2nd assignment: Emission limits and thermal power plants

Concepts: Coal versus natural gas power plants; emission legislation; NO formation and control. SO_2 formation and control. CO control.

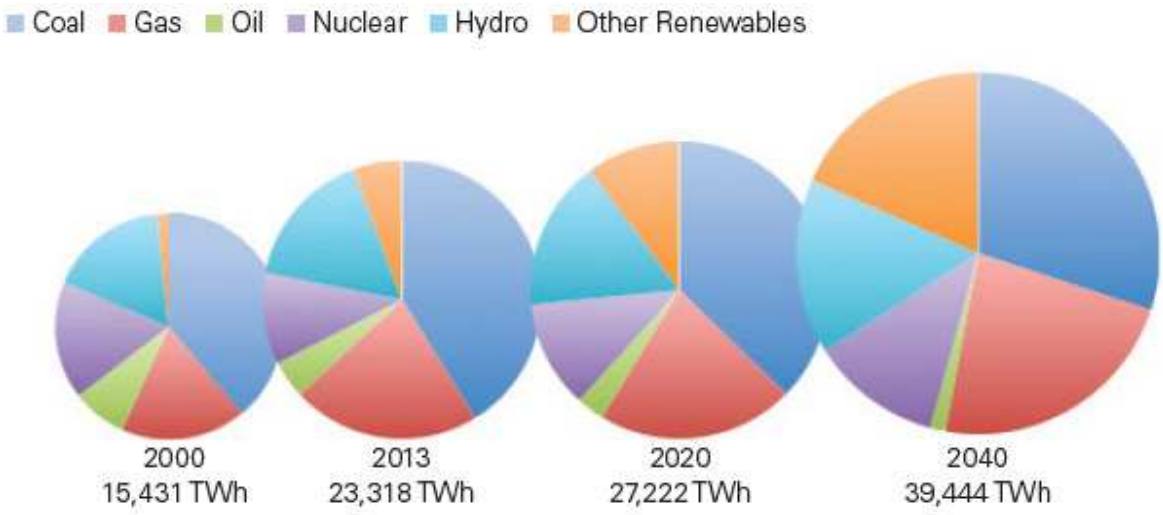
Problem Motivation

To reduce emissions from Thermal Power Stations, the Ministry of Environment, has issued new environmental norms regarding Suspended Particulate matter (SPM), SOx, NOx. Norms for specific water consumption by Thermal Power Stations have also been notified to conserve water (2.5 m^3/MWh) and achieve zero water discharge. To commit with emission limits, coal power plants are being shut down or modified. Typically they are replaced by natural gas combined cycle.

Let's compare the emission burden of each one and understand why natural gas is gaining relevance over coal.

Legislation for Europe (and Portugal) and a glimpse in the world

World electricity production is still (and probably will be) largely based on coal and natural gas.



All over the world the emission limits are getting tighter. Coal based thermal power plants are expected to pollute more. For NOx, or you invest in doing exhaust gas recirculation, if not enough, invest in NH_3 injection (SNCR) or invest in a SCR system.

Table: Air pollutant emission standards for coal-fired power plants in China, European Union and the United States (mg/m³)

		China	EU	US
SO_2	New	100	200	160
	Existing	200/400[1]	400	160/640[3]
NOx	New	100	500/200[2]	117
	Existing	100/200[4]	500/200[2]	117/160/640[5]
PM	New & existing	30	50	22.5
Mercury	New	0.03	-	0.001
	Existing	0.03	-	0.002

1) 400 for four provinces with high-sulphur coal
2) 500 until end 2015; 200 as from 2016
3) 160 for plants built 1997-2005; 640 for plants built 1978-1996
4) 100 for plants built 2004-2011; 200 for plants built before 2004
5) 117 for plants built after 2005; 160 for plants built 1997-2005; 640 for plants built 1978-1996
Source: WRI (2012)

The recent legislation for Europe (and Portugal) can be found here: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:309:0001:0021:PT:PDF

Exhaust treatment systems for NO_x and SO_2 in Sines coal Power Plant:

For the NOx problem, e.g. , Sines coal power plant "Com o objectivo de reduzir a emissão de gases poluentes (NOx) para a atmosfera, a EDP decidiu proceder a modificações nas caldeiras de 3 dos 4 grupos geradores da sua Central Termoeléctrica em Sines.

Esta modificação consistiu fundamentalmente em proceder à recirculação de parte dos gases de escape das caldeiras a fim de aproveitar o excesso de O_2 presente reduzindo assim a formação de NOx.

Parte dos gases de escape são conduzidos através de uma conduta de 2,2 m a um ventilador que injecta os gases na conduta principal de admissão através de uma conduta de 1,8 m."

When no more "modifications" could be done in combustion an exhaust aftertreatement system is required:

"Com o objective de reduzir ainda mais as emissões de NOx foram instalados os sistemas de redução catalítica seletiva em cada unidade (SCR - Selective Catalytic Reduction), em serviço desde 2011.

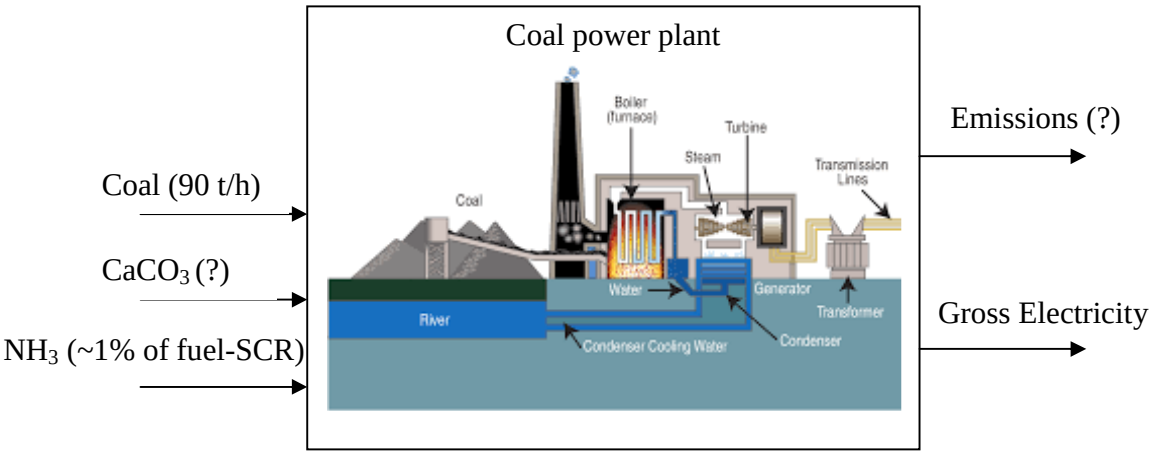
Regarding dessulfurization, "Quanto ao enxofre, sistema de dessulfuração dos gases de escape (FGD - Flue-Gas Desulfurization) instalado em 2005 e posto em funcionamento em todos os grupos em 2008."
The Sines power plant is therefore equipped with a flue gas desulfurization unit: "A remoção do SO_2 ocorre pela sua reacção, no absorvedor, com uma suspensão de calcário ($CaCO_3$) que é injectada nos chuveiros existentes na parte superior deste equipamento. Com a injecção de ar na parte inferior do absorvedor é então favorecida a produção de gesso, que pode ser posteriormente comercializado se cumprir as especificações exigidas.

$CaCO_3+SO_2+2H_2O+1/2O_2 \rightarrow CaSO_4.2H_2O+CO_2$"

Consider coal fuel with the following specifications in a coal power plant:

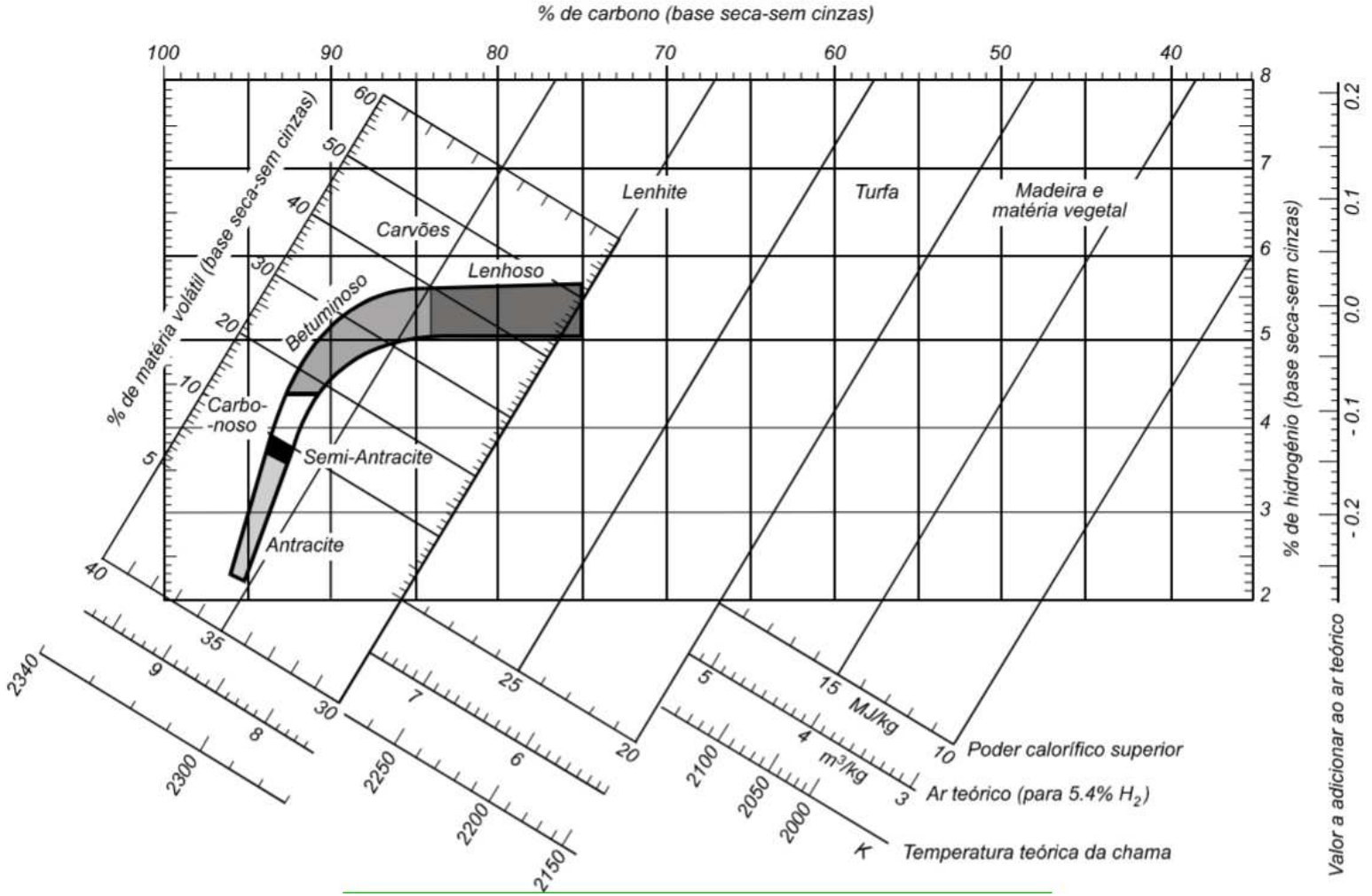
Coal composition by weight (%wt). Ash is the general term used to describe the inorganic matter in a fuel, e.g. Fe, Ca, K, Si, etc. Fixed carbon is 51% (volatile matter+fixed carbon+ash+moisture=100%). Moisture is water.

C	***67.7***
H	4.4
N	1.5
S	1.0
O	5.2
Ash	13.4



Seyler Diagram for coals (dry basis, without ashes), volatiles are all except fixed carbon:

Diagrama de Seyler (adaptado)



Questions:

1- Classify the coal. Estimate the adiabatic flame temperature, the lower heating value (MJ/kg) of coal.

2- The exhaust gas measurement revealed the following dry composition: 1% O_2, CO 4300 ppm, NO_2 400 ppm, SO_2 0.148 %. Estimate the $(A/F)_{real}$.

3- The coal consumption is 90 ton/h with 1256 MW installed power. For such conditions estimate the CO_2 emissions and SO_2 emissions in g/h.

4- For what desulfurization efficiency the coal power plant (1256 MW installed power) respects the SO_2 limits in mg/Nm^3 imposed by the legislation? Consider dry emissions. What would be the new CO_2 emissions in kg/MJ?

5- Estimate the minimum value of particles in mg/Nm^3 and compare with the limits for the coal power plant (1256 MW installed power).

6- How could you decrease the CO emissions? And how this change would affect CO_2, SO_2 and PM emissions?