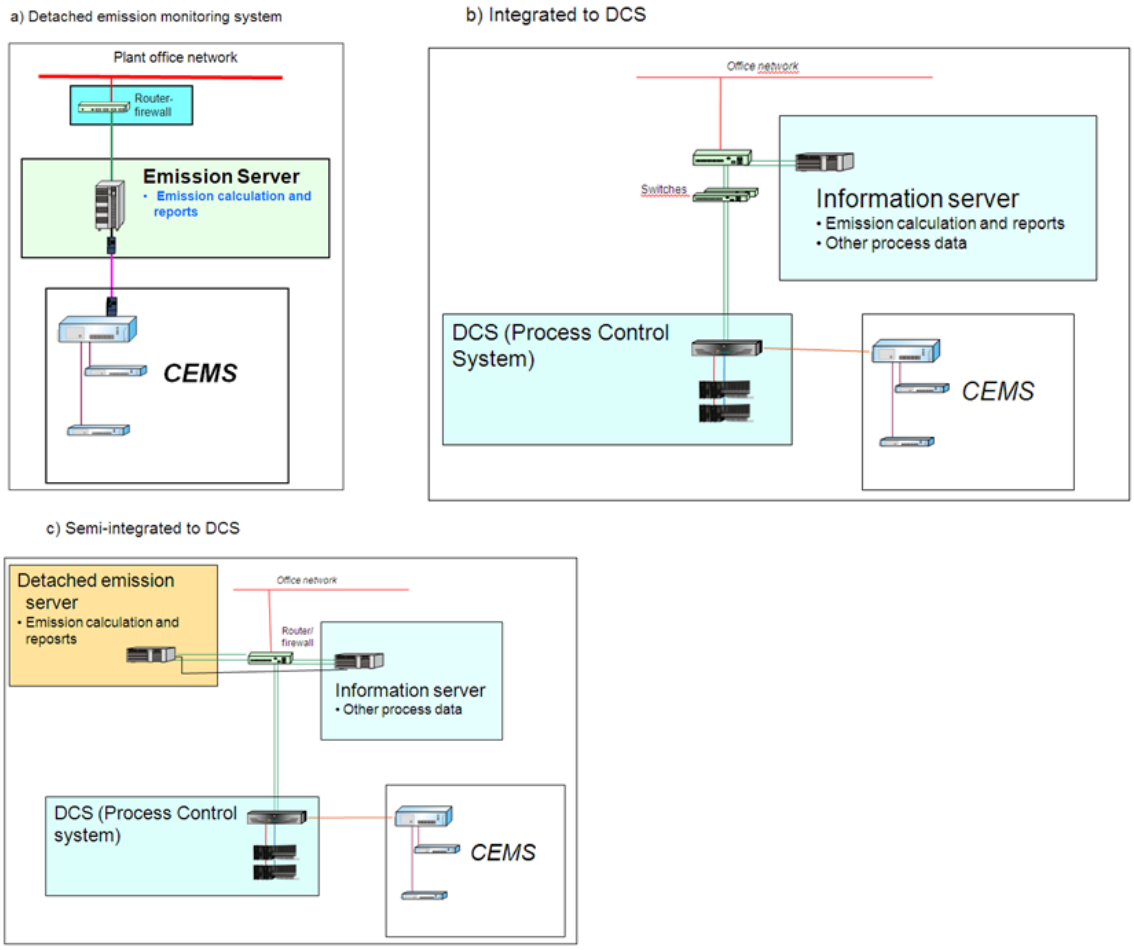
3. **What is the output limit (MW) of a plant after which continuous measurement system is required?**
   In LCP directive the limit is 100 MW.

4. **How are the emission limits calculated for multi-fuel boilers?**
   e.g. is it allowed to calculate online by operator or is it set by competent authority? Please, define more detailed.

5. **Do you comply only the emission limit values mg/m3(n) stated in LCP- and WI directives? If not, what are the tightened limits you have set for your country? Please specify the unit that they are reported in.**

5.1 Do you have any other special requirements?
e.g. requirements for the time the equipment are allowed to be off or out of order.

6. Is it inevitable to have detached emission reporting system or is it possible to integrate it to DCS (Process Control System)?
Choose one of the three options. Please specify if needed. (CEMS = Continuous emission monitoring system)



7. How long plant owner has to store the measurement results and emission reports?

8. Implementation of EN 14181 standard

8.1 What are the uncertainty requirements for the new plants AMS (Automated Measuring System)?
Do you comply the EN standards (EN 14181, EN 14956 and EN 15267-3)?
Please, specify more detailed.

8.2 In general whose responsibility is to manage the first QAL2 tests in the situation of delivering new power plant?
Plant deliverer ***or*** *Plant owner?*

8.3 In the situation that plant supplier starts trial run for the plant, when at the latest the first authority QAL2 tests have to be carried out?

8.4 Which measurands has to be measured/tested in the first QAL 2 test/ reference measurement?

9. **Do you have some national emission trading in addition to EU`s CO_2 trading or some taxation on emissions, such as in Sweden there is tax on NO_x emissions.**

10. **Do you have monitoring requirements for effluents (waste water)?**
e.g. is it allowed to empty the condensation water to river/lake? Do you require some measurements from waste water (fly ash)?

11. Do you have local requirements for measurement platform?
e.g. accessories, reference measurement connections or power supplies? If you have, can you sent related information for us?

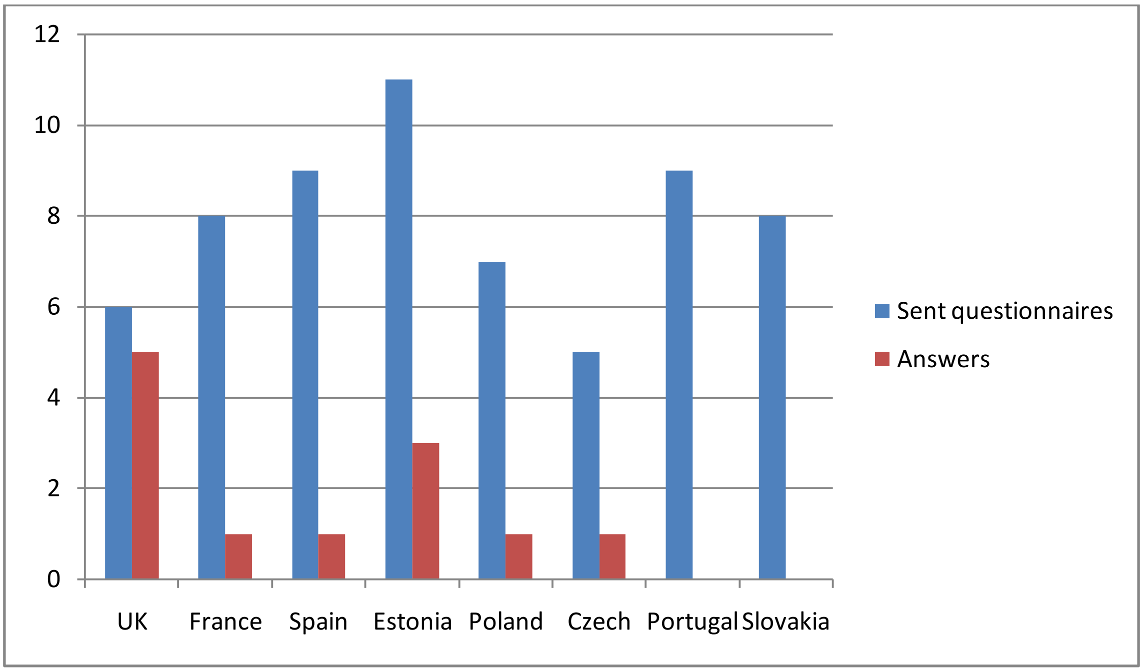
APPENDIX 2

Appendix 2. Water pollutants from large combustion plants.

Parameter	**Parameter***
Ph	TOC
Temperature	N(Total)
Colour	P(Total)
TSS	Cd
TDS	Cr
BOD	Cu
COD	Hg
Mineral oils	Ni
Free chloride	Pb
NH_3	Zn
Fish toxicity	Cl^-
As	F^-
V	PAH
Tl	BTEX
Sb	
Co	
Mn	
Sn	
CN	
S	
SO_3	
SO_4	
EOX	
Phenol	
PCDD/PCDF	
*Sector-specific sub-list for combustion plants which power is over 50MW	

APPENDIX 3

Number of sent questionnaires to each target country and the number of received answers.



APPENDIX 4

Emission limit values for water discharges from flue gas cleaning devices according to waste incineration directive 2000/76/EC.

Pollutants	**Emission limit values expressed in mass concentrations for unfiltered samples**	
Total suspended solids	$\frac{95\%}{30\ mg/l}$	$\frac{100\%}{45\ mg/l}$
Mercury and its compounds , expressed as mercury (Hg)	0,03 mg/l	
Cadmium and its compounds, expressed as cadmium (Cd)	0,05 mg/l	
Thallium and its compounds, expressed as thallium (Th)	0,05 mg/l	
Arsenic and its compounds, expressed as arsenic (As)	0,15 mg/l	
Lead and its compounds, expressed as lead (Pb)	0,2 mg/l	
Chromium and its compounds, expressed as chromium (Cr)	0,5 mg/l	
Copper and its compounds, expressed as copper (Cu)	0,5 mg/l	
Nickel and its compounds, expressed as nickel (Ni)	0,5 mg/l	
Zinc and its compounds, expressed as zinc (Zn)	1,5 mg/l	
Dioxins and furans, defined as the sum of the individual dioxins and furans I-TEC	0,3 mg/l	