Coal quality control techniques and selective grinding as means to reduce CO_2 emissions

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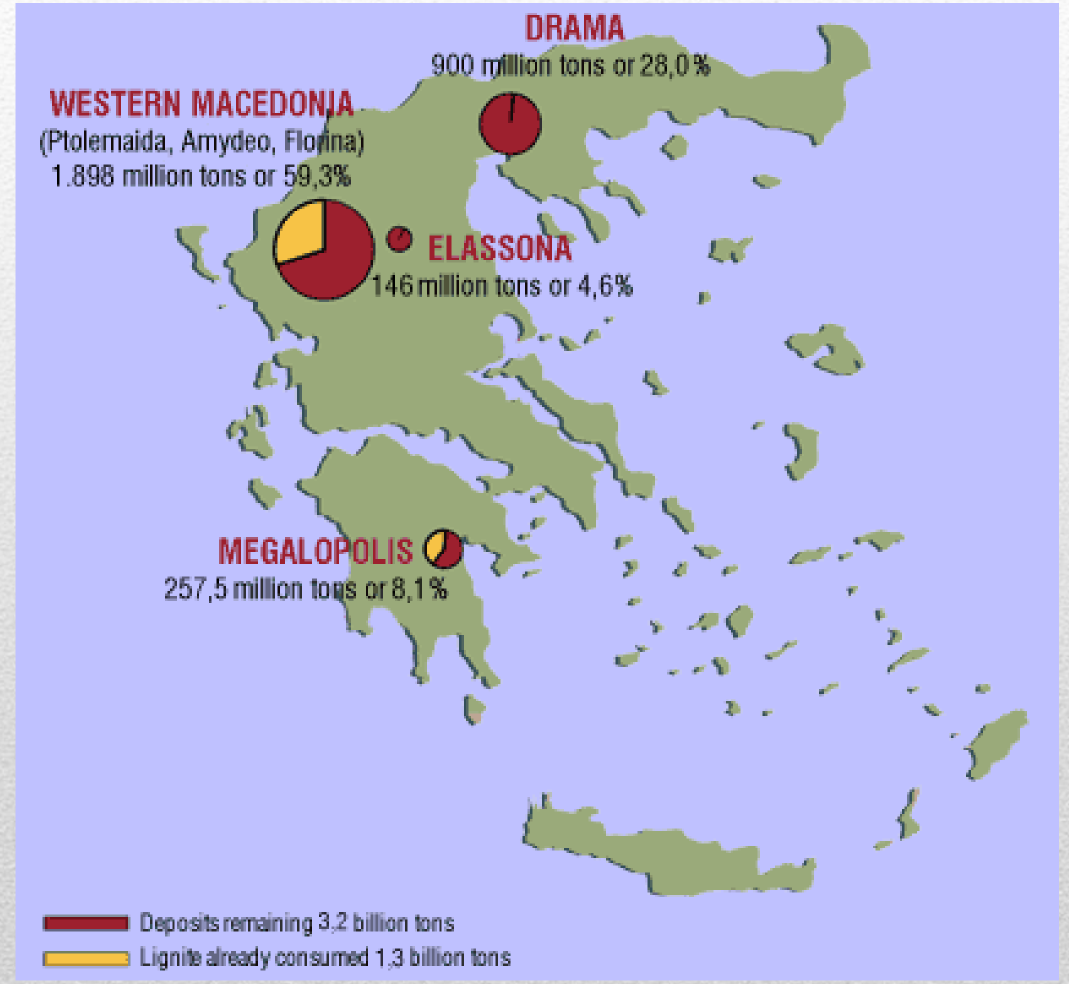
Objective

To investigate how Selective Size Reduction or (SSR) and homogenization/blending of lignite can affect the CO_2 emissions during its combustion.

Overview

- INTRODUCTION
  - Lignite mining in Greece
  - Greenhouse Gases (GHGs) and mineral fuels
  - Lignite quality and CO_2 emissions
- HOMOGENIZATION
  - Homogenization methods
  - Estimation of the impact of homogenization factor to CO_2 emissions
- SELECTIVE SIZE REDUCTION
  - Experimental procedure
  - Discussion of results
- CONCLUSIONS

Geographical distribution of lignite reserves in Greece

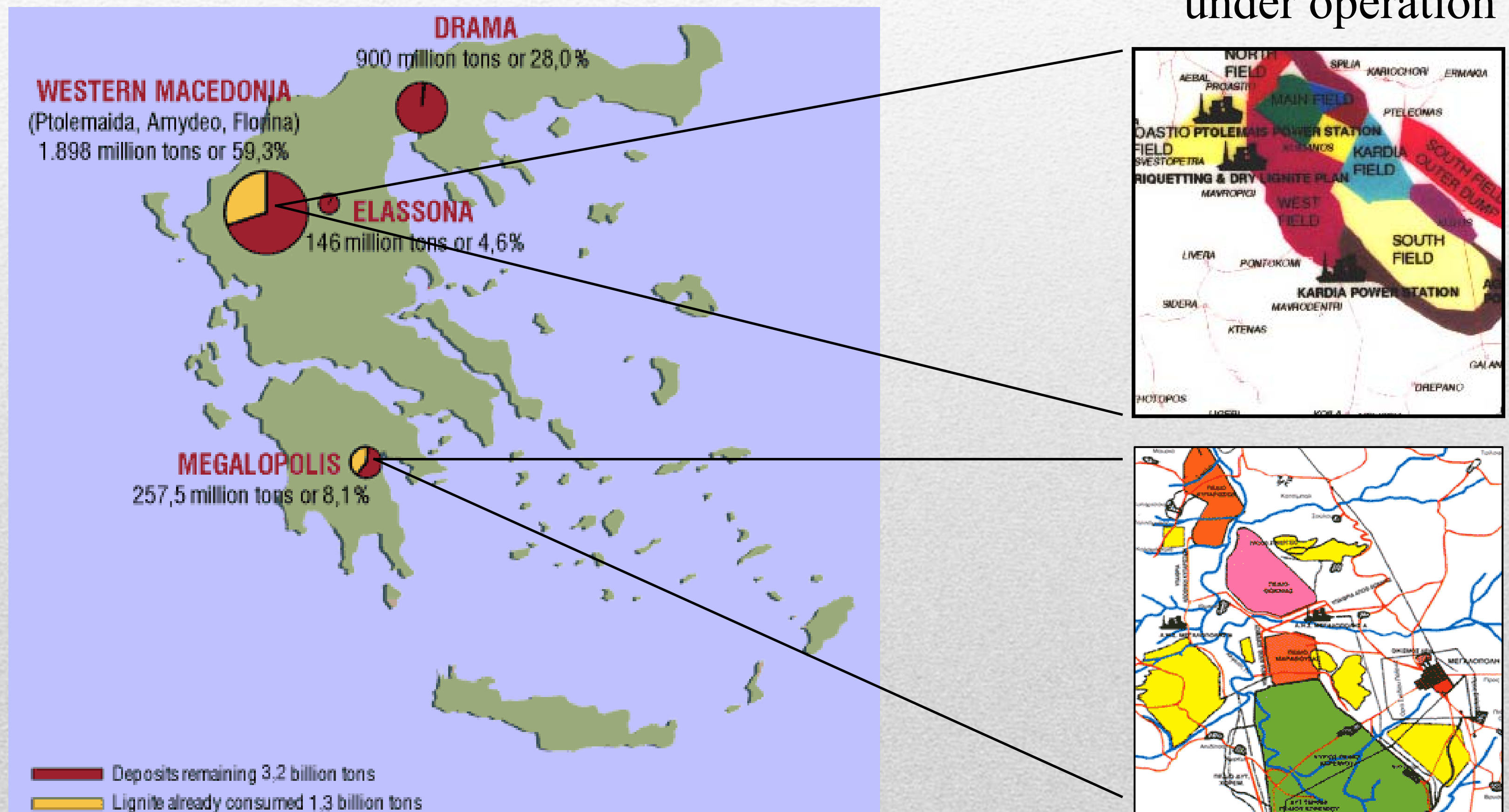


Proven geological reserves: 5000 Mt

Exploitable reserves:3200 Mt

Active lignite mines in Greece

Mines and power stations under operation

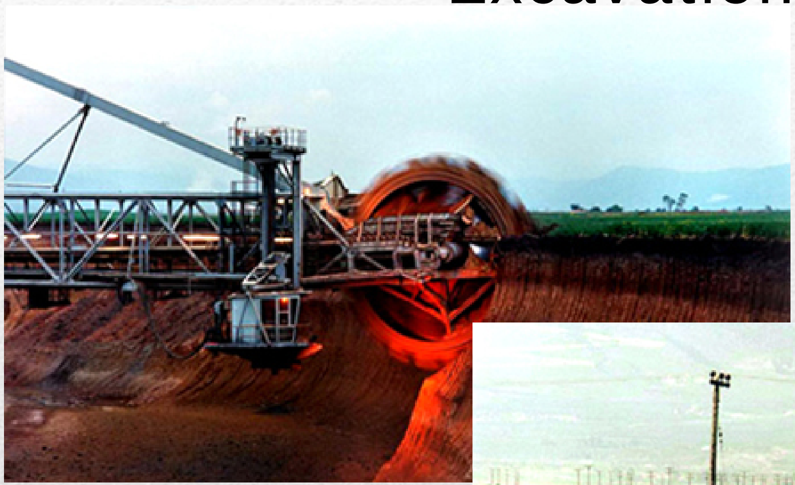


Lignite Centers of Western Macedonia and Megalopolis

- Proven geological reserves: 4000 Mt
- Remaining exploitable reserves: 1800 Mt
- Annual lignite production: 50 Mt
- Annual total excavations: 250 M m^3
- Number of active mines: 4
- Power production (% of the total power production in Greece) 62

Lignite mining in Greece

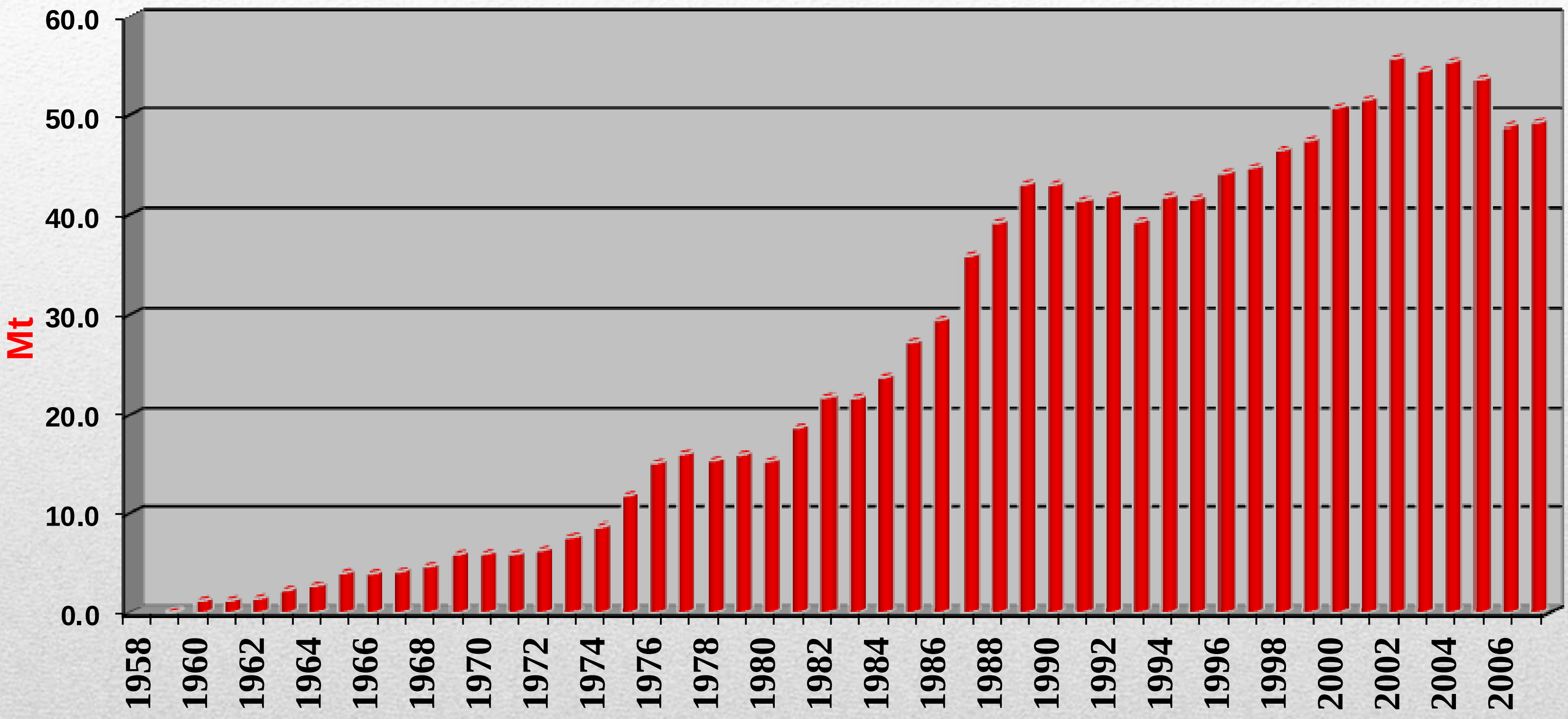
Excavation



Conveying

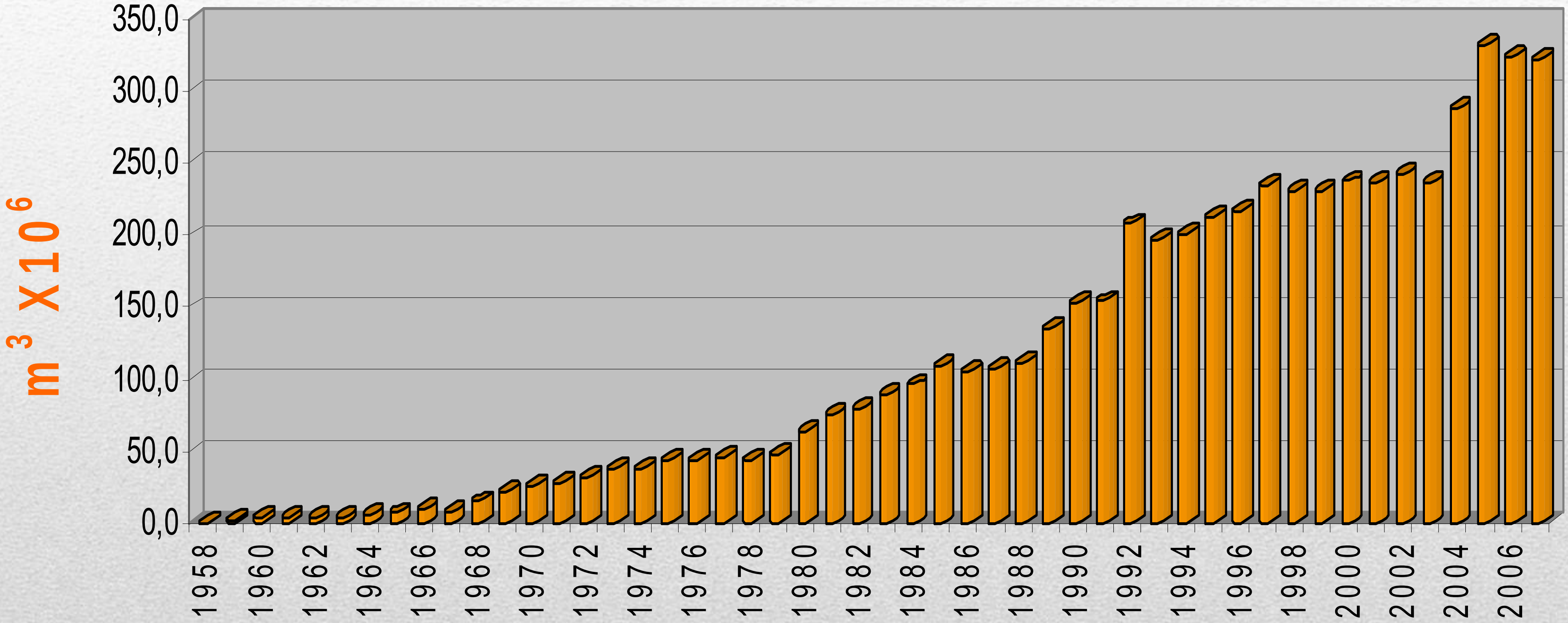
Stacking

Lignite production in WMLC



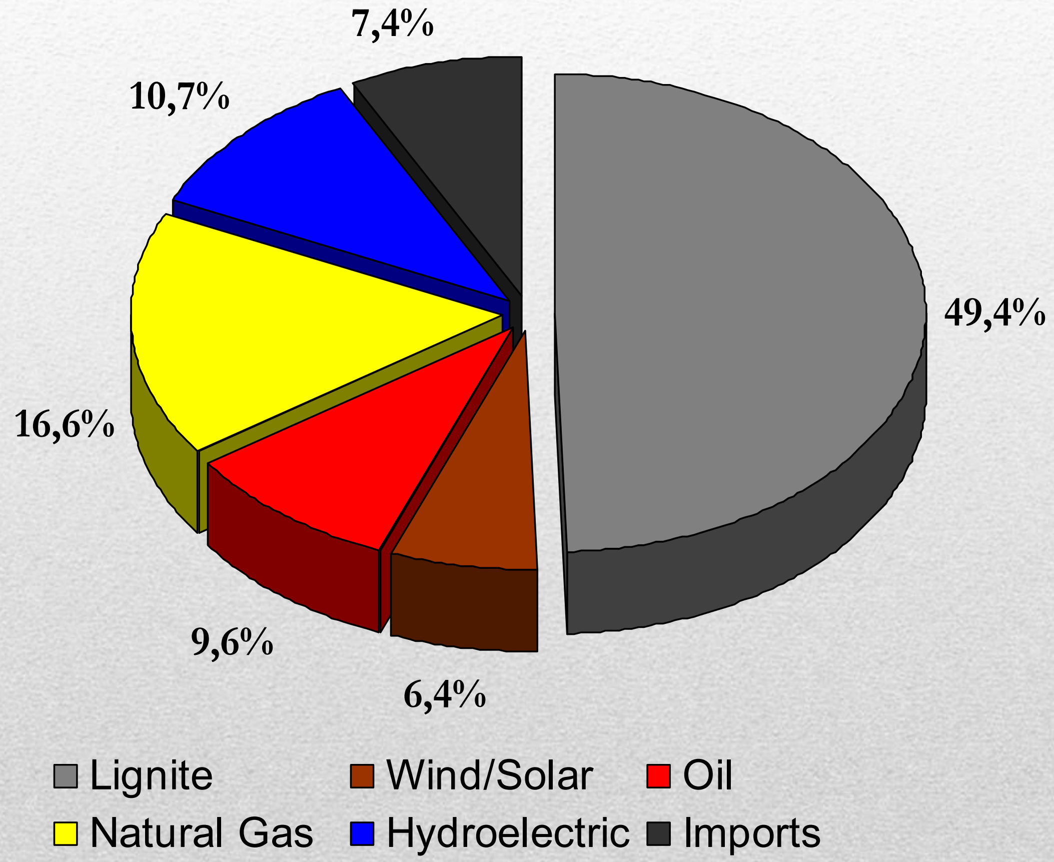
Over the last five years lignite production is almost constant at the level of **~50Mt per annum**.

Total excavated material in WMLC

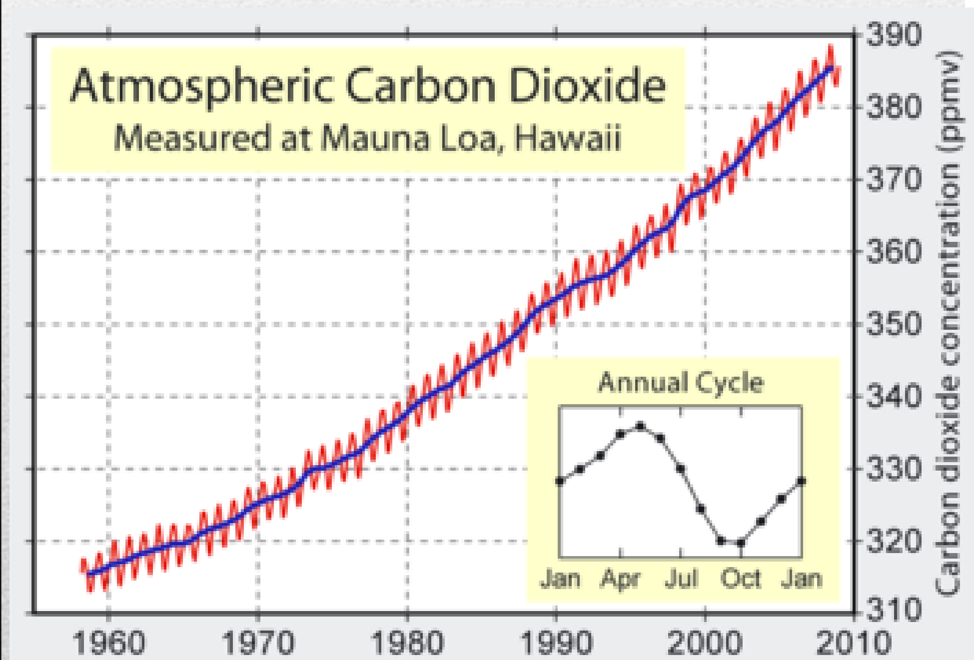


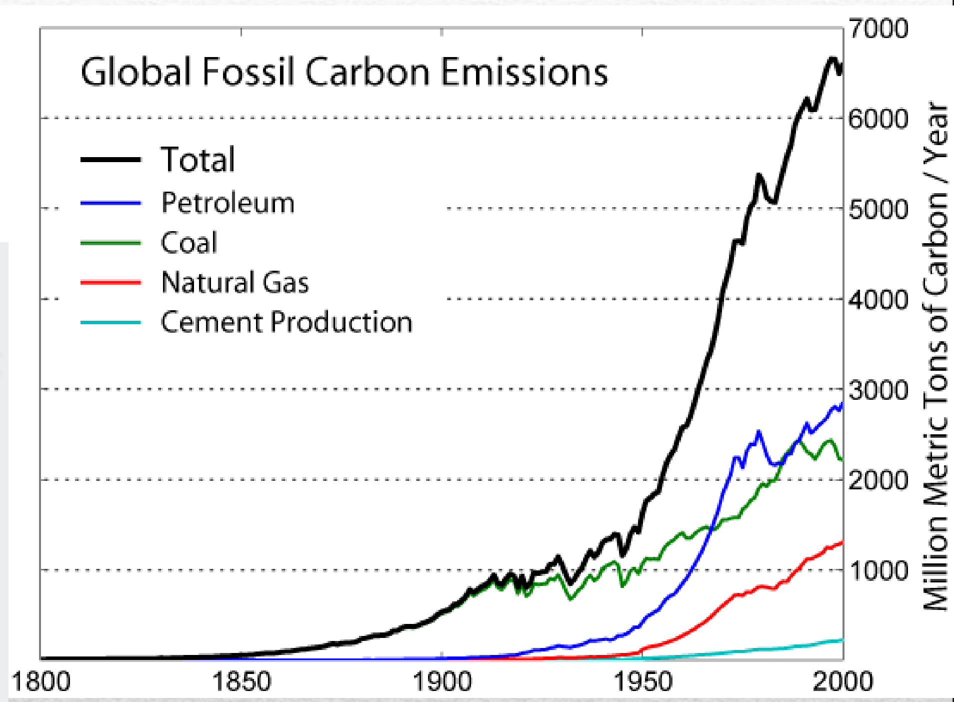
In the last 5 years total excavations are at the level of **~250M m^3 annually**

Contribution of energy sources to the electricity production in Greece (2009)



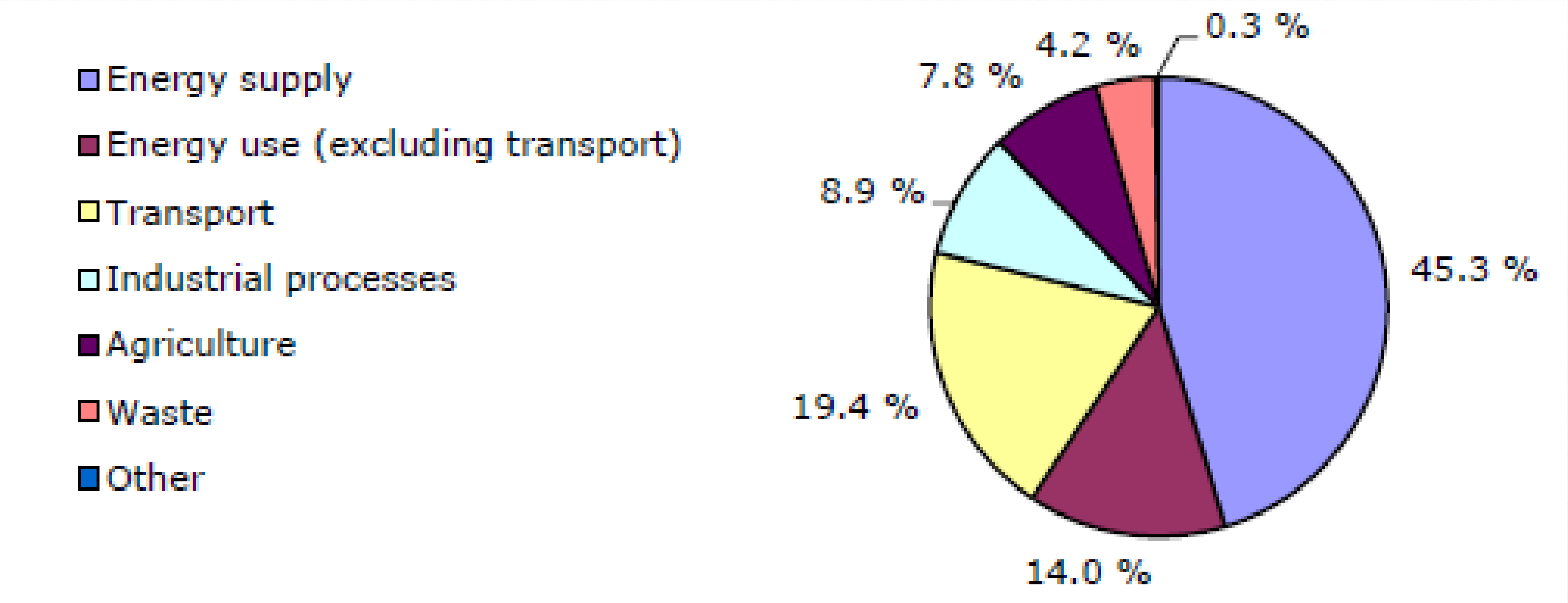
Carbon emissions – atmospheric CO_2





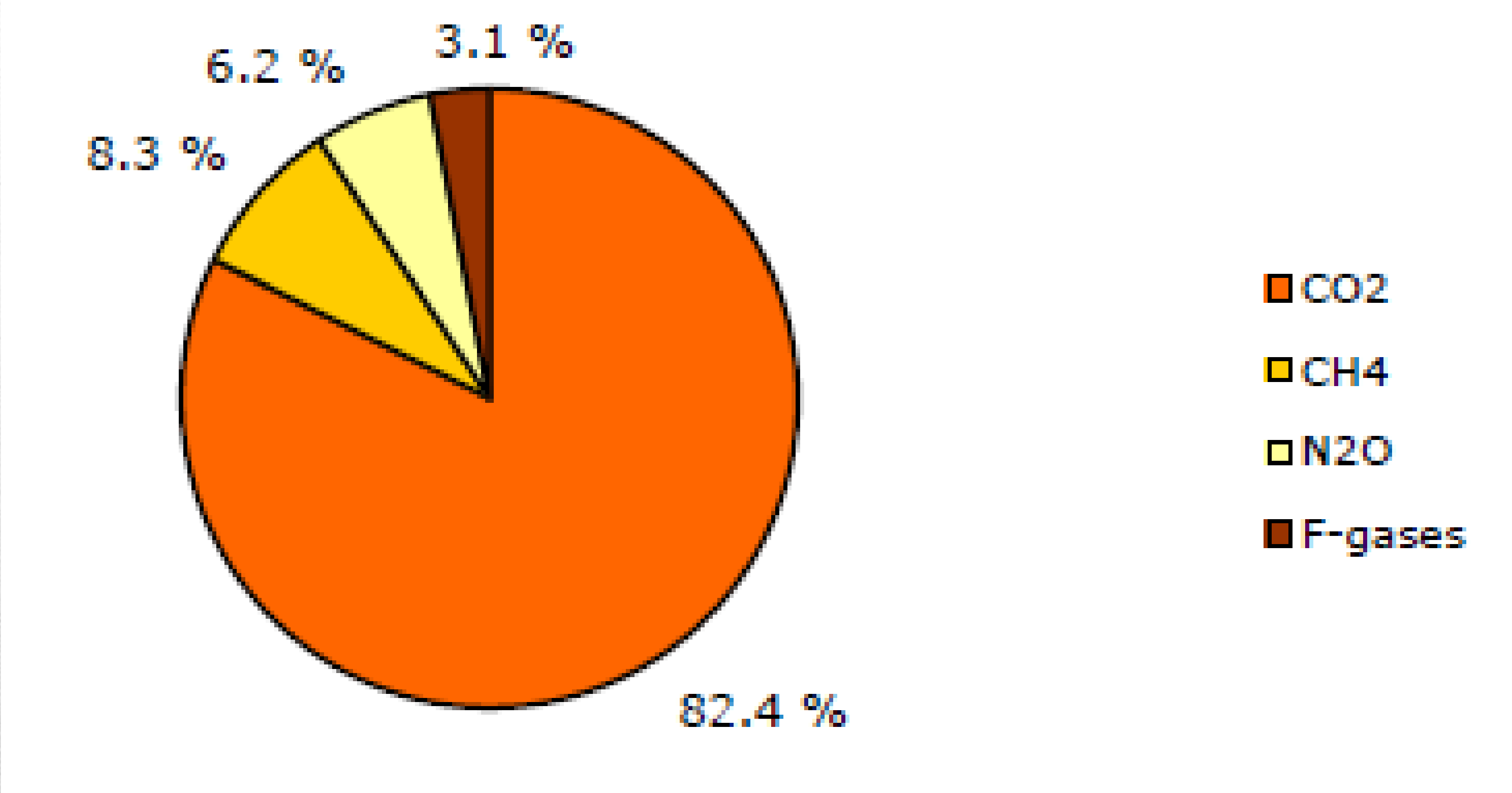
Source: http://www.globalwarmingart.com/wiki/Image:Carbon_Emission

Greek GHG emissions by sector in 2010



(Source: EEA Report No 6 / 2012)

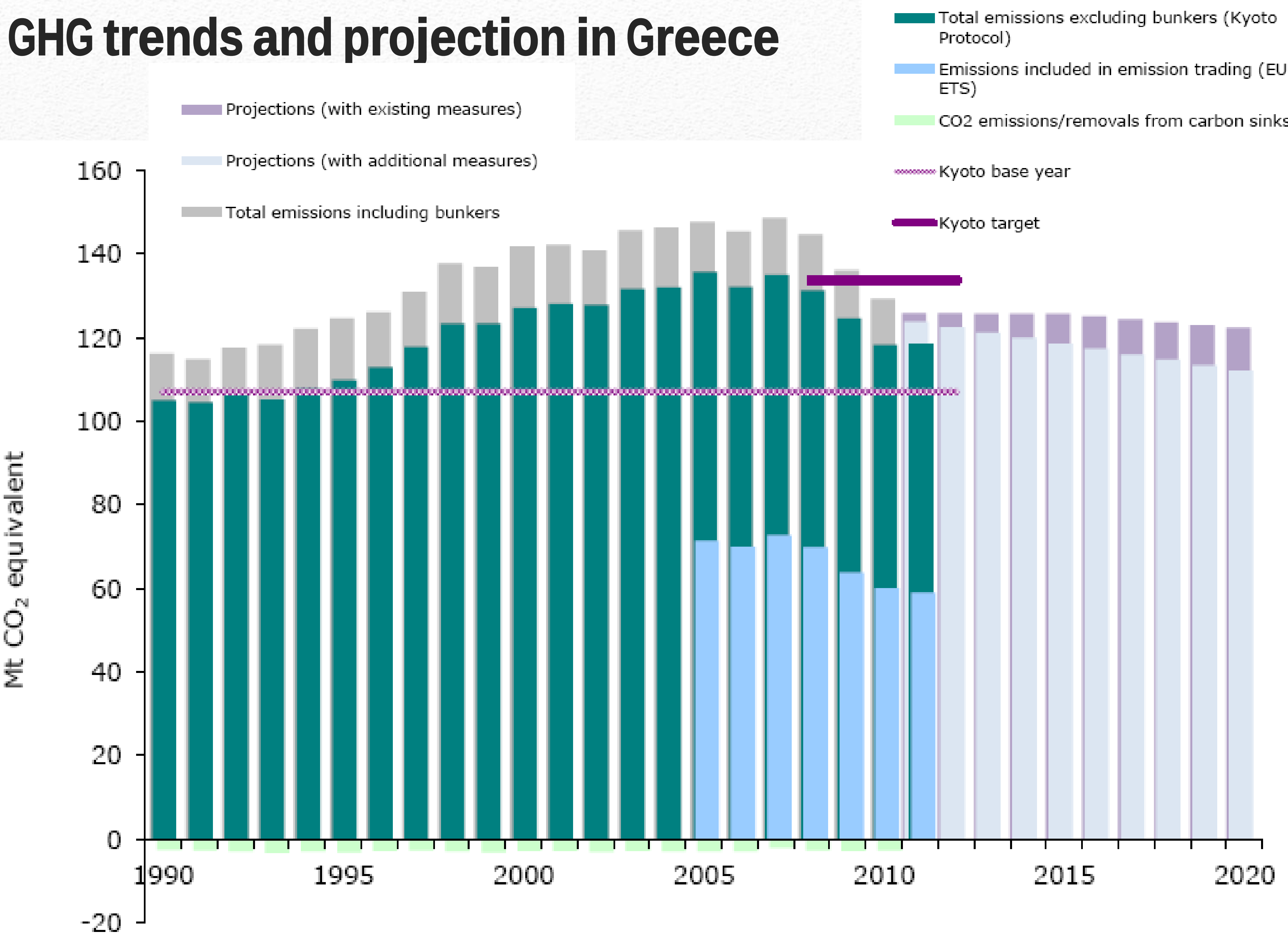
Greek GHG emissions by gas in 2010



(Source: EEA Report No 6 / 2012

Emissions of CO_2 in Greece account for 82.4% of total GHG emissions

GHG trends and projection in Greece



GHG trends and projection in Greece

- Greece showed the largest emission reductions within the EU **(-5.1%**) in 2010 compared to 2009.

- The significant decline in emissions was mainly due to **fuel related emissions decreases in public electricity** and heat, road transportation, manufacturing industries and households as well as process related emissions from cement production.

- This trend mainly reflects the continuing effects of the economic crisis.

Quality of mined lignite

The quality of the mined lignite varies significantly due to the:

- Deposit nature (multiple seams)
- Mining conditions (high capacity bucket wheel excavators with limited flexibility)
- Dilution from the co-excavation of inter-bedded waste layers

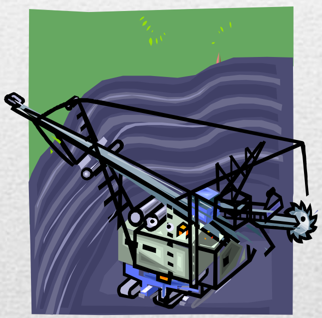
Quality parameter	Western Macedonia Lignite Centre			Megalopolis Lignite Centre		
	Mean value	Range	Standard deviation	Mean value	Range	Standard deviation
Moisture %	56.0	43.4-60.6	1.84	60.0	57.5-65.0	1.75
Ash %	12.8	6.7-24.6	2.45	14.9	12.3-23.5	2.02
Low calorific value MJ/Kg	1340	1150-2000	100	955	860-1170	70

Lignite quality – CO_2 emissions

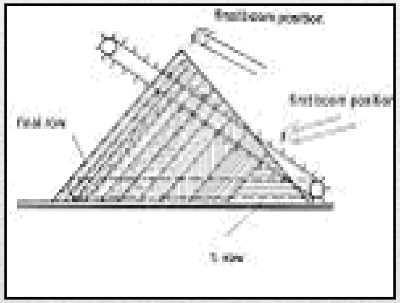
- Feeding the power plants with lignite which does not meet the specifications results in decrease of efficiency, loss of energy, high gaseous emissions (mainly CO_2 and NO_x).
- Lignite-produced electricity is affected much more than gas-produced electricity, because of the higher (approximately double) CO_2 emission per unit of output.
- The estimation of CO_2 emissions is therefore crucial for the evaluation of the additional cost that affects significantly the competitiveness of lignite.
- The development of techniques for the mitigation of CO_2 emissions is therefore of paramount importance.

Calculation of CO_2 emissions based on the mass balance of total carbon

Lignite mining



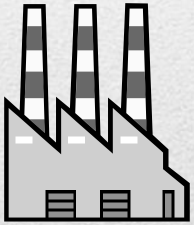
Blending - Homogenization



Lignite feed
L, t/y
A, W_t, C_L , %
LHV, Mcal/t

CO_2 emissions
Q, t /y

Power Plant



Fly ash
F, t/y
C_F, %

Wet ash
W, t/y
C_W, %

Calculation of CO_2 emissions based on the mass balance of total carbon

$$Q_s = \frac{3153}{LHV \cdot n} \cdot C_L \cdot O_F$$

Q_s = Specific emission factor (t of CO_2/ MWh)

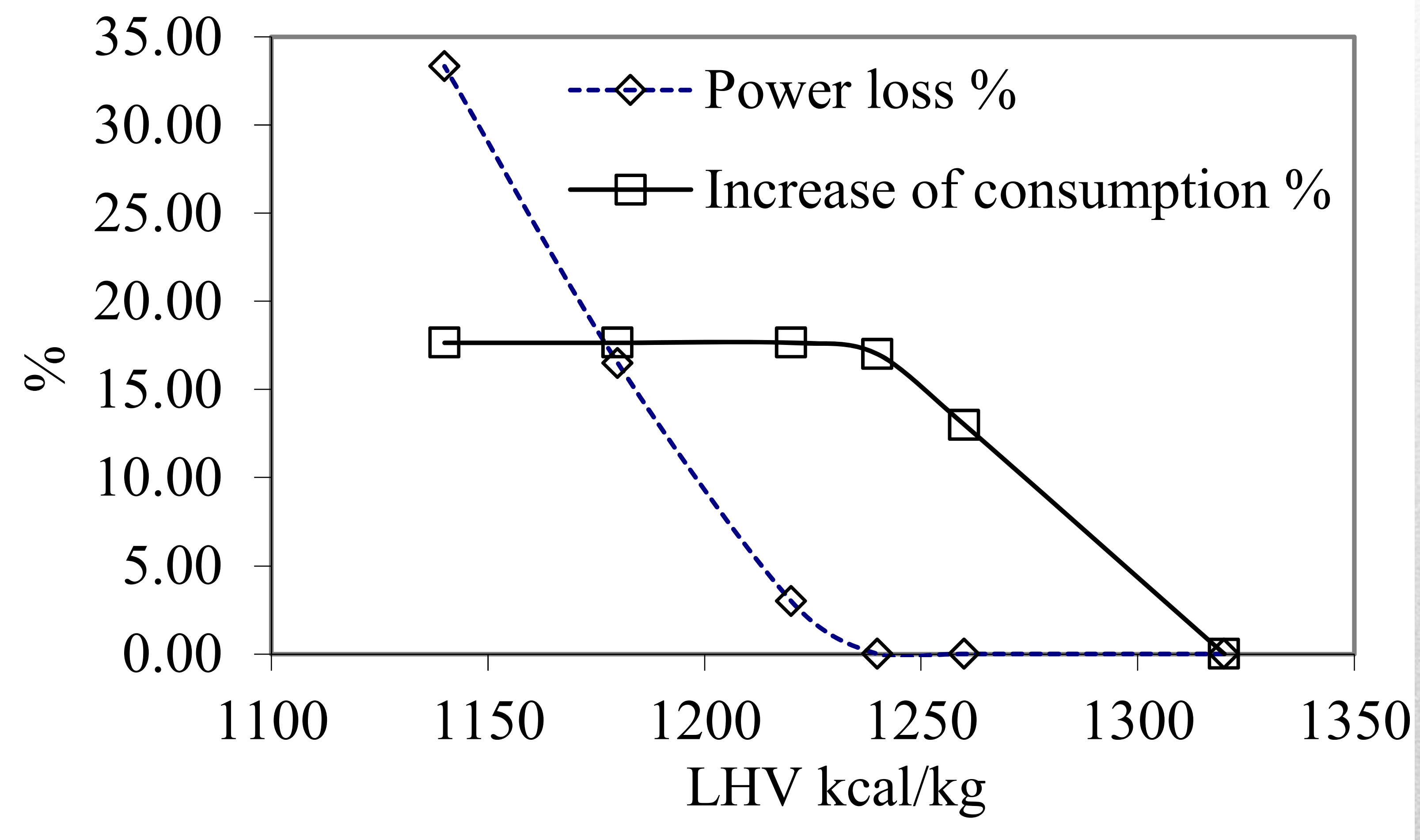
LHV=Low heating value of mineable lignite (kcal/kg)

C_L = Total carbon content of lignite in as received basis, %

O_F = oxidation factor, indicating the percentage of carbon converted to CO_2, %

n = power plant efficiency, %

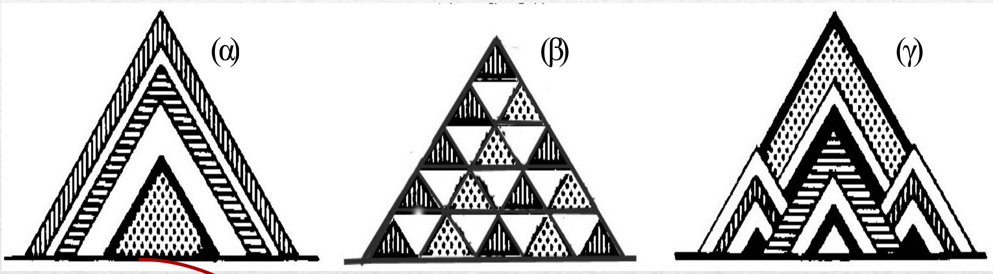
Effect of LHV fluctuation on power loss and on consumption for a typical 300 MW lignite thermal unit.

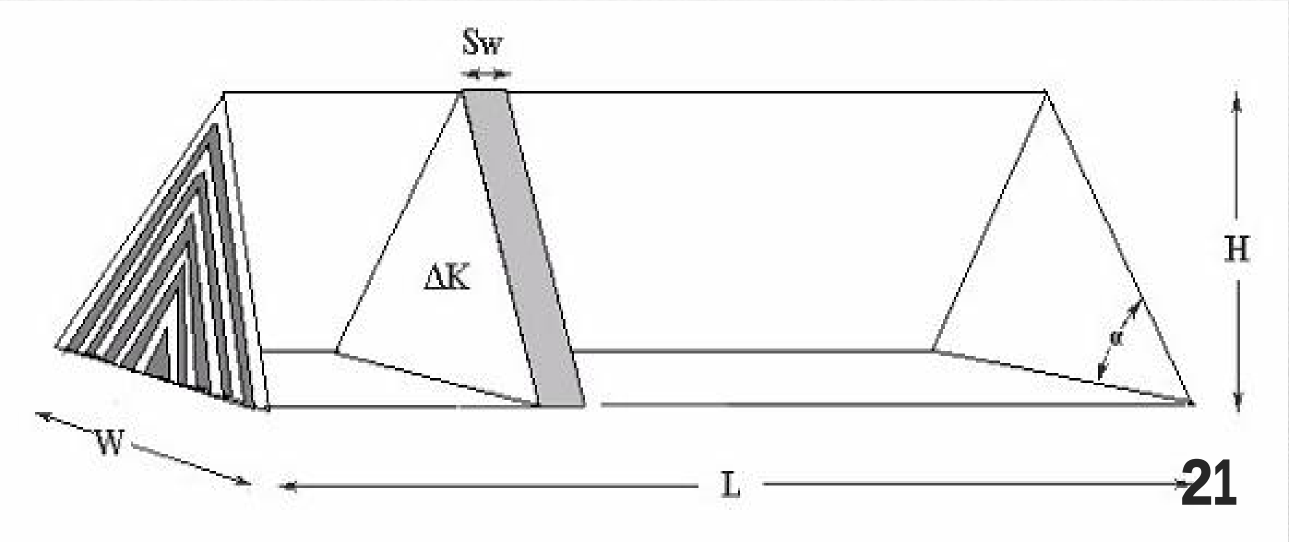


Coal homogenization – linear or circular piles

Pile formation

Chevron Windrow Combined





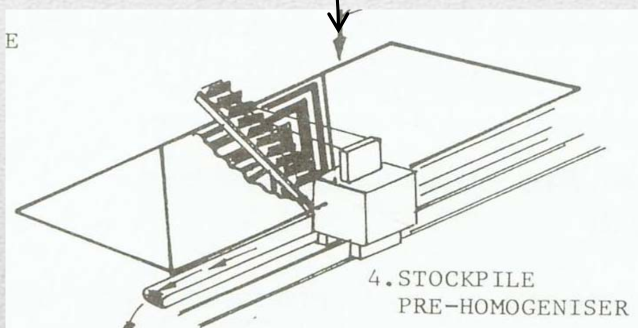
Lignite homogenization

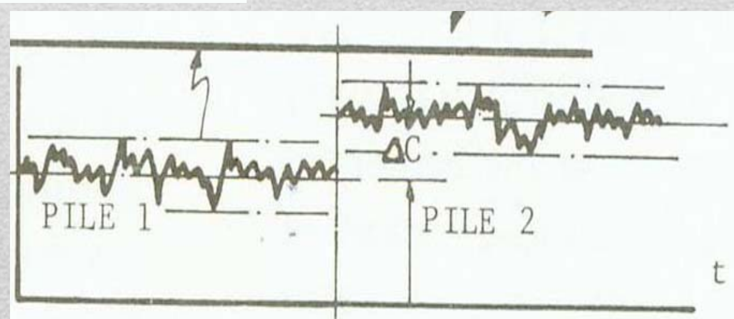
Homogenization ratio $R=\sigma_o/\sigma_i$

σ_o=standard deviation of output

σ_i= standard deviation of input

σ_i

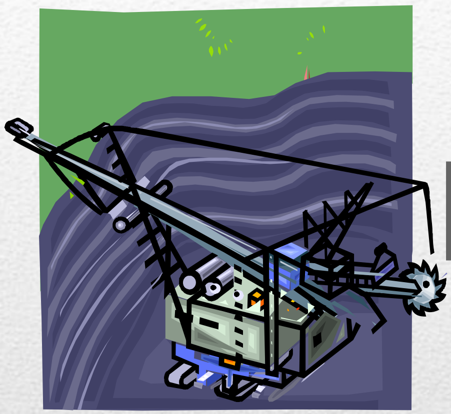




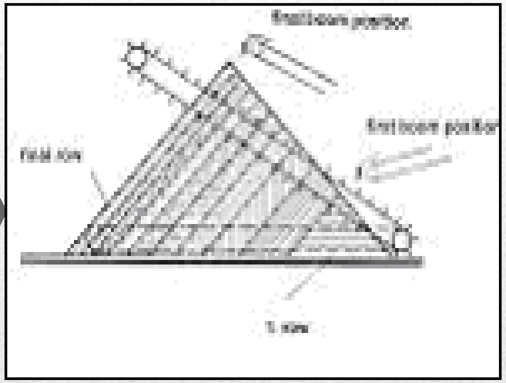
σ_o

Lignite quality variations

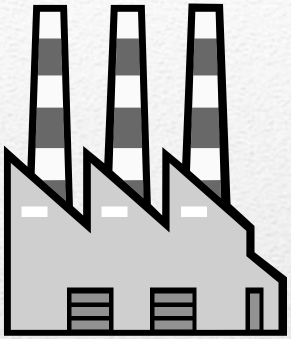
Lignite mining



Homogenization

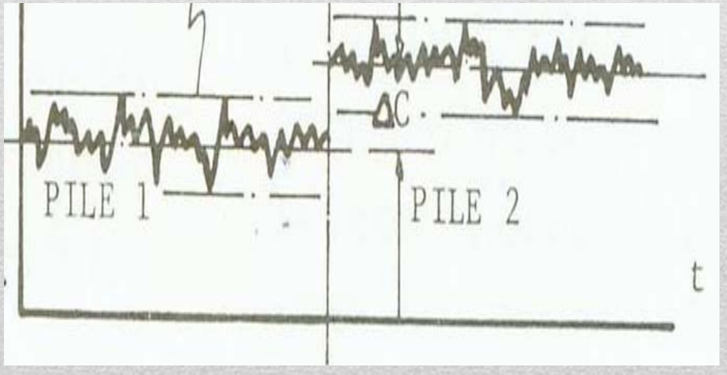


Power station



Run of mine lignite

Homogenized lignite



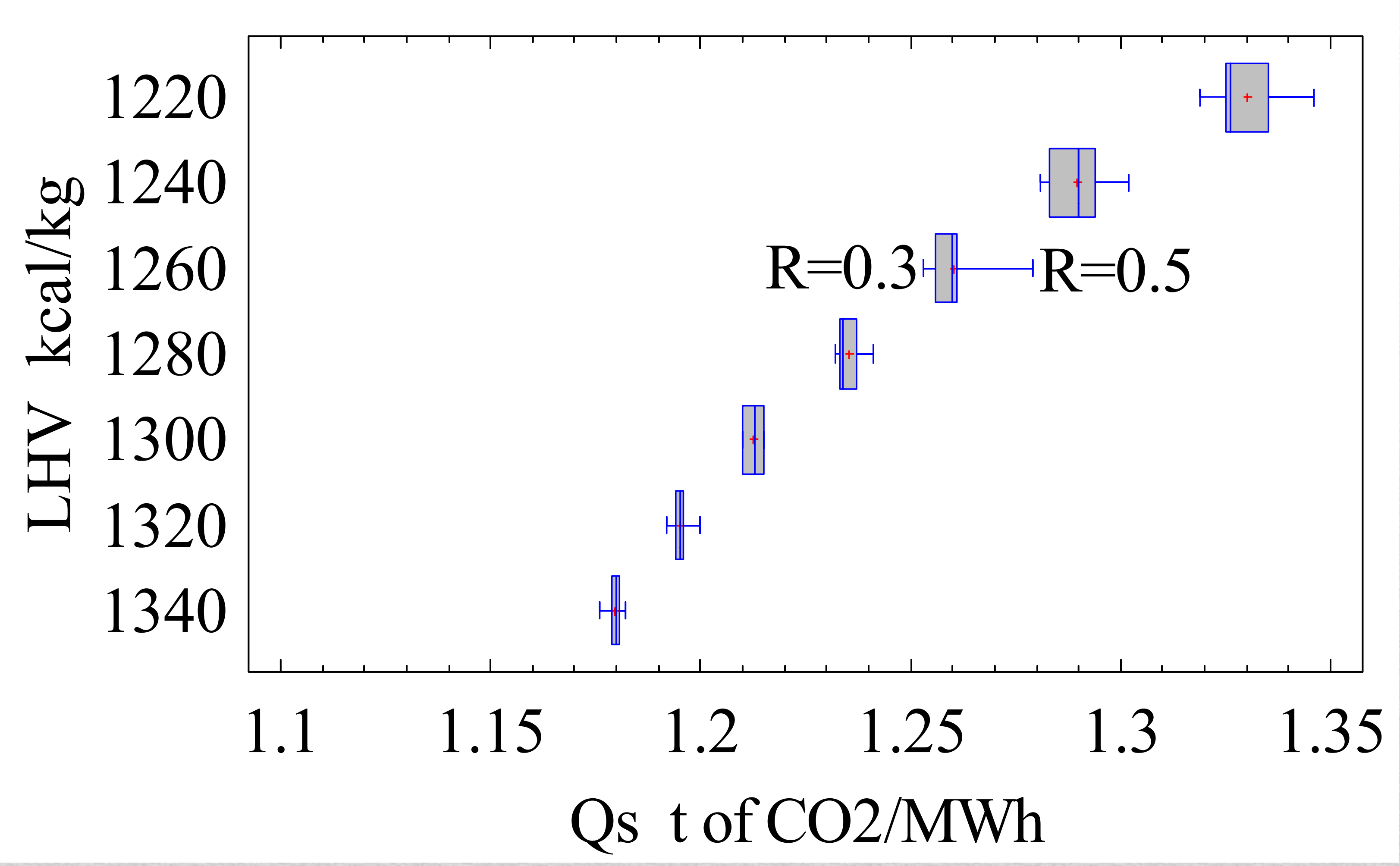
Stochastic estimation of CO_2 emission factor (Monte Carlo simulation)

- Definition of input variables used for the analysis (LHV, R, C_L)
- Selection of ranges and the probability distribution functions for each input variable (min, max, m, s)
- Determination of the possible dependencies among inputs (LHV-C_L)
- Generation of samples within the probability distribution functions (10,000)
- Evaluation of the model output for each element of the input factor sample (Q_s)

Probability distribution functions of the uncertain factors

Factor	Symbol	Unit	Distribution function	Mean	Standard deviation	Range
Daily low heating value	*LHV*	kcal/kg	Normal	1300	67.5	1200-1500
15 minutes low heating value	*LHV*	kcal/kg	Normal	Daily LHV	90	
Homogenization factor	*R*		Uniform			0.3-0.5
Total carbon	C_L	%	$C_L=a+bC_L$			
Power plant efficiency	*n*	%	Constant	36		
Oxidation factor	O_F	%	Constant	98		

Effect of LHV and R to the Q_s



Boxplots shows the distribution of Qs (minimum, 1st quartile, median, 3rd quartile and maximum) when R varies uniform between 0.3 and 0.5.

Effect of LHV and R to the Q_s

Homogenization results in a reduction of 2-5% of in CO_2 emissions.

For a 300 MW unit the annual reduction of CO_2 emissions varies from 52000 – 130000t.

For all installations (~ 4300MW) in WMLC the annual reduction of CO_2 emissions is estimated from 750,000 – 1,860,000t

Selective Size Reduction

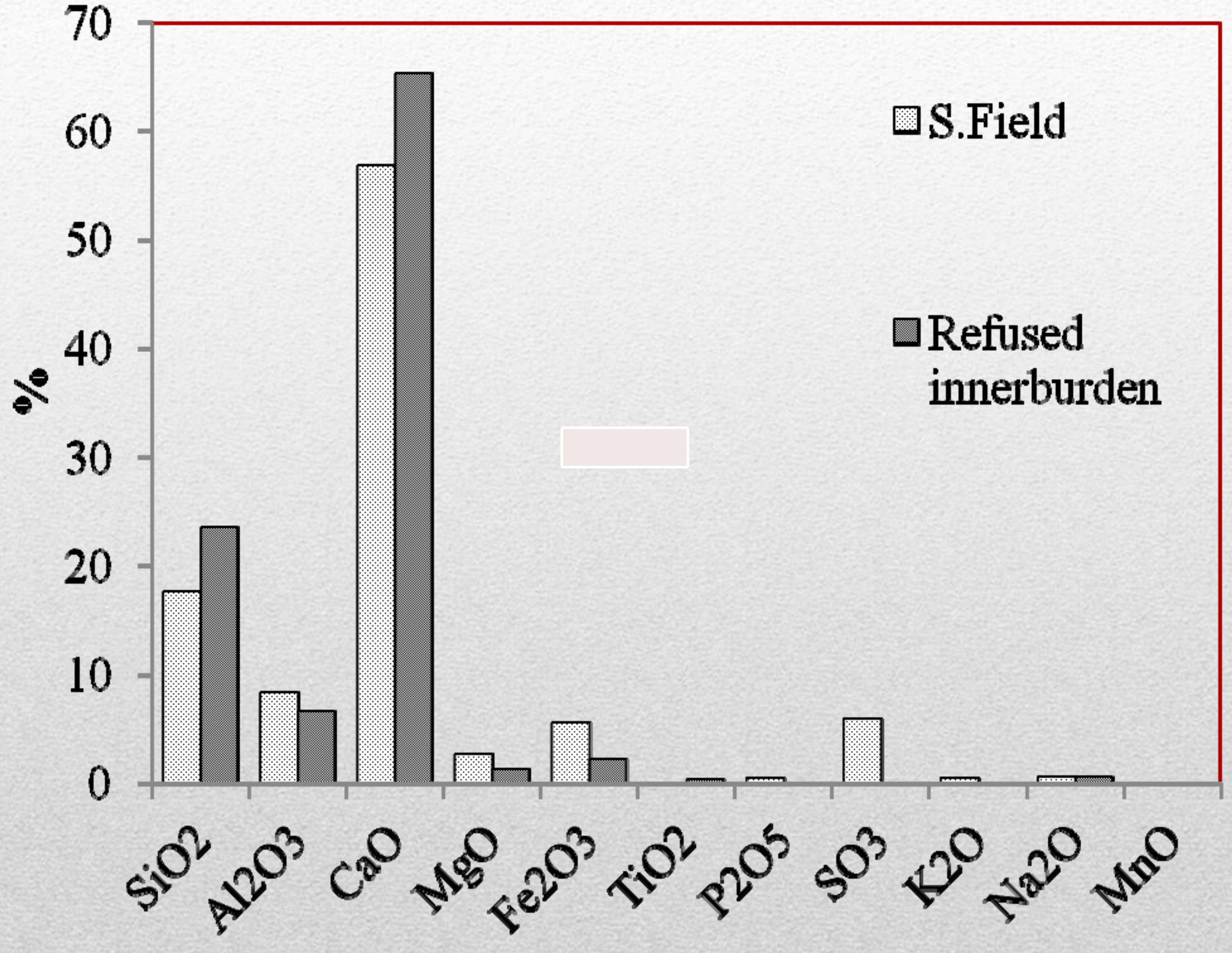
Raw samples were initially crushed with a jaw crusher and classified by sieving to different particle sizes -0.1mm (1st stage of crushing). Consequently, the coarser fraction was crushed and sieved to the same particle sizes as before and a new size distribution was obtained (2nd stage of crushing) and so on.

Representative samples from all fractions of all stages of crushing were analyzed to determine the optimum cut size of the screening, in terms of quality of both organic and inorganic components of the lignite materials.

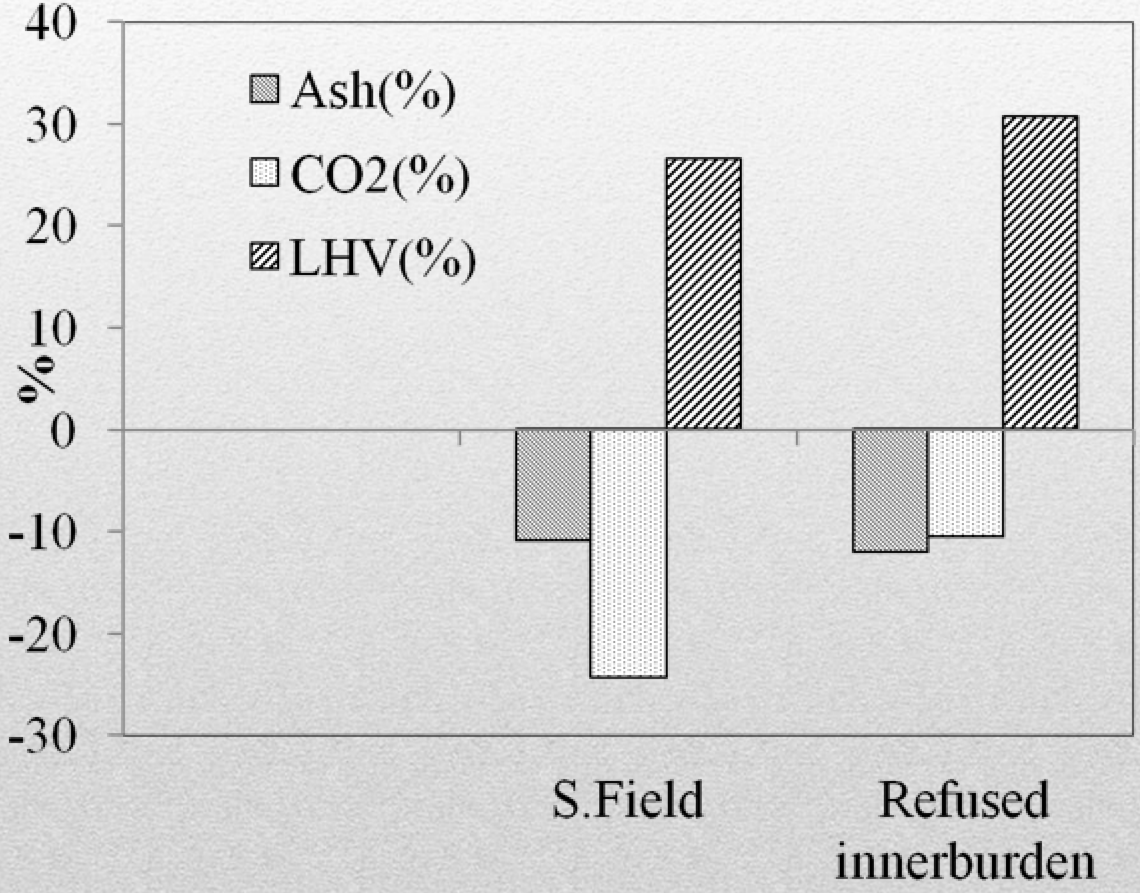
Qualitative characteristics of raw fuels (% dry)

Sample	Ash	CO_2	LHV (kcal/kg)
S. Field Lignite	34.9	15.2	953
Refused innerburden (East Komanos mine)	40.0	23.9	1035

Ash chemical composition



Variation of qualitative characteristics of upgraded samples



Selected fractions

S. Field lignite

-3 +0.1 mm (recovery 65%)

Refused innerburden

-16 +0.2

(recovery 88.6%)

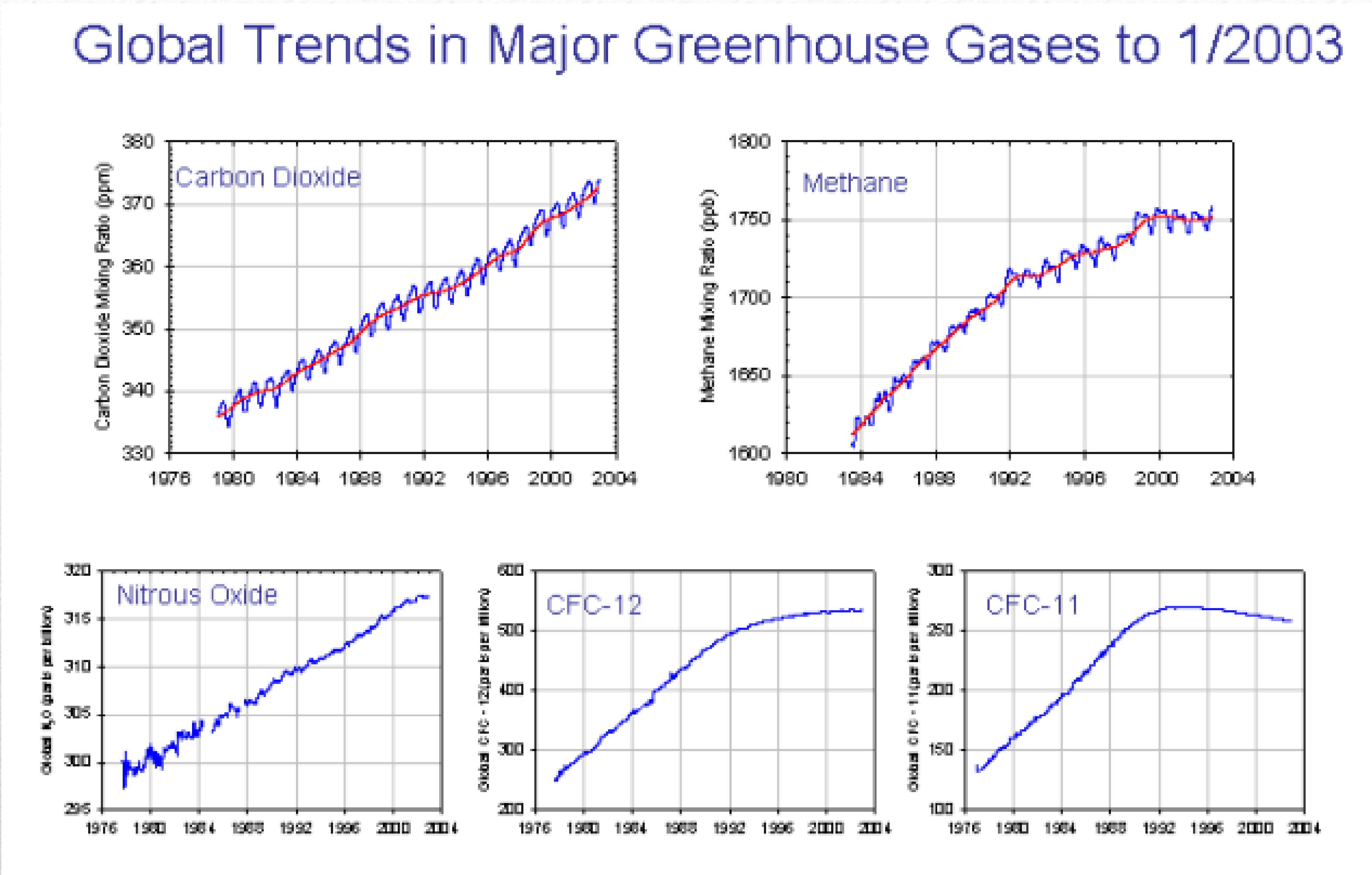
Discussion of results - Conclusions

- Homogenization results showed that a reduction of 2-5% of CO_2 emissions can be achieved by effectively controlling the short and long- term variation of the lignite quality.
- SSR is also a simple method for upgrading lignite quality with no use of chemical additives. The upgraded samples showed lower carbon dioxide emissions from carbonate minerals, ranging between 11% and 28% and reduction of ash between 11% and 15%, revealing decreased deposition problems in boilers, as well as less environmental pollution.
- The LHV of the beneficiated samples increased up to 31%, rendering lignite and refused innerburden of acceptable quality for combustion in the WMLC power plants.

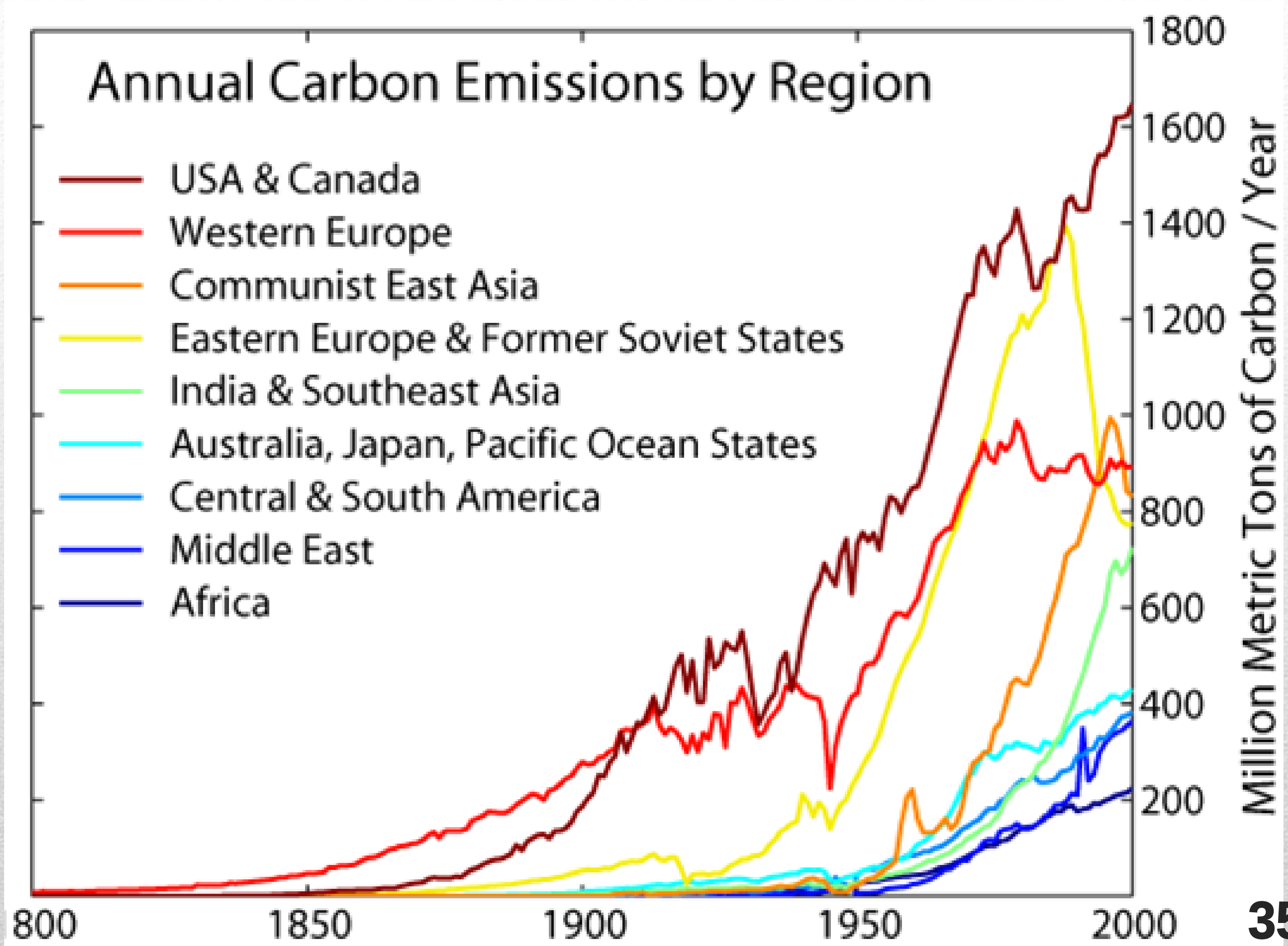
END

Thank you for your attention !

Major Greenhouse Gases



Source: NOAA (http://www.cmdl.noaa.gov/albums/cmdl_overview/Slide11.sized.png)



Source: http://www.globalwarmingart.com/wiki/Image:Carbon_Emission

Changes in GHGs

Country	Change in greenhouse gas Emissions (1990-2004) excluding LULUCF	Change in greenhouse gas Emissions (1990-2004) including LULUCF	EU Assigned Objective for 2012	Treaty Obligation 2008-2012
Denmark	-19%	-22.2%	-20%	-11%
Germany	-17%	-18.2%	-21%	-8%
Canada	+27%	+26.6%	n/a	-6%
Australia	+25%	+5.2%	n/a	+8%
Spain	+49%	+50.4%	+15%	-8%
Norway	+10%	-18.7%	n/a	+1%
New Zealand	+21%	+17.9%	n/a	0%
France	-0.8%	-6.1%	0%	-8%
Greece	+27%	+25.3%	+25%	-8%
Ireland	+23%	+22.7%	+13%	-8%
Japan	+6.5%	+5.2%	n/a	-6%
United Kingdom	-14%	-58.8%	-12.5%	-8%
Portugal	+41%	+28.9%	+27%	-8%
EU-15	-0.8%	-2.6%	n/a	-8%

Country	Change in greenhouse gas Emissions (1992-2007)
India	+103%
China	+150%
United States	+20%
Russian Federation	-20%
Japan	+11%
Worldwide Total	+38%

EU Trading Scheme

- Overall emission reductions
- **Phase I**
- In 2004, Ecofys analysed the then available preliminary NAPs of all EU countries.[26] The information suggested that the caps for Phase I were lenient; in most countries, the power sector would not need to reduce CO2 emissions as much as the country as a whole, in other words the other sectors must make more ambitious emission reductions than the power sector under the scheme. More strikingly, a few countries (such as the Netherlands) gave more allowances than Ecofys estimated to be needed under a business-as-usual scenario, implying that no 'real' efforts to reduce emissions would be required. In their analysis of the Phase I NAPs, the NGO Climate Action Network called the caps a 'major disappointment',[27] arguing that only two (UK and Germany) of the 25 EU states asked the participating industry sectors to reduce emissions compared to historic levels and found that in the 15 old EU member states as a whole, allocations were 4.3% higher than the base year. In May 2006, when several countries revealed registries indicating that their industries had been allocated more allowances than they could use, trading prices crashed from about €30/ton to €10/ton, and (after an initial slight recovery) declined further to €4 in January 2007[28] and below €1 in February 2007, reaching an all time low of €0.03 at the beginning of December 2007[29]
- **Phase II**
- In 2006, Ecofys performed an initial assessment of NAPs for phase II, using the proposed but not-yet-approved NAPs.[30] They found that most member states did not have sufficiently strict caps, and that they would be insufficient in assisting the members in meeting their Kyoto targets. They also compared caps with official business-as-usual (BAU) projections and with independent BAU projections to assess stringency of caps. They concluded that the caps were 7% under official BAU but (except for Portugal, Spain, and UK) the proposed cap was "higher" than the independently estimated BAU, suggesting overallocation.
- Partly in response to this, the Commission cut eleven of the first twelve Phase II plans it reviewed (accepting only the U.K.'s plan without revision). The commission tightened the caps some 7%,[31] also corresponding with 7% below the 2005 emissions. However, as of January 2007, not all plans have been finalized.

Kyoto Protocol

• Establishes legally binding commitment for the reduction of four greenhouse gases (**carbon dioxide**, methane, nitrous oxide, sulphur hexafluoride), and two groups of gases (hydrofluorocarbons and perfluorocarbons).

• As of January 2009, 183 parties have ratified the protocol, which was initially adopted for use on 11 December 1997 in Kyoto, Japan and which entered into force on **16 February 2005**.

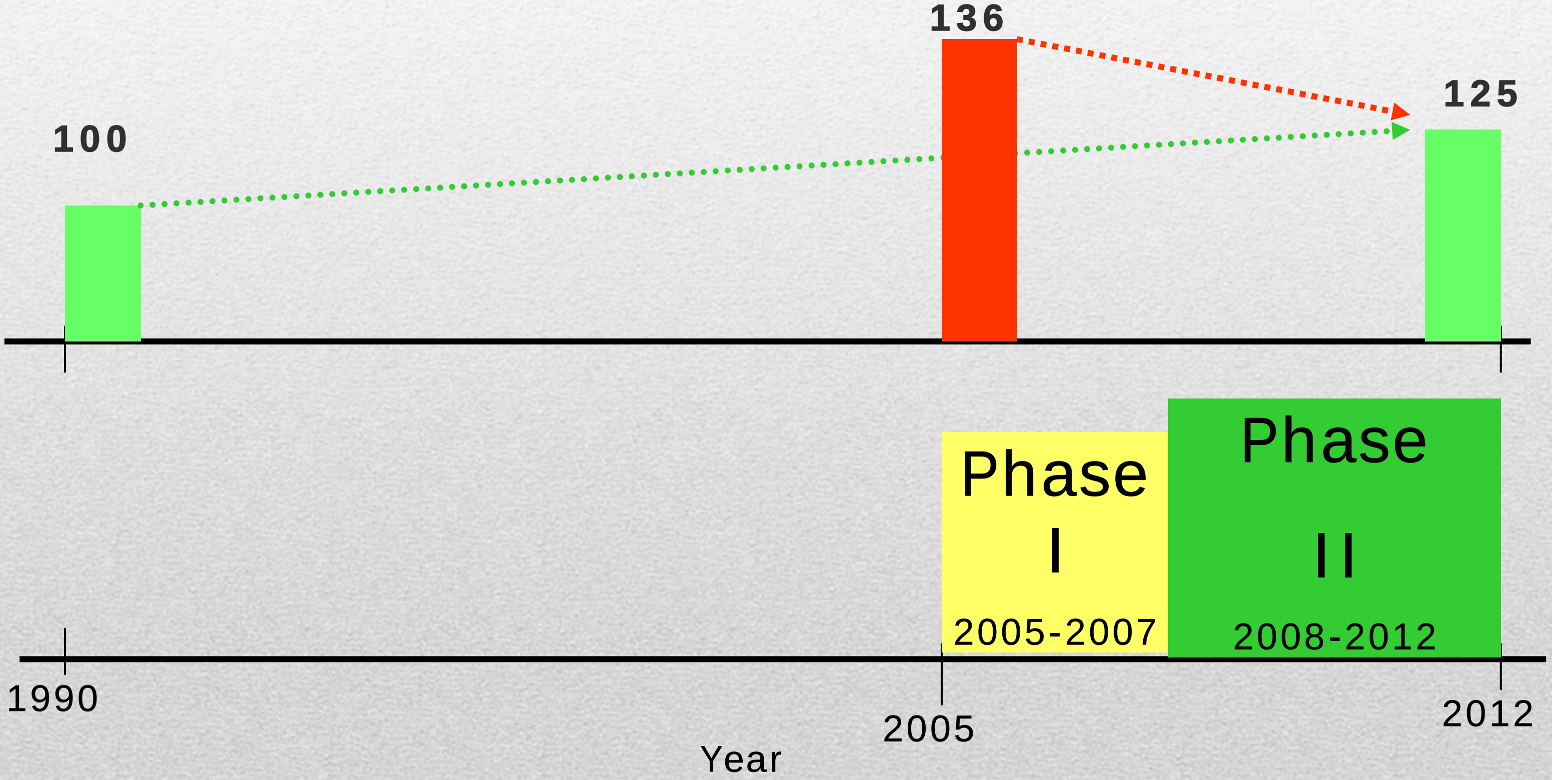
• Industrialized countries agreed to **reduce** their collective green house gas (GHG) emissions **by 5.2% from the level in 1990**.

- **8% for the European Union and others**
- 7% for the United States
- 6% for Japan
- 0% for Russia

- 8% increases for Australia
- 10% increase for Iceland

Greece and its Obligations under the Kyoto Protocol

The national target for Greece is to limit the increase of its greenhouse gas emissions in the period 2008-2012 to 25% over 1990 levels.



Phase I

2005-2007

Country	Verified emissions			Change
	2005	2006	2007	2005–2007
Austria	33,372,826	32,382,804	31,751,165	-4.9%
Belgium	55,363,223	54,775,314	52,795,318	-4.6%
Cyprus	5,078,877	5,259,273	5,396,164	6.2%
Czech Republic	82,454,618	83,624,953	87,834,758	6.5%
Germany	474,990,760	478,016,581	487,004,055	2.5%
Denmark	26,475,718	34,199,588	29,407,355	11.1%
Estonia	12,621,817	12,109,278	15,329,931	21.5%
Spain	183,626,981	179,711,225	186,495,894	1.6%
Finland	33,099,625	44,621,411	42,541,327	28.5%
France	131,263,787	126,979,048	126,634,806	-3.5%
Greece	71,267,736	69,965,145	72,717,006	**2.0%**
Hungary	26,161,627	25,845,891	26,835,478	2.6%
Ireland	22,441,000	21,705,328	21,246,117	-5.3%
Italy	225,989,357	227,439,408	226,368,773	0.2%
Lithuania	6,603,869	6,516,911	5,998,744	-9.2%
Luxembourg	2,603,349	2,712,972	2,567,231	-1.4%
Latvia	2,854,481	2,940,680	2,849,203	-0.2%
Netherlands	80,351,288	76,701,184	79,874,658	-0.6%
Poland	203,149,562	209,616,285	209,601,993	3.2%
Portugal	36,425,915	33,083,871	31,183,076	-14.4%
Sweden	19,381,623	19,884,147	15,348,209	-20.8%
Slovenia	8,720,548	8,842,181	9,048,633	3.8%
Slovakia	25,231,767	25,543,239	24,516,830	-2.8%
United Kingdom	242,513,099	251,159,840	256,581,160	5.8%
Total	**2,012,043,453**	**2,033,636,557**	**2,049,927,884**	**1.9%**

Figures are in tonnes of CO_2

Source: European Commission Press Release 23 May 2008

Phase II 2008-2012

Member State		1st period cap	2005 verified emissions	Proposed cap 2008-2012	Cap allowed 2008-2012
Austria		33.0	33.4	32.8	30.7
Belgium		62.08	55.58 †	63.33	58.5
Czech Republic		97.6	82.5	101.9	86.8
Estonia		19	12.62	24.38	12.72
France		156.5	131.3	132.8	132.8
Hungary		31.3	26.0	30.7	26.9
Germany		499	474	482	453.1
Greece		74.4	71.3	75.5	69.1
Ireland		22.3	22.4	22.6	21.15
Italy		223.1	222.5	209	195.8
Latvia		4.6	2.9	7.7	3.3
Lithuania		12.3	6.6	16.6	8.8
Luxembourg		3.4	2.6	3.95	2.7
Malta		2.9	1.98	2.96	2.1
Netherlands		95.3	80.35	90.4	85.8
Poland		239.1	203.1	284.6	208.5
Slovakia		30.5	25.2	41.3	30.9
Slovenia		8.8	8.7	8.3	8.3
Spain		174.4	182.9	152.7	152.3
Sweden		22.9	19.3	25.2	22.8
United Kingdom		245.3	242.4	246.2	246.2
Totals		**2057.8**	**1910.66**	**2054.92**	**1859.27**

All quantities are in units of Million Metric Tonnes of CO_2

Source: EU press release IP/07/459

CO_2 emission allowances for the Public Power Corporation according to National Allocation Plan (2008-2012)

2008-2010   44.3 Mt/a (14.8% reduction from 2005-2007)
2011-2012   43.4 Mt/a (16.5% reduction from 2005-2007)

2005-2007   52.0 Mt/a (verified)

GHG trends and projection in Greece

GHG trends and projections in Greece

European Environment Agency

Key GHG data (1)	1990	2008	2009	2010	2011 (2)	2012	1990–2011	2010–2011 (2)
Average 2008–2012 target under the Kyoto Protocol (Mt CO_2-eq.)		133.7	133.7	133.7	133.7	133.7		
Total GHG emissions (Mt CO_2-eq.)	105.0	131.3	124.7	118.3	118.5	n.a.	12.9%	0.2%
GHG from international bunkers (3) (Mt CO_2-eq.)	11.2	13.3	11.4	11.0	n.a.	n.a.	n.a.	n.a.
GHG per capita (t CO_2-eq. / capita)	10.4	11.7	11.1	10.5	10.5	n.a.	1.0%	0.2%
GHG per GDP (constant prices) (4) (g CO_2-eq. / euro)	836	626	615	605	651	n.a.	-22.1%	7.6%
Share of GHG in total EU-27 emissions (%)	1.9 %	2.6 %	2.7 %	2.5 %	2.6 %	n.a.	37.0%	2.8%
EU ETS allocated allowances (free + auctioning)		63.7	63.2	64.6	74.6	n.a.		15.5%
EU ETS verified emissions - all installations (5) (Mt CO_2-eq.)		69.9	63.7	59.9	58.8	n.a.		-1.8%
EU ETS verified emissions - constant scope (6) (Mt CO_2-eq.)		69.8	63.6	59.8	57.0	n.a.		-4.8%
Share of EU ETS verified emissions (all install.) in total GHG (%)		53.2 %	51.1 %	50.7 %	49.6 %	n.a.		-2.0%
ETS verified emissions compared to annual allowances (7) (%)		109.7%	100.7%	92.7%	78.8%	n.a.		-15.0%
GHG emissions in the non-ETS sectors		61.4	61.0	58.3	59.7	n.a.		2.3%
Equivalent annual target for non-ETS GHG emissions		70.0	70.5	69.1	59.1	n.a.		-14.5%

Share of GHG emissions (excluding international bunkers) by main source and by gas in 2010 (1) (8)

Qualitative characteristics of upgraded (dry basis)

Particle size (mm)	Cummulative weight (%)		Cummulative ash (%)		Cummulative CO_2 (%)		Cummulative $LHV_{as\ rec}$ (kcal/kg)	
	1	2	1	2	1	2	1	2
-16+8		40.0		32.0		21.4		1455
-8+4		56.1		33.8		21.3		1435
-4+2		63.4		34.7		21.3		1382
-2+1	7.8	68.4	24.9	35.2	4.9	21.4	1548	1353
-1+0.5	24.4	78.4	26.3	36.3	6.5	21.7	1452	1294
--0.5+0.2	41.2	88.6	28.4	37.3	8.6	21.9	1332	1154
-0.2+0.1	63.5	100	31.1	38.4	11.5	22.0	1207	1109
-0.1	100		34.3		15.2		1012	

1: S.Field lignite, 2: Refused innerburden