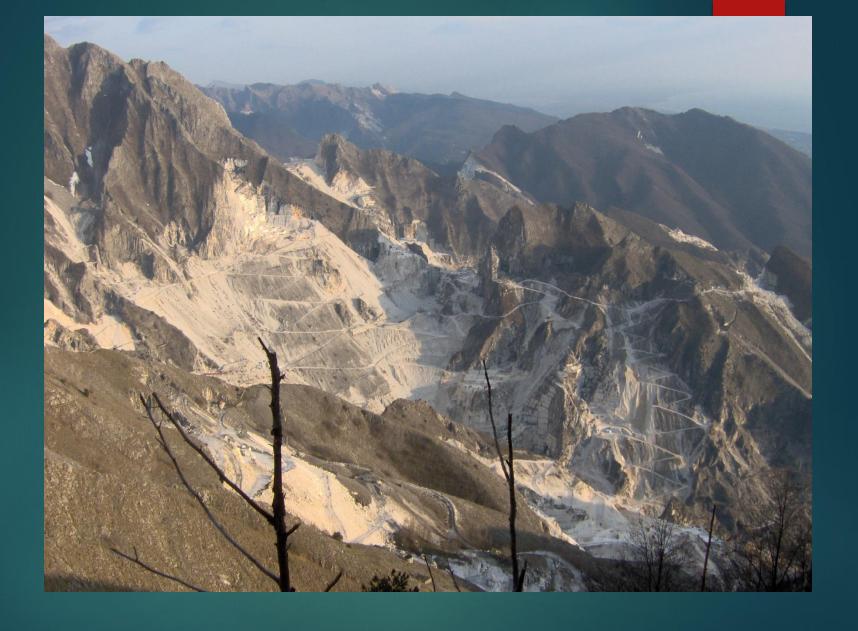
Environmental impact of energy resources and conversion











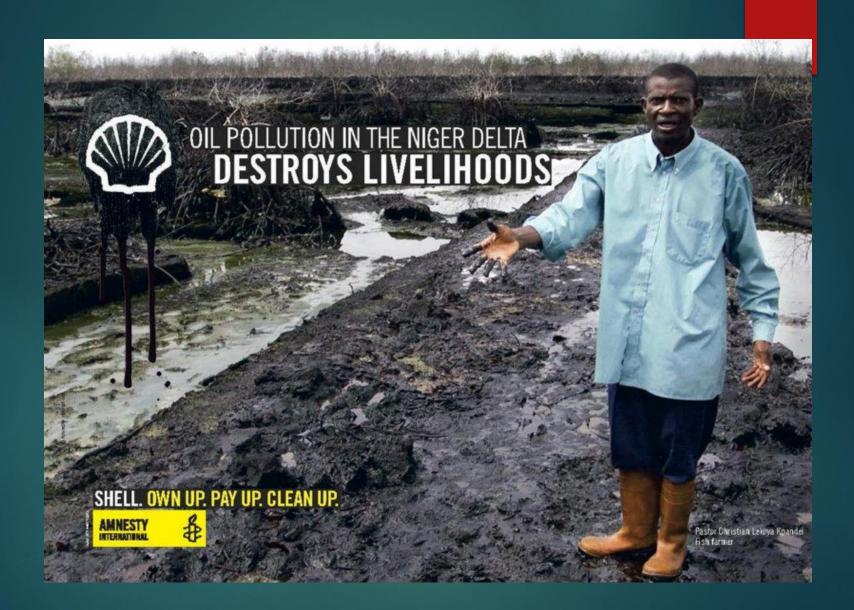








Energy resource









The Deepwater Horizon oil spill

▶ The **Deepwater Horizon oil spill** (also referred to as the BP oil spill, the BP oil disaster, the Gulf of Mexico oil spill, and the Macondo blowout) began on 20 April 2010 in the Gulf of Mexico on the <u>BP</u>-owned <u>Transocean</u>-operated <u>Macondo</u> Prospect. Following the explosion and sinking of the Deepwater Horizon oil rig, a sea-floor oil gusher flowed for 87 days, until it was capped on 15 July 2010. [6][7] Eleven people went missing and were never found [6] [8] [9] [10] and it is considered the largest accidental marine oil spill in the history of the petroleum industry, an estimated 8% to 31% larger in volume than the previously largest, the <u>lxtoc I oil spill</u>.



Uranimum





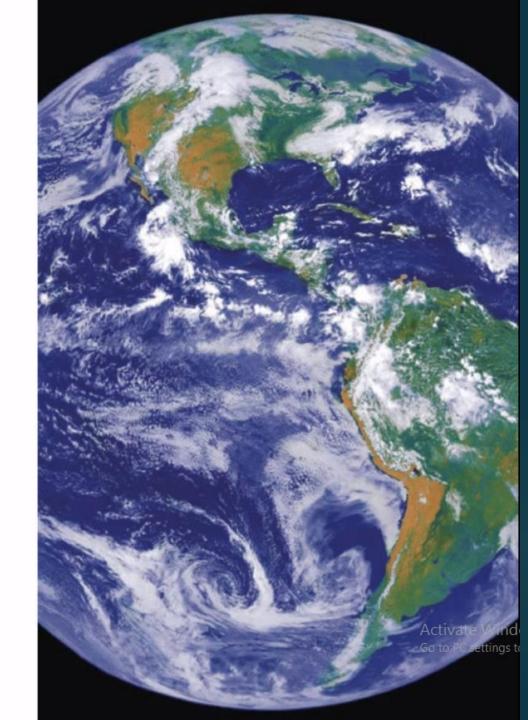
Air Pollution

Enough Chemicals, Particles, or Microorganisms in the troposphere to harm.



The Grand System

A global system of inputs and outputs



Clean Air Act

- 1970
- Identified 6 Criteria air pollutants for the EPA to regulate
- Sulfur Dioxide, Nitrogen Oxides, Carbon monoxide, Particulate Matter, Lead, Ozone
- Carbon Dioxide, Mercury, and VOCs have been added to the list
- Subject to political pressures

Sulfur Dioxide

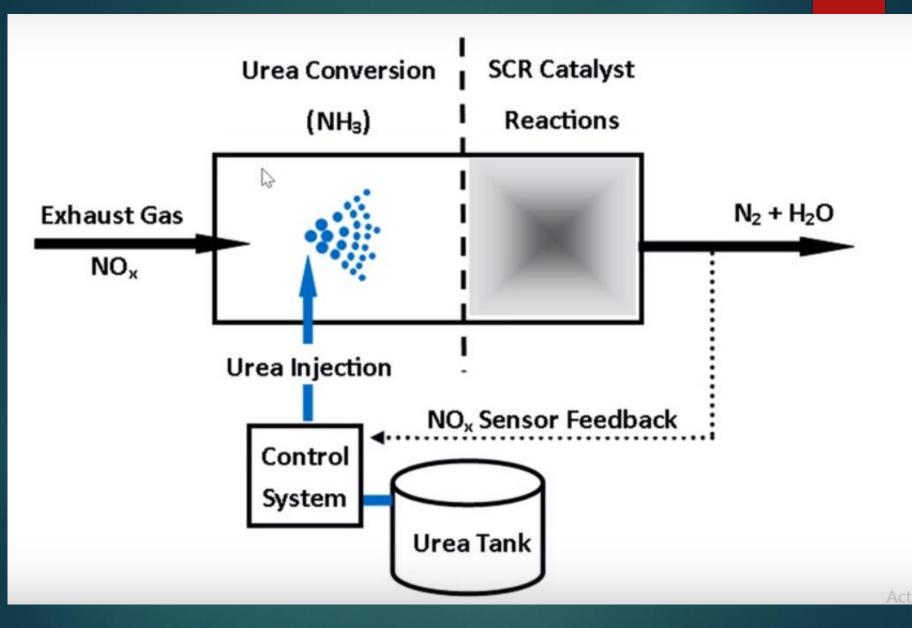
Corrosive gas released by burning fossil fuels. Respiratory irritant that can damage plants.



Nitrogen Oxides

Anthropogenic and Biological sources. Major component of tropospheric ozone and smog.

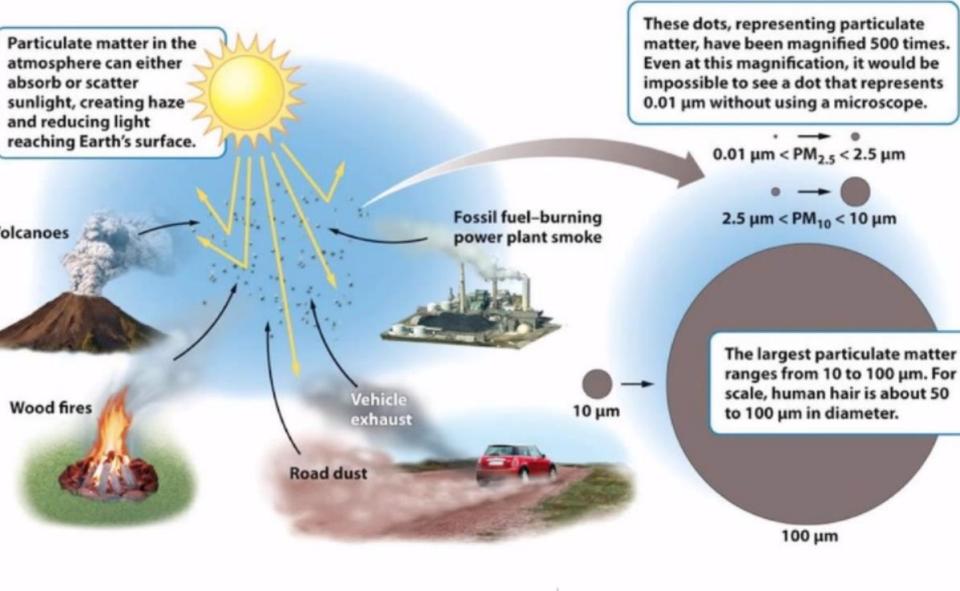




Carbon Oxides

Carbon Monoxide and Carbon Dioxide





Primary vs. Secondary Pollutants

From the source or chemistry needed



Volatile Organic Compounds (VOCs)

Organic compounds that vaporize at room temp. Strong smells. Role in ozone formation.



Literature review on atmospheric emissions SO_2 , NO_x and associated environmental effects from conventional power plant, case study from JORDAN IPP3 Diesel Engine Power Plant

Content

- •literature review
- Emissions, regulation and policy
- •Case Study Evaluation of ${\rm SO_2}$, ${\rm No_x}$ Emission from IPP3 Power Plant Based on International and National Environmental Regulation
- •Emissions Reduction for Diesel Engine
- Emissions Monitoring
- Results

Organization of the literature review document

For priority substances (sulfur dioxide SO_2 , nitrogen oxide NO_x), abstracts are categorized by pollutant type and sub-categorized by the study objective. The subcategories are arranged as follows:

- Emissions, atmospheric deposition, and modeling
- Environmental effects
- Regulation and policy



Summary of findings and key studies

A total of 25 abstracts related to emissions and environmental effects of pollutants associated with electricity generation. The abstracts cover a range of fuel types (coal, diesel, oil, natural gas, biomass). The following section provide a brief overview of the search results on a pollutant-by-pollutant basis.

A- Sulfur dioxide SO₂

research focus on the environmental effects of Sulfur dioxide are on aspects of forest health (Akselsson et al. 2004), soil biogeochemistry (Hultberg and Ferm 2006), and acidification of terrestrial and aquatic ecosystems (e.g., Fenn et al. 2006), ecological responses to declines in atmospheric deposition of Sulfur dioxide (e.g., Laudon and Bishop 2002; Watras and Morrison 2008), modeling forest response to changes in deposition rates (Gbondo-Tugbawa et al. 2002), and comparative assessments of emissions from different fuel types (e.g., de Castro Villela and Silveira 2006; Chatzimouratidis and Pilavachi 2007).

Author and year	Title
Chatzimouratidis and Pilavachi 2007	Objective and subjective evaluation of power plants and their nonradioactive emissions using the analytic hierarchy process
de Castro Villela and Silveira 2006	Thermo economic model considering the environment impacts on thermoelectric power plants: Natural gas versus diesel
Fenn et al. 2006	Status of soil acidification in North America
Gbondo-Tugbawa et al. 2002	A model to simulate the response of a northern hardwood forest ecosystem to changes in S deposition
Puig et al. 2008	Sulfur isotopes as tracers of the influence of a coal-fired power plant on a Scots pine forest in Catalonia (NE Spain)
Tzimas et al. 2007	Trade-off in emissions of acid gas pollutants and of carbon dioxide in fossil fuel power plants with carbon capture

B -Nitrogen oxides

As with Sulfur dioxide, nitrogen oxides are appearing atmospheric pollutants with multiple anthropogenic sources. Researchers continue to focus on the impacts of anthropogenic nitrogen on forests, with studies throughout North America and Europe documenting increases in nitrate export (e.g., Dise and Gundersen 2004), changes in soil chemistry (Aber 2003), eutrophication (e.g., Rodriguez and Macias 2006), changes in plant growth rate and community composition (Kochy and Brakenhielm 2008), and loss of biodiversity (Dise and Stevens 2005). Other relevant studies examined aspects of nitrogen source apportionment (Fenn et al. 2003), monitoring of power plant emissions (e.g., Kim et al. 2006), and life-cycle assessment on the effect of GHG capture technologies on emissions of other pollutants (e.g., Tzimas et al. 2007)

Author and year	Title
Aber et al. 2003	Is nitrogen deposition altering the nitrogen status of northeastern forests?
Chatzimouratidis and Pilavachi 2007	Objective and subjective evaluation of power plants and their nonradioactive emissions using the analytic hierarchy process
de Castro Villela and Silveira 2006	Thermo-Economic model considering the environment impacts on thermoelectric power plants: Natural gas versus diesel
Dise and Gundersen 2004	Forest ecosystem responses to atmospheric pollution: Linking comparative with experimental studies
Dise and Stevens 2005	Nitrogen deposition and reduction of terrestrial biodiversity: evidence from temperate grasslands
Fenn et al. 2003	Nitrogen pollution in the northeastern United States: Sources, effects, and management options
Kim et al. 2006	Satellite-observed US power plant NO _x emission reductions and their impact

Sulfur dioxide and Nitrogen oxides

Fottova, D. 2003. Trends in Sulfur and Nitrogen deposition fluxes in the GEOMON network, Czech Republic, between 1994 and 2000. Water Air and Soil Pollution 150: 73-87.

Abstract: Deposition fluxes of sulphur and nitrogen in bulk and throughfall precipitation were monitored for the 1994-2000 period for seven small forest catchments in the GEOMON network, Czech Republic (CR). Four catchments are situated at similar elevations (roughly between 800 and 1000 m) and represent three areas: the Black Triangle near the Krusnehory Mts. coalfield (catchments JEZ and LYS), the Orlickehory Mts., close to the Polish industrial regions (UDL), and the Sumava Mts., a relatively unpolluted area (LIZ). Three catchments (GEM, POM, LES) lie at lower elevations (400-600 in) in Central Bohemia. A substantial decrease in the bulk and throughfall deposition of pollutants occurred as a result of the desulphurisation programme implemented in the Czech Republic between 1996 and 1998. A reduction has been described mainly in the Krusnehory Mts. (JEZ), in Slavkovskyles (LYS) and also in Central Bohemia (GEM). The decrease in the throughfall to less than one half within a single year in POM (Central Bohemia) was an example of a direct response to the local emission reduction in the nearby Chyaletice power plant. However, in some areas, the throughfall deposition of sulphur, which includes wet and dry deposition, is still significant, especially at higher elevations. Recent forest degradation was observed in the Orlickehory Mts., where, particularly in 1998, as much as 91.1 kg S was found in coniferous throughfall. The fraction of dry deposition in the coniferous forests of CR represents 30-70% of the total deposition. The difference between coniferous (higher) and deciduous (lower) throughfall fluxes is significant because of the larger surface area of conifers and year-round exposure to air-borne sulphur. At several of the GEOMON sites, the flux of nitrogen via throughfall increased during the observation period and, at the end of the studied period (2000), nitrogen became the main source of acidification, replacing sulphur compounds. hest fluxes (81.7 kg N ha-1 yr-1) were measured in 2000 in the Orlicke? hory Mts., which an example of multiple causes of forest decline - the direct impact of air pollution, abu ace of nitrogen, acidification and secondary stressors (weather changes, insect pests, Infections). A comparison is given with data from other countries.

Kaldellis, J. K., G. T. Vlachos, A. G. Paliatsos, and E. M. Kondili. 2005. Detailed examination of the Greek electricity sector nitrogen oxides emissions for the period 1995- 2002. Environmental Science & Policy 8:502-514.

Abstract: The importance of energy in economic development has been globally recognised, A considerable electricity consumption increase has taken place in Greece since the country's incorporation in the European Union. Unfortunately, the electricity generation up to now is mainly based on fossil fuels. As a direct result of this policy, electricity generation is one of the main contributors it) the Greek air pollutant emissions. The present work is focused on investigating in detail the corresponding nitrogen oxides emissions for the period 1995-2002. One of the most negative observations resulting from the presented analysis is that the undesirable NOx emissions factors increase, mainly during the last 3 years of the period analysed. Moreover, annual NOx emissions continue to increase, as a result of the noteworthy electricity consumption amplification registered during the concerned period. Therefore, local data were compared with similar information from the literature regarding other territories and then used accordingly to evaluate the Greek compliance with the existing EU decisions (e.g. Directive 2001/80/EC). Finally, considering that more than 90% of national electricity production is based on carbon containing fuels, further emissions of noxious nitrogen oxides increase is expected for the next described appropriate abatement technologies are promptly applied.

Kim, S. W., A. Heckel, S. A. McKeen, G. J. Frost, E. Y. Hsie, M. K. Trainer, A. Richter, J. P. Burrows, S. E. Peckham, and G. A. Grell. 2006. Satellite-observed US power plant NOx emission reductions and their impact on air quality. Geophysical Research Letters 33.

Abstract: Nitrogen oxide (NOx) emissions resulting from fossil fuel combustion lead to unhealthy levels of near-surface ozone (O-3). One of the largest U. S. sources, electric power generation, represented about 25% of the U. S. anthropogenic NOx emissions in 1999. Here we show that space-based instruments observed declining regional NOx levels between 1999 and 2005 in response to the recent implementation of pollution controls by utility companies in the eastern U. S. Satellite-retrieved summertime nitrogen dioxide (NO2) columns and bottom-up emission estimates show larger decreases in the Ohio River Valley, where power plants dominate

McGonigle, A. J. S., C. L. Thomson, V. I. Tsanev, and C. Oppenheimer. 2004. A simple technique for measuring power station SO_2 and NO_x emissions. Atmospheric Environment 38:21-25.

Abstract: Emissions of SO2 and NO2 from fossil fuel power stations can have serious environmental consequences via conversion to sulphuric and nitric acids and subsequent deposition. Consequently, there is considerable interest in techniques capable of monitoring these emissions, in order to ensure compliance with environmental legislation. Here we present a novel approach to measuring power station SO2 and NO2 emissions by traversing underneath the plume by car or on-foot or scanning the power station's plume from a fixed position with a compact and lightweight UV spectrometer. This work was performed at a power station in eastern England during January, February and June 2003, resulting in a SO2 flux of 5.2 kg s(-1), which is in above correspondence with the in-stack measured value of 5.3 kg s(-1). This technique is rably simpler and cheaper than other remote sensing approaches to monitoring these

Hondo, H. 2005. Life cycle GHG emission analysis of power generation systems: Japanese case. Energy 30:2042-2056.

Abstract: This study presents the results of a life cycle analysis (LCA) of greenhouse gas emissions from power generation systems in order to understand the characteristics of these systems from the perspective of global warming. Nine different types of power generation systems were examined: coal-fired, oil-fired, LNG-fired, LNG-combined cycle, nuclear, hydropower, geothermal, wind power and solar-photovoltaic (PV). Life cycle greenhouse gas (GHG) emission per kW h of electricity generated was estimated for the systems using a combined method of process analysis and input-output analysis. First, average power generation systems reflecting the current status in Japan were examined as base cases. Second, the impacts of emerging and future nuclear, wind power and PV technologies were analyzed. Finally, uncertainties associated with some assumptions were examined to help clarify interpretation of the results.

Ali, M., Athar, M., and Ali, E. 2007. The emissions and environmental impact of power plants operating on fossil fuel at Distt. Kasur, Pakistan. Ekoloji 16: 74-80.

Abstract: A comprehensive assessment of four power plants operating on fossil fuel (Diesel Power Plant) was conducted near the industrial area of Raiwind, Distt. Kasur, Pakistan. The installed capacity of these power plants is 117 MW, 112 MW, 90 MW, and 60MW respectively. The emissions of all the engines of the individual plants were monitored for six months at an interval of fifteen days. The emissions of priority pollutants Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Sulfur Dioxide (SO2), Suspended Particulate Matter (SPM), Lead (Pb) and Mercury (Hg) were monitored. The emission results of the four plants were compared and some of the pollutant parameters were found higher when compared with local National Environmental Quality Standards (NEQS) as well as the World Bank guidelines for Power Plants. The ground level ambient air quality at 1 km downwind was also monitored for 24 hours at each individual

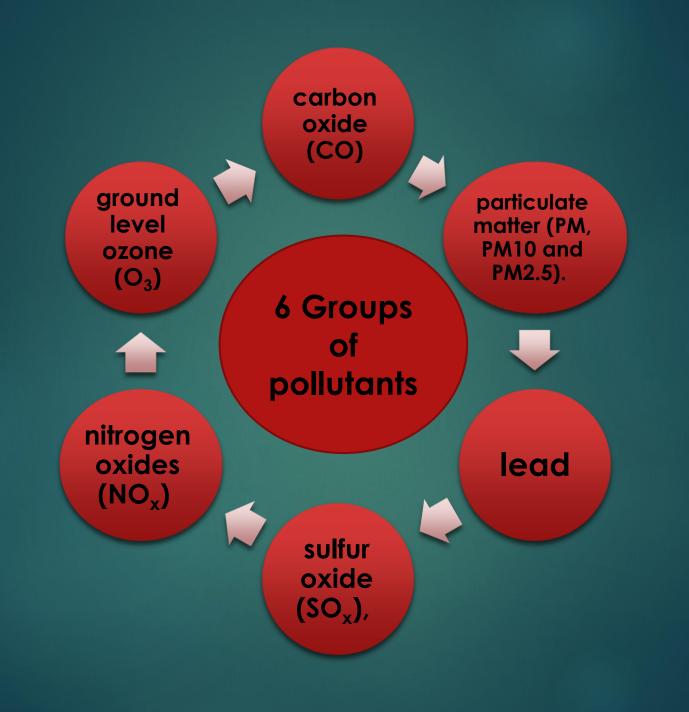
Environment

Environment Impact

The environment refers to all that surrounds such as water, air and land as well as biodiversity, various forms of energy, systems and natural processes that influence human health and well being.

The effect of an activity on the environment, whether positive or negative. Negative environmental impacts will result in damage and/or pollution to the environment or in endangerment to local communities.

MITIGATION



Why Nitrogen Oxides (NO_x)

When fuels are burned, nitrogen (N₂) and oxygen (O₂) are combined at high temperatures and pressure, resulting in compounds like nitrogen

dioxide (NO₂) and nitric monoxide (NO).

Once released into the atmosphere, such compounds play an important role in creating harmful particulate matter, ground-level ozone (smog) and acid rain.

NO_x emissions contribute to the formation of fine particles and ozone smog that cost billions annually from illnesses, deaths and environmental problems

Ground-level ozone makes it harder to breathe

What are the harmful effects of NO_x emissions?

Health Effects:

- Coughing, and pain when taking deep breaths;
- •Wheezing and breathing difficulties during exercise or outdoor activities;
- Inflammation on the skin;
- Respiratory illnesses like pneumonia and bronchitis; and,
- Permanent lung damage with repeated exposures.

Environmental Effects:

- Interfering ability plants to produce and store food;
- Damaging the leaves of trees and other plants, negatively impacting the appearance of urban vegetation,
- Reducing forest growth and crop yields, potentially impacting species diversity in ecosystems



Why Sulfur Oxides (SO_x)

The two major ones being sulfur dioxide (SO₂) and sulfur trioxide (SO₃). Sulfur dioxide is a colorless gas.

Itself can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation.

When dissolved by water vapor to form acids it can again have adverse effects on the respiratory systems of humans and animals, and it can cause damage to vegetation, buildings and materials.

NEED VS MITIGATION

Emissions, regulation and policy

World Bank. 1991. "Guideline for Diesel Generating Plant Specification and Bid Evaluation." Industry and Energy Department Working Paper, Energy Series Paper 43. Washington, D.C.

WHO (World Health Organization). 1987. Air Quality Guidelines for Europe. Copenhagen: WHO Regional Office for Europe.

United States. CFR (Code of Federal Regulations). Washington, D.C.: Government Printing Office.

IEA (International Energy Agency.) 1992. Coal Information. Paris

Relevant National Legislation laws and Regulations

- •The Environment Protection Law No. 52 for the year 2006.
- •The Protection of the Environment from Pollution in Emergency Situations Regulation No. 26 for the year 2005.
- Air Protection Regulation No. 28 for the year 2005.
- •Regulation of Controlling the Use of Substances that Deplete the Ozone Layer for the year 2003, issued in accordance with Law No. (1) 2003 Articles 9-15; 'Law for the Protection of the Environment'.
- Jordan Noise Regulations for 1997.
- •Groundwater Control Regulation No. 85 of 2002, Issued pursuant to Articles 6 and 32 of Water Authority Law No. 18 or 1988.

Relevant National Standards and Instruction

- •Standard for the Maximum Allowable Limits of Air Pollutants Emitted from Stationary Sources (JS 1189/1998).
- •Standard for the Requirements for Discharges of Industrial Effluents (JS 202/1991).
- Standards for the prevention and elimination of noise (2003).
- Jordanian Emissions Standards for Electricity Generation (1999).
- •Instruction for Controlling the Use of Substances that Deplete the Ozone Layer for the year 2003, issued in accordance with Law No. (1) 2003 Articles 9-15; 'Law for the Protection of the Environment'.

Regional and International Agreements and Protocols

Emission Guidelines and Standards

Parameter	WB / IFC EHS Guidelines	Jordanian Standards
NO _x	740 mg/m ³	740 mg/m ³
SO ₂	585 mg/m³ or use of 1% or less	S in fuel 6,500 mg/m ³

Solutions to Pollution

Pollution prevention (input control) Front-of-the-pipe

Pollution cleanup (output control) End-of-the-pipe

EXAMPLE:

FGD Vs. 1% Sulfur content, cost trade! flue-gas desulfurization unit

Evaluation of SO₂, No_x Emission from *IPP3* Power Plant Based on International and National Environmental Regulation

Overview: IPP3 - Jordan Power Plant

The plant is powered by 38 Wärtsilä 50DF multi-fuel engines with a combined capacity of 573 MW " 18V50DF

Fast starting and the capability of ramping output up and down quickly and efficiently.

Caption: IPP3 is the world's largest internal combustion engine power plant.

wartsila_20v46f_power_plant_concept_animation.wmv



The world's largest diesel engine
power plant
is the 573 MW IPP3 Project
built by
Amman Asia Electric Power Company
(Jordan)
as verified on 23 October 2014

OFFICIALLY AMAZING







Dual fuel engine

Wärtsilä 50DF Diesel Engine Generators (Units) are usually installed for dual fuel operation meaning the Unit can be run either on a Natural Gas or on a liquid fuel (diesel) operating mode.

The operating mode can be changed while the Unit is running, within certain limits, without interruption of power generation.

If the Natural Gas supply fails, the Unit will automatically switch to liquid fuel mode operation (using HFO or Distillate Fuel)

Heavy Fuel Oil

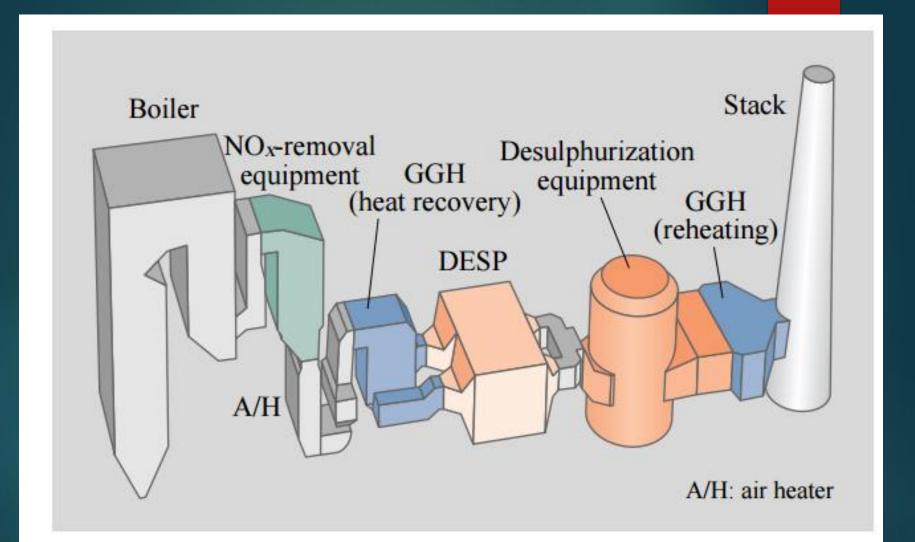
Natural Gas mode operation

In the Natural Gas operating mode, the main fuel is Natural Gas which is injected into the Diesel Engine Generator at a low pressure. The Natural Gas is ignited by injecting a small amount of pilot Distillate Fuel. Natural Gas and pilot fuel injection are solenoid operated and electronically controlled common rail system.

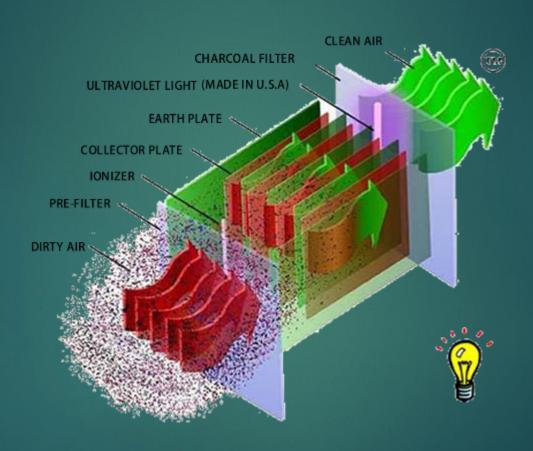
Liquid Fuel mode operation

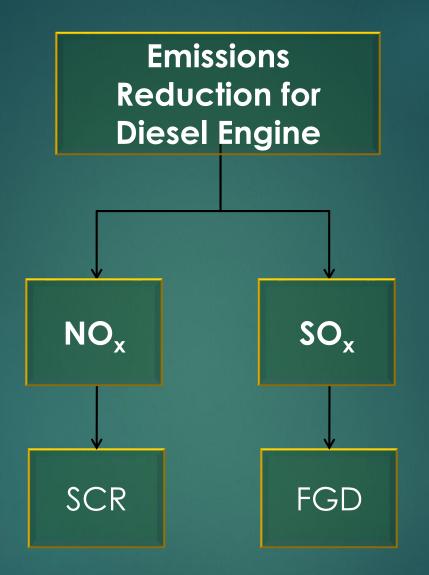
In the liquid (diesel) fuel operating mode, the Units operate only on liquid fuel oil. HFO or Distillate Fuel is used as fuel with a conventional diesel fuel injection system. The liquid fuel pilot injection is always active.

Engines-final..mpeg



dry electrostatic precipitator







SCR system

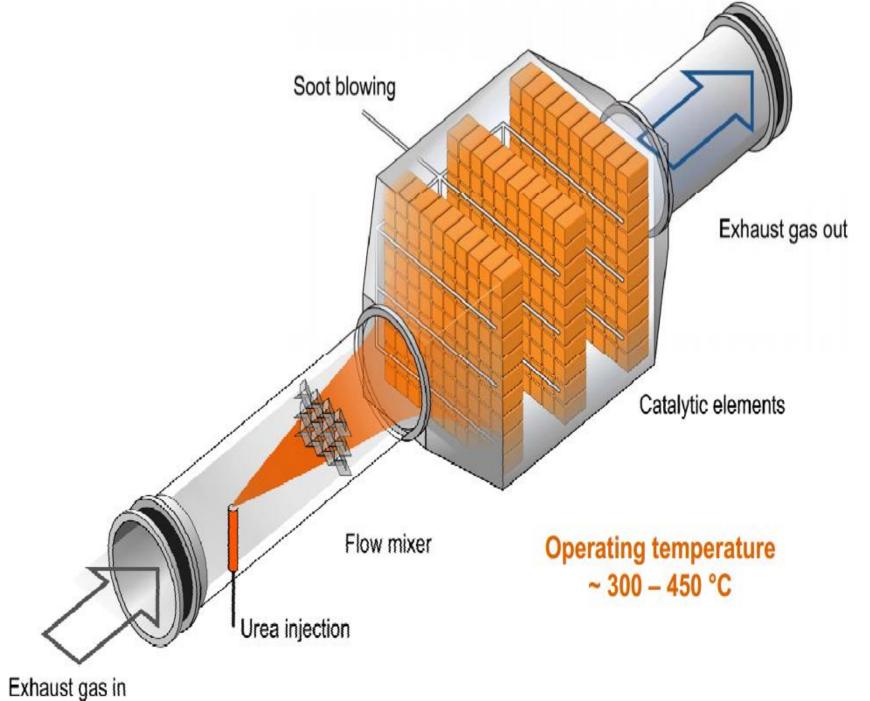
<u>Selective Catalytic Reduction (SCR)</u> is an advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. The reductant source is usually automotive-grade **urea**, otherwise known as **Diesel Exhaust Fluid** (DEF).

NO_x formation and reduction

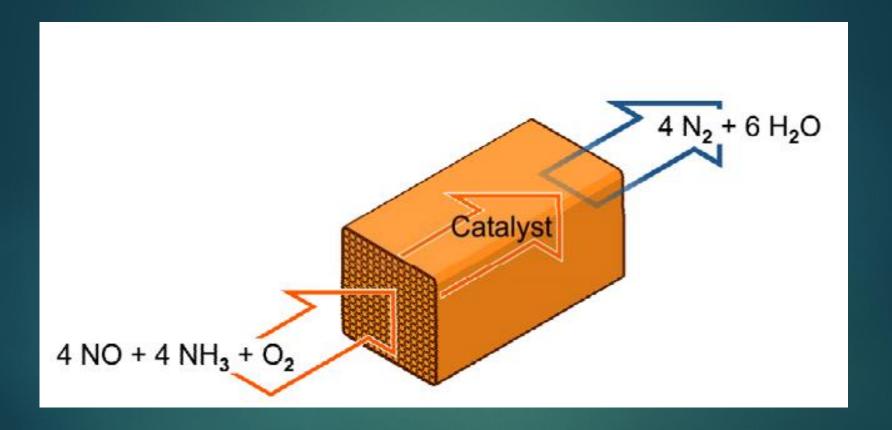
- Nitrogen Oxides (NO_x) are formed during the combustion process from oxygen (O_2) and nitrogen (N_2) in air.
- The NO_X Reducer SCR catalyst converts NO_X molecules back to harmless O_2 and N_2 molecules by means of urea.

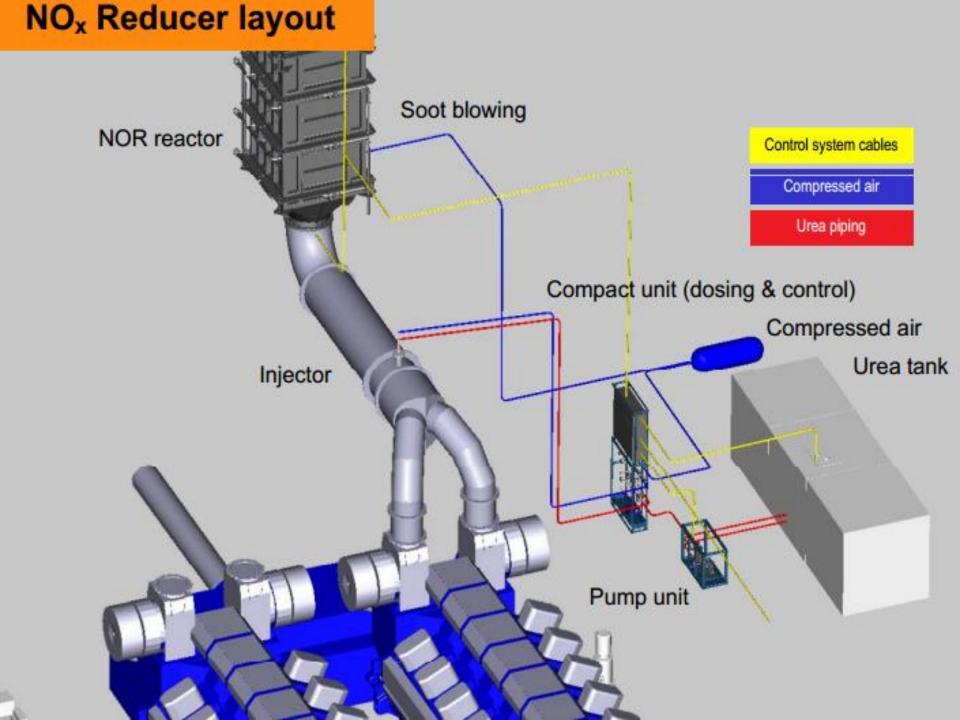
NO_x reducer – description

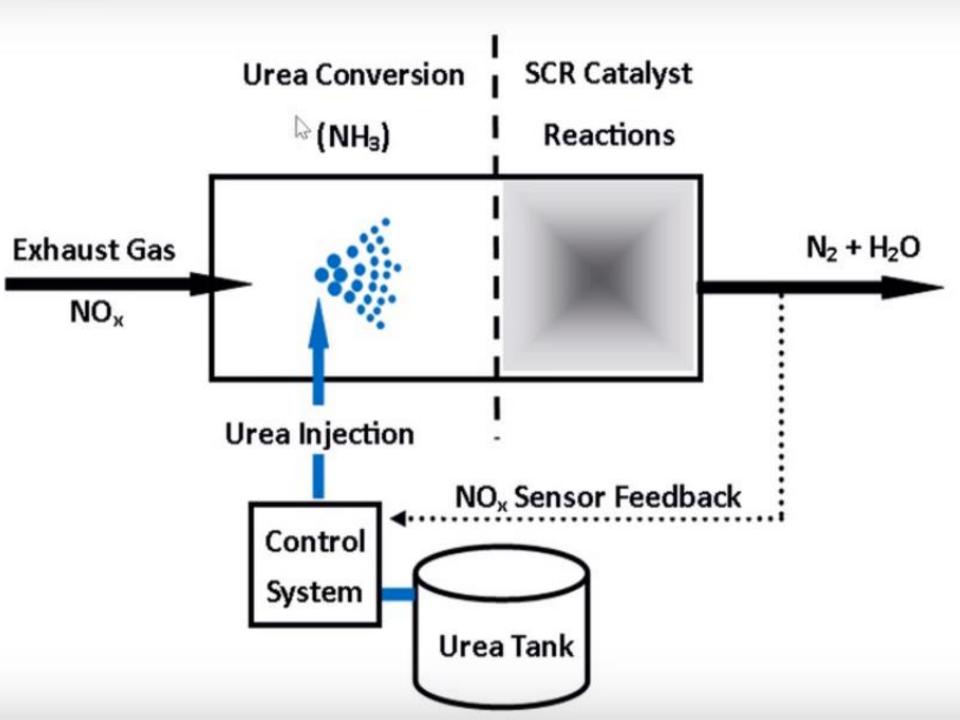
- The Nitrogen Oxide Reducer (NOR) is based on selective catalytic reduction (SCR) technology. The NO_X reducer portfolio covers medium-speed engine portfolio for marine applications.
- The size of the NO_X Reducer is optimized in terms of modularity, performance and costs. The typical NO_X emission reduction is 90 %.
- The main component of the NO_X reducer installation is the reactor with the catalyst inside. Other modular essential parts of NOR system are agent pumping unit a reagent dosing unit a control unit and an a reagent dosing unit, a control unit and an injection unit.
- •Nitrogen oxides (NO_X) are reduced into nitrogen (N_2) and water vapor (H_2O) using ammonia or urea at a suitable temperature on the surface of the catalyst.



Catalytic elements





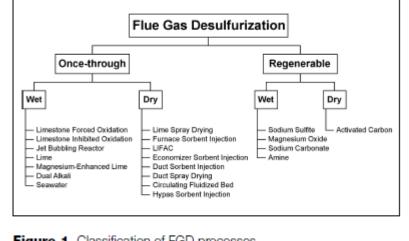


FGD (Flue Gas Desulfurization)

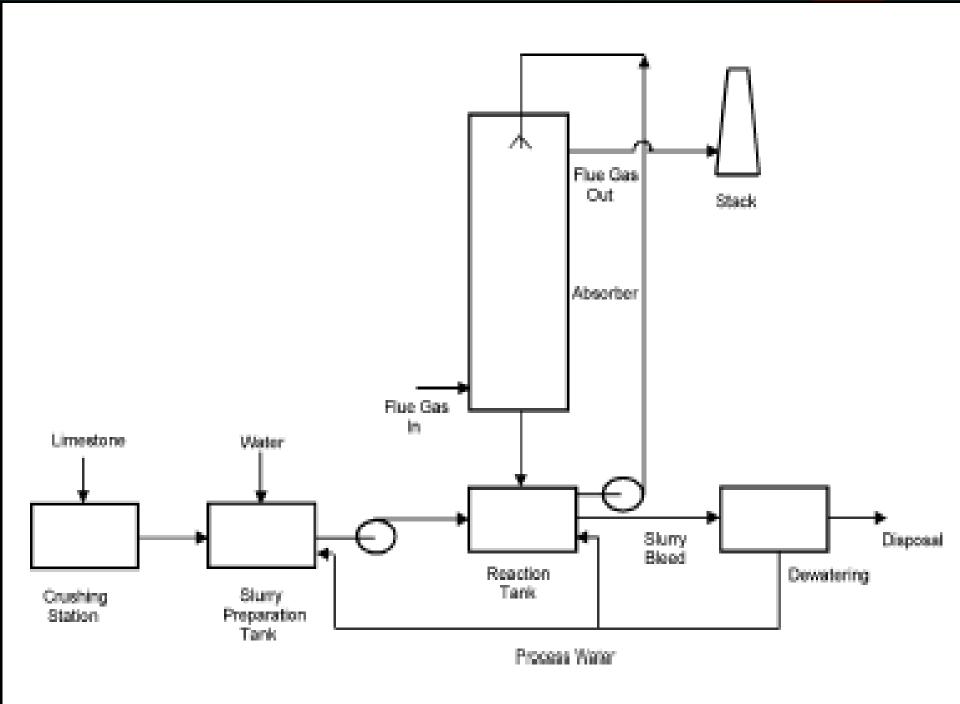
Flue Gas Desulfurization is a method of controlling the emission of sulfurs.

Flue Gas Desulfurization takes place in a complex, large-scale chemical reactor which is located between the combustion chamber and the smokestack. The combustion products (flue gases) are exposed to a lime or limestone slurry that is sprayed in their path. Sulfur dioxide in the gas reacts with the spray and goes into solution, from which it is later removed, dewatered and extruded in the form of

sludge.







Emissions Monitoring

Engines will be equipped with pollution control technology which will limit NOx levels to a maximum of 740mg/Nm3 during HFO firing.

The emission of sulphur dioxide (SO2) into the atmosphere is directly related to the sulphur content in the fuel oil. The fuel supply contracts will specify sulphur content for HFO of less than 1% weight by weight (w/w) and DFO typically has a lower sulphur content of less than 1% w/w.



Emissions Monitoring





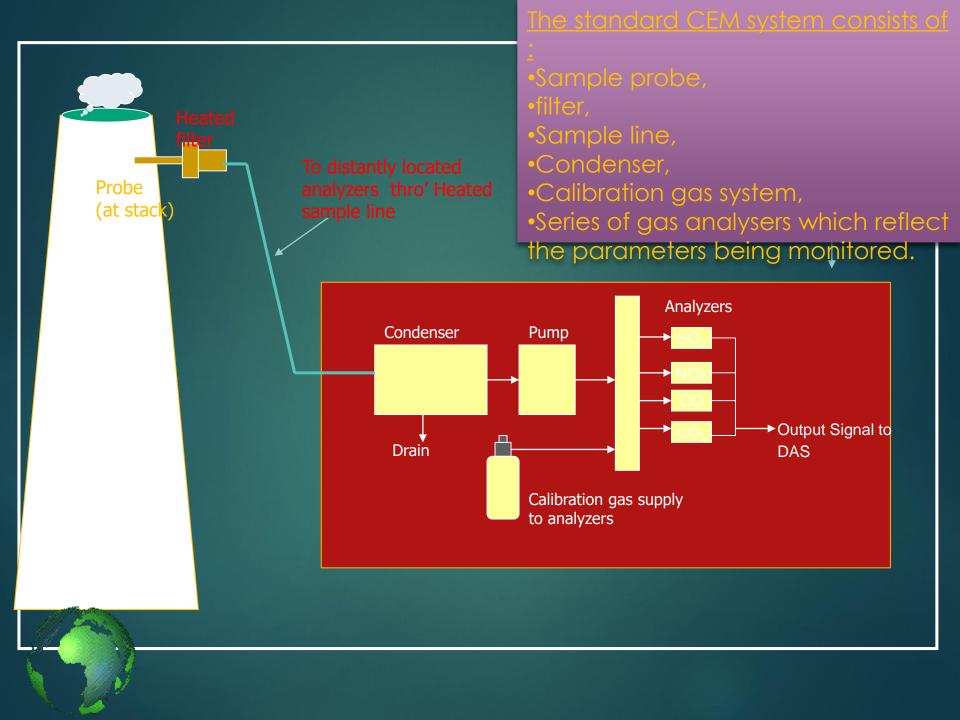
Automatic: CEMS Analyzer

Continuous Emissions Monitoring System (CEMS) is a perfect tools to monitor flue gas to provide information for combustion control in Monitoring exhaust from power plant.

Typical monitored emissions include: <u>sulfur dioxide</u>, <u>nitrogen oxides</u>, <u>carbon monoxide</u>, <u>carbon dioxide</u>, hydrogen chloride, airborne particulate matter, volatile organic compounds, and oxygen.

CEM systems can also measure air flow, flue gas opacity and moisture.





Benefits of CEMS

- Provides real time data.
- Remotely accessible to operator/regulator.
- Continuous performance check of Air Pollution Control Devices and optimization of resources used.
- Time series analysis possible with continuous data.
- Reduction in regulatory cost as well as long term monitoring cost.



Manual: Testo 350 Portable Emission Analyzer

Test up to six gases simultaneously, or swap sensors out:

O2, CO, COlow, NO, NOlow, NO2, SO2, H2S, CO2 (NIDIR), CH (total hydrocarbons)

AC and rechargeable battery operation with optional DC connection operation

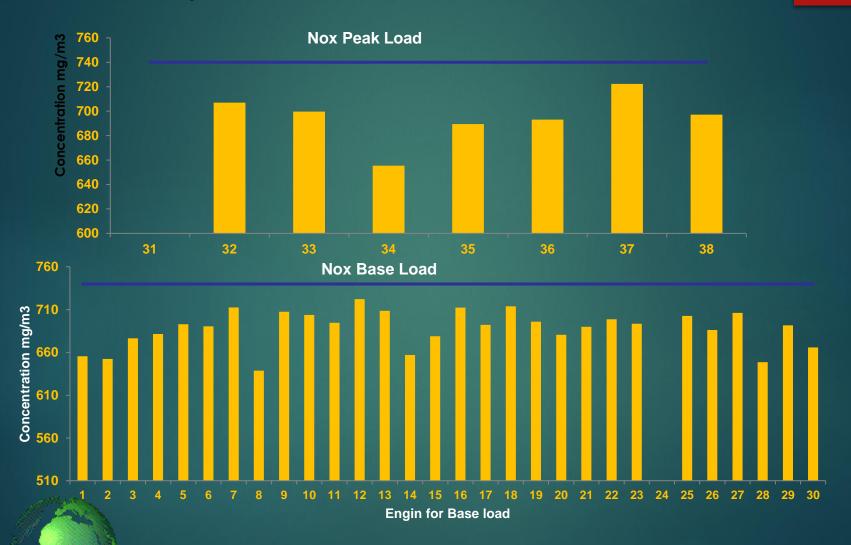
Flow rate and sensor temperature monitoring for US EPA CTM-030, -034, ASTM D6522, and SCAQMD 1110.2 and 1146 requirements

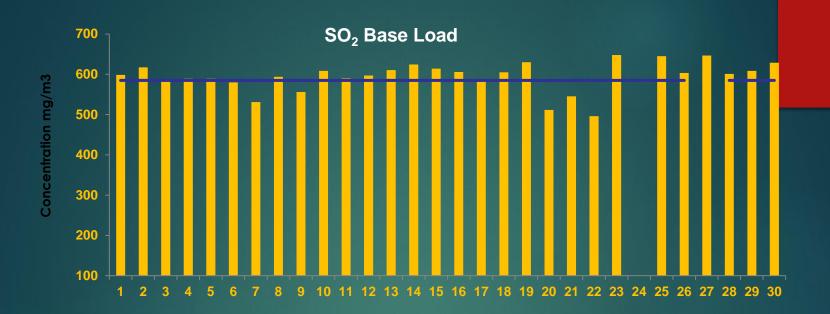


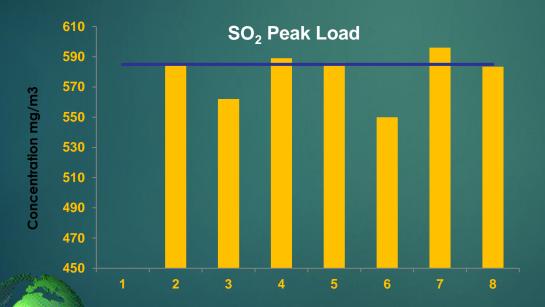


Example

Evaluate of Sep-2015







Evaluation for result:

Mitigation Techniques "Reduction Techniques" plays vital rule to keep emission complies with the environmental regulation and standards.

Standard and Regulation set the regulatory frame work.

Monitoring Techniques is a way to ensure the compliance of the power plant are within the allowable limitations, it is also used for reporting.

The emission result of the IPP3 power plant was found as follows:

- All NO_X readings of emissions are less than the local environmental quality standard as well as World Bank guidelines for power plants.
- •Some violation for the SO₂ measurements but the yearly violation is about 3.9 % (the allowable yearly violation is 5%). Anyway, there is no international regulation asks for such monitoring as fuel used is 1% S.