

**Sustainability indicators for lignite open
cast mines of Greek Public Power
Corporation S.A. in Ptolemais area of
Western Macedonia, Greece**

by

I. Tsolas

G. Pagonis, B. Patmanidou, A. Sokratidou

**Presentation to 3rd International Conference
on Sustainable Development Indicators in the
Mineral Industries (SDIMI 2007)**

Milos Island, 17th to 20th June 2007

Process for Derivation of Sustainability Indicators

- Use of Data Envelopment Analysis (DEA) for the calculation of open cast lignite mines productive efficiency.
- Use of actual data from the annual reports of the mines operation.

Data Envelopment Analysis (DEA)

Is a method based on mathematical programming principles which evaluates the relative efficiency of multi-input multi-output different production units known as Decision Making Units (DMUs).

Sustainability Indicators

Derivation of sustainability indicators at the mine level by means of DEA using operational actual data.

The sustainability indicators, S.I., concerns three large scale open cast lignite mines of Public Power Corporation (PPC) in Western Macedonia - Greece at PTOLEMAIS area (Figures 1,2,3) :

Main Field mine,

Kardia Field mine and

South Field mine

**Figure 2 :Location of PPC`s lignite mines of
in GREECE**

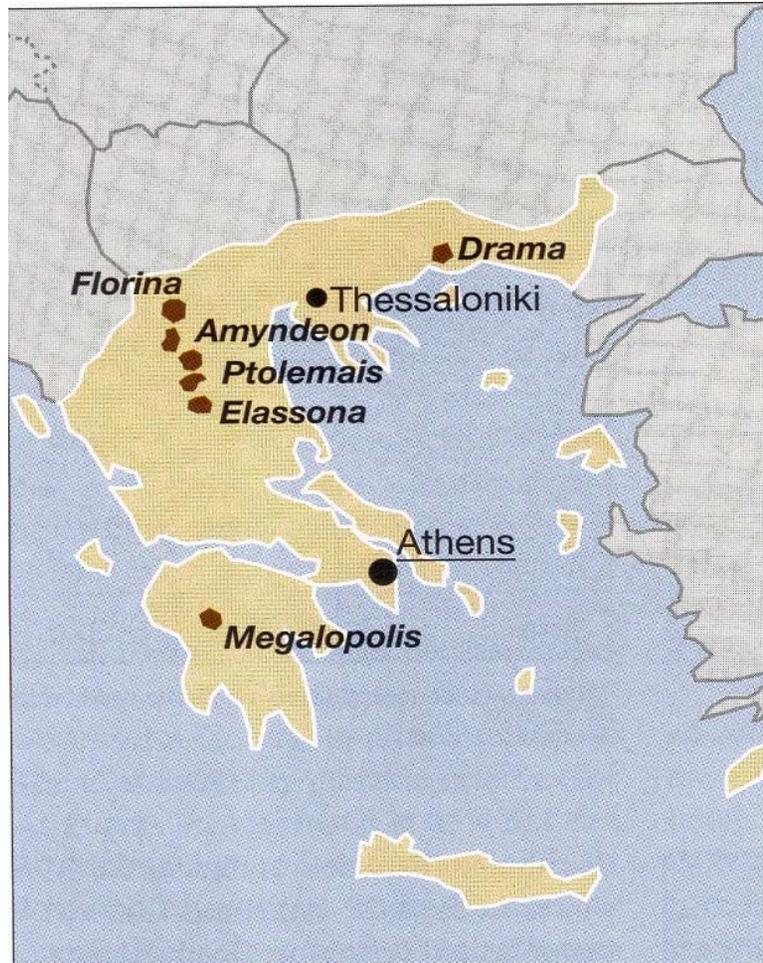
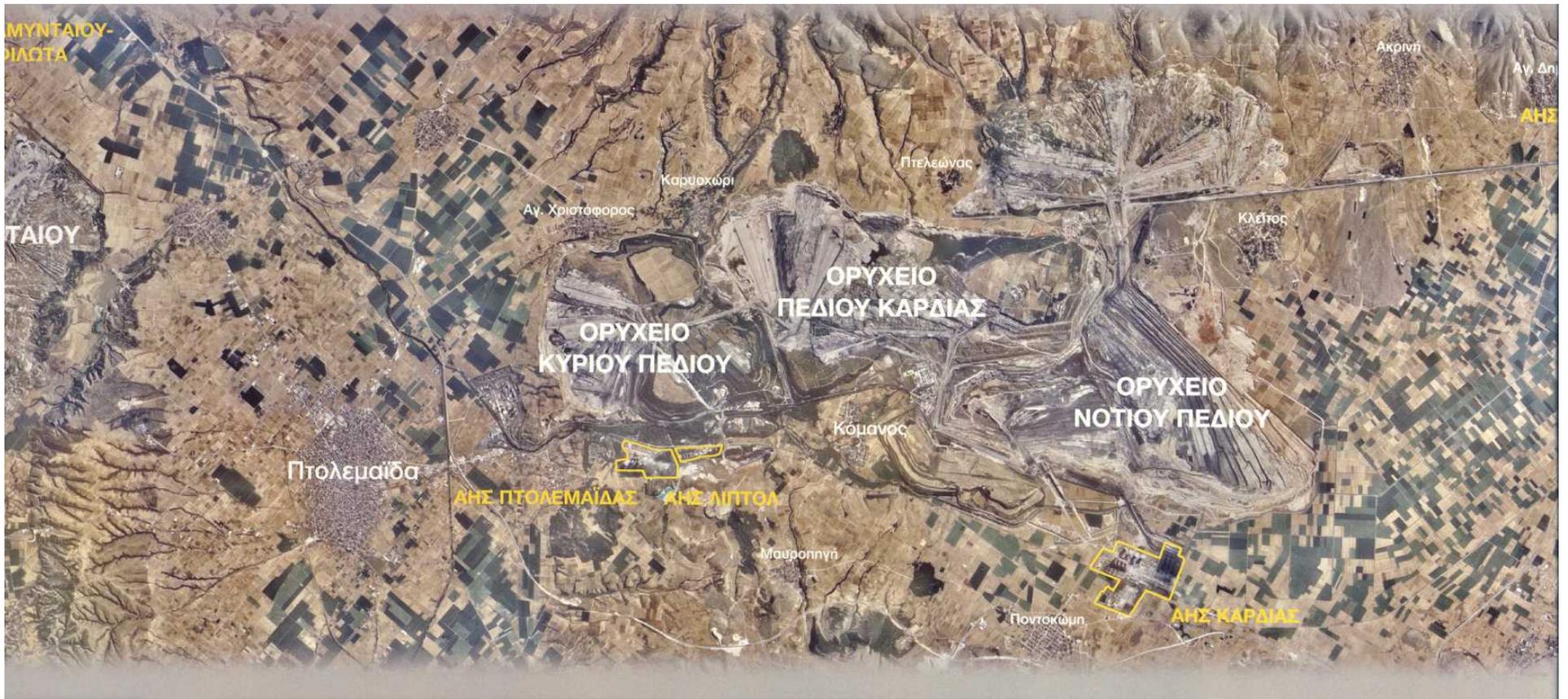


Figure 3 : Air photo of the lignite mines

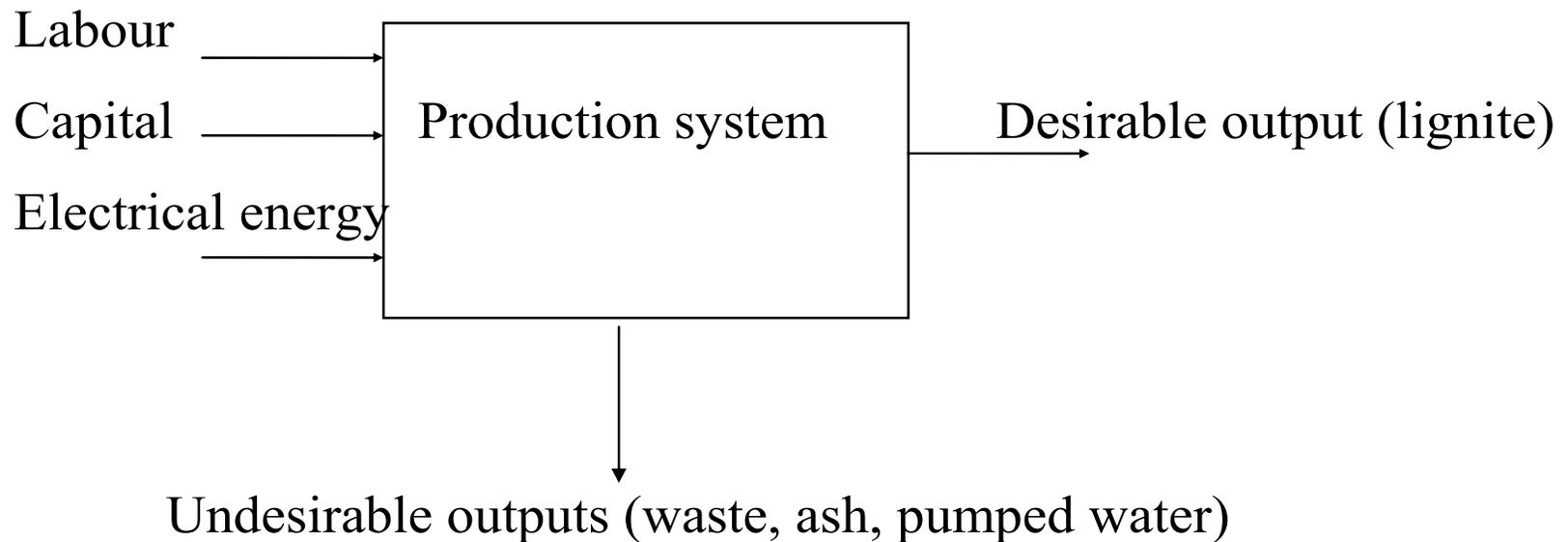




Use of Sustainability Indicator for mine`s activities evaluation

Use of DEA and the input-undesirable output (IUO) model to evaluate the yearly operation of a mine, using conventional inputs ,desirable outputs and undesirable outputs (FIGURE 4).

Figure 4 : Flow chart of lignite mines annual data used to derive Sustainability Indicators



Data set

- **Inputs**

- labour in terms of aggregate total man-shift hours paid
- capital in terms of bucket wheel excavators operating hours and
- intermediate inputs in terms of electrical energy consumed.

- **Output:** excavated lignite

- **Undesirable outputs**

- volume of waste disposed to the environment
- ash quantity produced by the lignite power plants supplied by the mines and
- volume of pumped water

Table 1 Kardia Field Mine annual data used to derive indicators

YEAR	1	2	3	4	5	6	7
	ELECTRICAL ENERGY	WASTE	LABOUR	CAPITAL	ASH	PUMPED WATER	LIGNITE PRODUCTION
	KWH	CUBIC METERS	8ΩPA	ΩPEΣ	TONS	CUBIC METERS	x106 T
1984	83.677.000	32.828.500	254.634	29.337	1.266.673	909.180	15,21
1985	91.923.000	33.807.600	245.092	30.608	1.234.852	837.780	17,01
1986	95.862.670	32.698.900	239.675	31.041	788.951	1.346.700	17,59
1987	100.874.000	34.862.600	247.534	30.392	866.396	1.434.960	17,38
1988	97.958.999	32.894.400	241.207	25.143	1.181.350	1.254.600	13,56
1989	104.883.000	31.016.200	239.284	19.519	1.133.655	1.302.120	12,3
1990	92.904.000	30.834.300	233.671	29.458	757.852	1.246.140	10,71
1991	89.651.000	29.254.200	223.751	28.814	923.226	1.074.600	9,68
1992	86.925.440	31.763.500	217.010	33.496	756.552	866.880	9,15
1993	87.516.000	33.470.900	219.090	36.948	907.500	826.200	7,4
1994	92.977.360	34.653.300	232.469	41.512	1.049.000	1.275.930	6,95
1995	91.082.044	37.515.700	240.755	35.165	1.535.604	1.238.410	10,34
1996	84.843.636	39.705.800	244.375	38.035	1.600.307	1.067.475	14,94
1997	130.516.147	41.361.000	225.903	37.015	1.913.123	1.072.950	15,42
1998	147.289.584	41.257.500	215.164	35.901	2.328.882	1.474.910	14,92
1999	147.464.356	42.604.400	204.181	35.727	2.424.430	1.540.950	15,42
2000	166.558.617	43.825.000	198.353	35.246	2.379.711	1.899.390	14,86
2001	165.882.328	45.290.600	197.105	30.557	1.260.100	988.508	18,43
2002	167.739.995	45.581.500	189.853	31.077	2.319.642	1.378.440	23,34
2003	153.278.447	44.089.000	185.483	30.437	2.088.305	1.541.095	22,61
2004	163.387.335	51.891.500	187.013	33.041	2.546.059	1.850.145	21,66
2005	156.896.077	52.833.600	183.409	32.102	2.004.230	1.919.990	15,99
2006	155.060.024	48.191.200	172.582	30.942	1.931.851	2.471.306	12,52

The input-undesirable output (IUO)-oriented model

Given a set of k years ($k=1,2,\dots,K$), that use a set of N inputs to produce M outputs and a set of J undesirable outputs, for a year indexed 't' the performance indicator, is :

$$\varepsilon^t = \inf\{\theta : (\theta x^t, y^t, \theta w^t) \in S\}$$

where S is the reference technology and z^k are the intensity variables

Calculation of an open cast lignite mine`s first year Sustainability Indicator , ε^1

Linear programming problem

Evaluation of first year`s operation activities

$$\varepsilon^1 : \min \theta$$

$$(z_1 A_1 + \dots + z_{23} A_{23}) \leq \theta A_1$$

$$(z_1 B_1 + \dots + z_{23} B_{23}) \leq \theta B_1$$

$$(z_1 C_1 + \dots + z_{23} C_{23}) \leq \theta C_1$$

$$(z_1 D_1 + \dots + z_{23} D_{23}) \geq D_1$$

$$(z_1 E_1 + \dots + z_{23} E_{23}) = \theta E_1$$

$$(z_1 F_1 + \dots + z_{23} F_{23}) = \theta F_1$$

$$(z_1 G_1 + \dots + z_{23} G_{23}) = \theta G_1$$

Evaluation of a mine`s Sustainability Indicator

Annual operation of a mine is
counted as efficient ,if

$$\boldsymbol{\varepsilon^t = 1}$$

Table 2 : Results Sustainability Indicators

Yearly Activities	Main Field mine	Kardia Field mine	South Field mine
1984		1.0000	
1985		1.0000	
1986		1.0000	
1987		1.0000	
1988		0.9134	
1989		1.0000	
1990		0.6490	1.0000
1991		0.6270	1.0000
1992		1.0000	1.0000
1993	0.7780	1.0000	1.0000
1994	1.0000	0.4297	1.0000
1995	0.9083	1.0000	1.0000
1996	0.9051	1.0000	0.8646
1997	1.0000	1.0000	1.0000
1998	1.0000	0.9693	0.9695
1999	0.8520	1.0000	1.0000
2000	1.0000	1.0000	1.0000
2001	1.0000	1.0000	1.0000
2002	1.0000	1.0000	1.0000
2003	1.0000	1.0000	0.9586
2004	1.0000	1.0000	1.0000
2005	1.0000	1.0000	1.0000
2006	1.0000	1.0000	1.0000

Results analysis

Possible explanation for low sustainability indicator, S.I., score on certain years , S.I. < 1.

Main Field Mine : 2 years out of 14

1993 : S.I. = 0,7780 the combination of higher value of electrical energy consumed with decreased lignite production.

1999 : S.I. = 0,8520 the combination of higher value of environmental impact data with decreased lignite production

Results analysis

Possible explanation for low sustainability indicator, S.I., score on certain years , S.I. < 1.

Kardia Field Mine : 3 years out of 23

1990, 1991 : S.I. = 0,6490 and 0,6270

start of operational life of the Sector 6 Field with equipment and personnel transferred from the old mine to the new mine

1994 : S.I. = 0,4297

higher value of electrical energy consumed, due to the addition of one more BWE to the mine's equipment and the lowest of the period studied lignite production .

Results analysis

Possible explanation for low sustainability indicator, S.I., score on certain years , S.I. < 1.

South Field Mine : 2 years out of 17

1996 : S.I. = 0,8646

the combination of higher value of environmental impact data ,such as pumped water,and decreased lignite production.

2003 : S.I. = 0,9586

the combination of higher value of environmental impact data with decreased lignite production

Conclusions

According to the results of this paper the calculated Sustainability Indicators of Main Field, Kardia Field and South Field mines were keeping constantly better during the last 7 years of operation of the mines.

For the period studied, the mines met their goals from both economic and environmental aspect during the last years of their operation.

Merit of the paper - Potential use of indicators

- The proposed methodological framework derives Sustainability Indicators for the PPC's Ptolemais lignite mines and can be used for performance reporting in the mines annual reports.
- Moreover, the indicators derived here by means of Data Envelopment Analysis and the input - undesirable output model, applied for the lignite mines, can be served as tools to detect where improvements can be made in combination with the existing targets set by the managers of each mine.
- The S.I. can also be used during the preparation of Feasibility Studies or Environmental Impact Studies using necessary benchmarking data.

ENVIRONMENTAL PERFORMANCE SYSTEM OF LIGNITE CENTER OF WESTERN MACEDONIA

**ON 5TH JUNE THE ENVIRONMENTAL
PERFORMANCE SYSTEM OF PPC'S
LIGNITE CENTER IN PTOLEMAIS, HAS
BEEN CERTIFIED ACCORDING TO ISO
14001, BY THE HELLENIC ORGANISATION
OF STANDARDIZATION.**