Given		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Kilowatt-hours	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551
Average Price/kilowatt-hour	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
Price of allowance/ton SO2					$ 250	$ 275	$ 303	$ 333	$ 366	$ 403	$ 443	$ 487
Cost of Capital	10%											
Tax Rate	37.7%											
Allowances Available (tons)					254,580	254,580	254,580	254,580	254,580	122,198	122,198	122,198
Total Revenue				$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000	$ 1,206,856,000

This solution values the alternative by calculating the present value of the incremental, after tax cash flows for each of

Cheapest Alternative

Option 1, No Change	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Amount of emission				266550	266550	266550	266550	266550	266550	266550	266550
Tons of permits to buy				11,970	11,970	11,970	11,970	11,970	144,352	144,352	144,352
Revenues				$ -	$ 1	$ 2	$ 3	$ 4	$ 5	$ 6	$ 7
-Costs				$ 2,992,500	$ 3,291,750	$ 3,620,925	$ 3,983,018	$ 4,381,319	$ 58,120,085	$ 63,932,093	$ 70,325,303
-Depn				$ -	$ 1	$ 2	$ 3	$ 4	$ 5	$ 6	$ 7
EBIT				$ (2,992,500)	$ (3,291,750)	$ (3,620,925)	$ (3,983,018)	$ (4,381,319)	$ (58,120,085)	$ (63,932,093)	$ (70,325,303)
-Tax				$ (1,128,173)	$ (1,240,990)	$ (1,365,089)	$ (1,501,598)	$ (1,651,757)	$ (21,911,272)	$ (24,102,399)	$ (26,512,639)
EBIAT				$ (1,864,328)	$ (2,050,760)	$ (2,255,836)	$ (2,481,420)	$ (2,729,562)	$ (36,208,813)	$ (39,829,694)	$ (43,812,664)
+Depn				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
-CapEx				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
-Delta WC				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
FCF				$ (1,864,328)	$ (2,050,760)	$ (2,255,836)	$ (2,481,420)	$ (2,729,562)	$ (36,208,813)	$ (39,829,694)	$ (43,812,664)
PV				$ (1,400,697)	$ (1,400,697)	$ (1,400,697)	$ (1,400,697)	$ (1,400,697)	$ (16,891,678)	$ (16,891,678)	$ (16,891,678)
NPV	$ (266,379,610)										

Interest on Capital Expenditures is capitialize for the years leading up to the start of the scrubbers (Following SFAS 34).
Caclulation for depriciation base:
143*(1.1)^2 + 503*(1.1) + 72 = 800

Option 2, Install Scrubbers '95	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Additional Cost ($.0013/kwhr)				$ 28,016,300	$ 28,016,300	$ 28,016,300	$ 28,016,300	$ 28,016,300	$ 28,016,300	$ 28,016,300	$ 28,016,300
Revenue reduction				$ 24,137,120	$ 24,137,120	$ 24,137,120	$ 24,137,120	$ 24,137,120	$ 24,137,120	$ 24,137,120	$ 24,137,120
Amount of Polution				26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655
Permits AFS				227,925	227,925	227,925	227,925	227,925	95,543	95,543	95,543
Revenues				56981250	62679375	68947312.5	75842043.75	83426248.13	38468239.23	42315063.16	46546569.47
-Costs				$ 52,153,420	$ 52,153,420	$ 52,153,420	$ 52,153,420	$ 52,153,420	$ 52,153,420	$ 52,153,420	$ 52,153,420
-Depn				$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 15,999,990	$ 15,999,990	$ 15,999,990
EBIT				$ (107,172,100)	$ (101,473,975)	$ (95,206,038)	$ (88,311,306)	$ (80,727,102)	$ (29,685,171)	$ (25,838,347)	$ (21,606,841)
-Tax				(40,403,881.70)	(38,255,688.58)	(35,892,676.14)	(33,293,362.46)	(30,434,117.41)	(11,191,309.38)	(9,741,056.76)	(8,145,778.88)
EBIAT				(66,768,218.30)	(63,218,286.43)	(59,313,361.36)	(55,017,943.79)	(50,292,984.47)	(18,493,861.39)	(16,097,290.08)	(13,461,061.65)
+Depn				$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 111,999,930	$ 15,999,990	$ 15,999,990	$ 15,999,990
-CapEx	$ 143,850,000	$ 503,610,000	$ 71,970,000								
-Delta WC											
FCF	(143,850,000.00)	(503,610,000.00)	(71,970,000.00)	45,231,711.70	48,781,643.58	52,686,568.64	56,981,986.21	61,706,945.53	(2,493,871.39)	(97,300.08)	2,538,928.35
PV	$ (143,850,000)	$ (457,827,273)	$ (59,479,339)	$ 33,983,254	$ 33,318,519	$ 32,714,214	$ 32,164,846	$ 31,665,420	$ (1,163,409)	$ (41,265)	$ 978,867
NPV	$ (435,838,048)										

Option 3, Delay Scrubbers	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Additional Cost ($.0013/kwhr)									$ 28,016,300	28016300	28016300
Revenue reduction	0	0	0	0	0	0	0	0	$ 24,137,120	$ 24,137,120	$ 24,137,120
Amount of Polution				266550	266550	266550	266550	266550	26655	26655	26655
Permits AFS				(11,970)	(11,970)	(11,970)	(11,970)	(11,970)	95,543	95,543	95,543
Revenues				$ -	$ -	$ -	$ -	$ -	$ 38,468,239	$ 42,315,063	$ 46,546,569
-Costs				$ 2,992,500	$ 3,291,750	$ 3,620,925	$ 3,983,018	$ 4,381,319	$ 52,153,420	$ 52,153,420	$ 52,153,420
-Depn				$ -	$ -	$ -	$ -	$ -	$ 111,999,930	$ 111,999,930	$ 111,999,930
EBIT				$ (2,992,500)	$ (3,291,750)	$ (3,620,925)	$ (3,983,018)	$ (4,381,319)	$ (125,685,111)	$ (121,838,287)	$ (117,606,781)
-Tax				$ (1,128,173)	$ (1,240,990)	$ (1,365,089)	$ (1,501,598)	$ (1,651,757)	$ (47,383,287)	$ (45,933,034)	$ (44,337,756)
EBIAT				$ (1,864,328)	$ (2,050,760)	$ (2,255,836)	$ (2,481,420)	$ (2,729,562)	$ (78,301,824)	$ (75,905,253)	$ (73,269,024)
+Depn				$ -	$ -	$ -	$ -	$ -	$ 111,999,930	$ 111,999,930	$ 111,999,930
-CapEx				$ -	$ -	$ 143,850,000	$ 503,610,000	$ 71,970,000	$ -	$ -	$ -
-Delta WC				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
FCF				$ (1,864,328)	$ (2,050,760)	$ (146,105,836)	$ (506,091,420)	$ (74,699,562)	$ 33,698,106	$ 36,094,677	$ 38,730,906
PV				$ (1,400,697)	$ (1,400,697)	$ (90,720,229)	$ (285,675,413)	$ (38,332,687)	$ 15,720,415	$ 15,307,667	$ 14,932,441
NPV	$ (282,530,884)										

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551	21551
	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
$	536	589	648	713	785	863	949	1,044	1,044	1,044	1,044	1,044	1,044	1,044
	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198	122,198
$	1,206,856,000	1,206,856,000	1,206,856,000	###########	#########	##########	###########	##########	1,206,856,000	##########	1,206,856,000	1,206,856,000	1,206,856,000	###########

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	266550	266550	266550	266550	266550	266550	266550	266550	266550	266550	266550	266550	266550	266550
	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352	144,352
$	8	9	10	11	12	13	14	15	16	17	18	19	20	21
$	77,357,833	85,093,616	93,602,978	###########	#########	##########	137,044,120	##########	150,748,532	##########	150,748,532	150,748,532	150,748,532	150,748,532
$	8	9	10	11	12	13	14	15	16	17	18	19	20	21
$	(77,357,833)	(85,093,616)	(93,602,978)	###########	#########	##########	(137,044,120)	##########	(150,748,532)	##########	(150,748,532)	(150,748,532)	(150,748,532)	(150,748,532)
$	(29,163,903)	(32,080,293)	(35,288,323)	(38,817,155)	#########	##########	(51,665,633)	##########	(56,832,197)	(56,832,197)	(56,832,197)	(56,832,197)	(56,832,197)	(56,832,197)
$	(48,193,930)	(53,013,323)	(58,314,655)	(64,146,121)	#########	##########	(85,378,487)	##########	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)
$	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$	(48,193,930)	(53,013,323)	(58,314,655)	(64,146,121)	#########	##########	(85,378,487)	##########	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)	(93,916,335)
$	(16,891,678)	(16,891,678)	(16,891,678)	(16,891,678)	#########	##########	(16,891,678)	##########	(15,356,071)	(13,960,065)	(12,690,968)	(11,537,244)	(10,488,403)	(9,534,912)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
$	28,016,300	28,016,300	28,016,300	28,016,300	#########	28,016,300	28,016,300	28,016,300	28,016,300	28,016,300	28,016,300	28,016,300	28,016,300	28,016,300
$	24,137,120	24,137,120	24,137,120	24,137,120	#########	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120
	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655	26,655
	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543
	51201226.42	56321349.06	61953483.97	68148832.36	74963715.6	82460087.16	90706095.88	99776705.46	99776705.46	99776705.46	99776705.46	99776705.46	99776705.46	99776705.46
$	52,153,420	52,153,420	52,153,420	52,153,420	#########	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420
$	15,999,990	15,999,990	15,999,990	15,999,990	#########	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990		
$	(16,952,184)	(11,832,061)	(6,199,926)	(4,578)	6,810,306	14,306,677	22,552,686	31,623,295	31,623,295	31,623,295	31,623,295	31,623,295	47,623,285	47,623,285
	(6,390,973.21)	(4,460,686.97)	(2,337,372.11)	(1,725.77)	#########	##########	8,502,362.57	##########	11,921,982.39	##########	11,921,982.39	11,921,982.39	17,953,978.62	17,953,978.62
	(10,561,210.37)	(7,371,373.97)	(3,862,553.92)	(2,851.87)	#########	##########	14,050,323.30	##########	19,701,313.07	##########	19,701,313.07	19,701,313.07	29,669,306.84	29,669,306.84
$	15,999,990	15,999,990	15,999,990	15,999,990	#########	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990		
	5,438,779.63	8,628,616.03	12,137,436.08	###########	#########	##########	30,050,313.30	##########	35,701,303.07	##########	35,701,303.07	35,701,303.07	29,669,306.84	29,669,306.84
$	1,906,259	2,749,343	3,515,783	4,212,546	4,845,968	5,421,806	5,945,294	6,421,193	5,837,448	5,306,771	4,824,337	4,385,761	3,313,414	3,012,194

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300	28016300
$	24,137,120	24,137,120	24,137,120	24,137,120	#########	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120	24,137,120
	26655	26655	26655	26655	26655	26655	26655	26655	26655	26655	26655	26655	26655	26655
	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543	95,543
$	51,201,226	56,321,349	61,953,484	68,148,832	#########	82,460,087	90,706,096	99,776,705	99,776,705	99,776,705	99,776,705	99,776,705	99,776,705	99,776,705
$	52,153,420	52,153,420	52,153,420	52,153,420	#########	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420	52,153,420
$	111,999,930	111,999,930	15,999,990	15,999,990	#########	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	63,999,960
$	(112,952,124)	(107,832,001)	(6,199,926)	(4,578)	6,810,306	14,306,677	22,552,686	31,623,295	31,623,295	31,623,295	31,623,295	31,623,295	31,623,295	(16,376,675)
$	(42,582,951)	(40,652,664)	(2,337,372)	(1,726)	2,567,485	5,393,617	8,502,363	11,921,982	11,921,982	11,921,982	11,921,982	11,921,982	11,921,982	(6,174,006)
$	(70,369,173)	(67,179,337)	(3,862,554)	(2,852)	4,242,820	8,913,060	14,050,323	19,701,313	19,701,313	19,701,313	19,701,313	19,701,313	19,701,313	(10,202,668)
$	111,999,930	111,999,930	15,999,990	15,999,990	#########	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	15,999,990	63,999,960
$	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$	41,630,757	44,820,593	12,137,436	15,997,138	#########	24,913,050	30,050,313	35,701,303	35,701,303	35,701,303	35,701,303	35,701,303	35,701,303	53,797,292
$	14,591,326	14,281,222	3,515,783	4,212,546	4,845,968	5,421,806	5,945,294	6,421,193	5,837,448	5,306,771	4,824,337	4,385,761	3,987,056	5,461,802

Non-numerical Factors:

- Holding allowances many have a high convenience yield, as they could provide insurance against unexpected demands for energy.
- By choosing the option not to install the scrubbers or to delay their installation, the managers retain the strategic option to install the scrubbers at a later date. Installation of the scrubbers may become the optimal solution depending on the actual market price of the allowances.
- There may be pressure from state officials and coal miners to choose one decision over the other.

Why develop a market for pollution allowances?

The marginal cost of pollution reduction is not the same across all sources. With a market solution such as the one described in the case, the market equalizes the marginal compliance cost across all sources. This reduces the cost to society of reducing pollutants.

An implicit assumption is that the marginal benefit of reduction is the same across all sources. This seems plausible for SO_2, as it has far reaching effects. The location of the pollution source is less relevant than the total amount of pollutants released.