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Decision Making in Energy Market with Producers with Different Profiles

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Abstract

The purpose of this paper is to formulate and study a game where there is a player who is involved for a long time interval and several small players who stay in the game for short time intervals. Examples of such games abound in practice. For example a Bank is a long-term player who stays in business for a very long time whereas most of its customers are affiliated with the Bank for relatively short time periods. Another example is the Hellenic Electrical Grid. There is the Grid Administrator, which is the major long time player, and there are many minor players (power producers with different technologies, quantity and quality features). The Grid Administrator is considered to have an infinite time horizon and the minor players are considered as players who stay in the game for a fixed period of five years (indicative number). A minor producer/consumer who enters the system a certain year is considered as one player who is involved for five (specific) time levels. This player overlaps in action with the other players who entered at different time and with the Grid Administrator. The minor players (energy producers) try to improve their strategies, by changing their profile, so as to penetrate in the electrical grid and succeed to sell more energy to the Grid (improve their profits). The Grid Administrator tries to imply the best policy so as to improve his gain.

JEL Classifications: C63, C78, D47.

Keywords: Energy optimization cost, Decision Policy tool, Strategies, Liberalized Energy Market.

1. Introduction

The purpose of this paper is to formulate and study a game where there is a player who is involved for a long time interval and several small players who stay in the game for short time intervals. Examples of such games abound in practice.

The work presented is motivated by the game between the Grid Administrator referred to as the major player and the many small (power producers) referred to as the minor ones.

Each small player (power producer) has different quality and operational features. Also the Grid Coordinator has different objectives and gain compared with the minor players. The minor players (energy producers) try to improve their energy profile so as to penetrate in the electrical grid and succeed to sell more energy to the Grid (improve their profits). The Grid Administrator tries to imply the best criteria and options so as to improve its gain.

Then we present an Application and we run many cases so as to study the influence of each parameter to the gains of the players. After the first run the producers change some of their parameters so as to gain a bigger market share. The Grid Administrator decides the rules and the gravity of each energy profile parameter and then the producers change some of their parameters (only these which are possible to be changed) so as to increase their market share.

The author and his coauthors (Kakogianis and Papavassilopoulos, 2010; Kakogianis and Papavassilopoulos, 2011) have presented earlier versions of portions of this work.

In the Introduction we present the basic model. In Section II we describe our energy problem and the basic parameters that define players' strategies and the outcome of the system. In Section III we present a static version of our problem with the mathematical formulation. In section IV we estimate the basic parameters of each technology based on real business plans of real energy projects. In section V we present a Java application we developed that calculates all the gains of the players. We run 20 times our system so as to make some conclusions, which we develop at section VI with our future work.

2. Energy Model Description

We intend to study a liberalized energy market. In our model there are 5 players, the one is the Greek Electrical Grid Administrator and the other four are different technologies of energy producers:

1. Electrical Energy producers with lignite – Player 1 (P1)
2. Electrical Energy producers with photovoltaic parks (PV) – Player 2 (P2)
3. Electrical Energy producers with Wind Parks – Player 3 (P3)
4. Electrical Energy producers with Biomass – Player 4 (P4)

Each technology has its own quality features. We will study the profile of its player and also we will study the objectives and gain of each player.

The Grid Coordinator decides at every time level to buy specific energy from each producer so as to cover the expected energy needs of the grid. The Grid

Coordinator (P5) at time level t will buy E_{s_t} energy.

E_{s_t} is the sum of the energies which will be provided by the 4 technologies:

$$E_{st}=E_{1t}+E_{2t}+E_{3t}+E_{4t} \quad (1)$$

The quality features of its technology are:

- C_{1j} – Operational cost of each MWh that is produced by player j.
- C_{2j} – The environmental footprint of player j (0 – 1).
- C_{3j} – The reliability of the offered energy of player j (0 – 1).
- C_{4j} – The social footprint of player j (0 – 1).

The producers buy the policy that they imply they can change their "grid profile" by changing their quality features. The minor players can change their operational cost by a more effective administration or by succeeding lower prices at their sources prices.

As regards their environmental footprint they can use measures to reduce their waste (gas or solid waste) and as regard their reliability, it can be improved by using backup systems or batteries. Finally the social footprint is related to the labor force they use or their contribution at the local and national economy.

The Grid Coordinator (P5) defines the rules of the energy market. So P5 defines the following:

- P_c - Penalty of CO_2. With this penalty P5 defines the environmental policy of the grid (and the state).
- P_b - Bonus of reliability. With this bonus (euros/ MWh) P5 gives a reward to reliable energy producers.
- P_p - Bonus of productivity. With this bonus (euros/ MWh) P5 gives a reward to players, which have a strong social footprint as they employ labor force for the energy production.
- P - price that Grid Coordinator (P5) buys energy from the other players.

We will imply a static case study using 4 time levels of the game evolution and five players (4 technologies and Grid Coordinator). The decision policy of P5 is defined by P_c, P_b, P_p, P.

In Greece the Regulatory Authority of Energy (www.rae.gr) is basically the agency, which defines the energy market rules. With this paper we present also how RAE can change the penetration of its technology (minor players) by changing the priority of the implied policies. When there is a major unemployment problem in the country RAE can give a bigger gravity at the social factor and give priority to technologies with a bigger social footprint.

When the grid has bigger energy needs (e.g. summer in Greece because of the high temperatures and big number of tourists) RAE can give priority to players with bigger reliability flag.

3. Static Energy Case

We intend to study the penetration of four different power producers' technologies in the electrical distribution grid of a liberalized energy market. It will be studied the cost of each player. There are totally 5 players, 4 technologies and the grid administrator.

There are four different quality features of each technology that will be takes in to consideration. The four producers (minor players) are:

1. Lignite Energy (power) Producer, i=1 , (P1)
2. Photovoltaic Energy (power) Producer, i=2 , (P2)
3. Wind Energy (power) Producer, i=1, (P3)
4. Biomass Energy (power) Producer, i=1, (P4)

The electrical grid needs are estimated periodically (e.g. every 24 hours). The total energy need is Es_t, Es_t is the sum of the energy which is bought from each producer/technology respectively:

$$Es_t = \sum_{i=1}^{4} E_{it} = E_{1_t} + E_{2_t} + E_{3_t} + E_{4_t} \tag{2}$$

Each technology profile has different quality specifications:

1. Production Cost / KWh. (euros/MWh) - C_1
2. Environmental Pollution. This parameter represents the amount of the produced CO_2 (or other gases) / MWh (environmental footprint). The range of this parameter is 0-1 - C_2
3. Level of Reliability of the offered energy (lack of stochasticity). - The range of this parameter is 0-1 - C_3
4. Productivity (social footprint). This parameter counts the labor force that is essential for each produces MWh. The range of this parameter is 0-1 - C_4 (Samuelson, 1958).

There are also penalties and bonus depending of the profile of each technology and the policy that the administrator wants to imply:

- Penalty $\mathbf{P}_c$, which is implied on the produced gr CO_2 / MWh
- Bonus $\mathbf{P}_b$, which is related to the reliability of produced energy
- Bonus $\mathbf{P}_p$, which is related to the social footprint of produced energy.

The equations of the players' gains are:

$$G_{lignite_t} = E_{lignite_t} * P - E_{lignite_t} * (C_{1_{lignite}} + P_c * C_{2_{lignite}} - P_b * C_{3_{lignite}} - Pp * (C_{1_{lignite}} / C_{4_{lignite}})) \tag{3}$$

$$G_{PVt}=E_{PVt} * P-E_{PVt} * (C_{1PV} + P_c * C_{2PV} - P_b * C_{3PV} - P_p * (C_{1PV}/C_{4PV})) \quad (4)$$

$$G_{wind_t}=E_{wind_t} * P-E_{wind_t} *(C_{1wind}+P_c*C_{2wind}-P_b*C_{3wind}-P_p*(C_{1wind}/C_{4wind})) \quad (5)$$

$$G_{biomas_t}=E_{biom_t} *P-E_{biom_t} *(C_{1_{biomass}} +P_c *C_{2_{biomass}} -P_b*C_{3_{biomass}}- P_p*(C_{1_{biomass}} / C_{4_{biomass}})) \quad (6)$$

$$\begin{aligned} G_{grid_t}=&P_c *(E_{lignite_t} *C_{2lignite}+E_{PV_t}*C_{2PV}+E_{wind_t} *C_{2wind}+E_{biom_t} *C_{2biomass}) \\ &+CO_{2tariff} * (E_{lignite_t}*C_{2lignite}+E_{PV_t}*C_{2PV}+E_{wind_t} *C_{2wind}+E_{biom_t}*C_{1biomass})P_b \\ &= Pc*(E_{lignite_t} *C_{2_{lignite}} +E_{PV_t} *C_{2_{PV}} +E_{wind_t} *E_{biom_t} *C_{2_{biomass}}) \\ &+C0_{2_{tariff}} *(E_{lignite_t} *C_{2_{lignite}} +E_{PV_t} *C_{2_{PV}} +E_{wind_t} *C_{2_{wind}} +E_{biom_t} *C_{1_{biomass}}) \\ &-P_b*(E_{lignite_t} *C_{2_{lignite}} +E_{PV_t} *C_{2_{PV}} +E_{wind_t} *C_{3_{wind}} *E_{biom_t} *C_{3biomass}) \\ &P_b*(E_{lignite_t} *C_{1_{lignite}} / C_{4_{lignite}})+E_{PV_t} *(C_{1_{PV}}/C_{4_{PV}})+E_{wind_t} *(C_{1_{wind}}/C_{4_{wind}}) \\ &-E_{biom_t} *(C_{1_{biomass}}/C_{4_{biomass}}))-P*(E_{lignite_t} +E_{PV_t} +E_{wind_t} +E_{biom_t}) \end{aligned} \quad (7)$$

4. Computation of the parameters

We will calculate the cost of the energy production of each technology, the reliability, and the labor force that is necessary for each player and finally the environmental footprint of each player.

We will present the following energy plants:

- Wind farm 18 MW
- Photovoltaic Park 1 MW
- Biomass Energy Plant 2.3 MW
- List of Greek Lignite Energy Plants.

The time horizon we imply our calculations is 20 years. We use data for the first three plants provided by the Athens Business Engineering Consulting (www.abec.gr). RAE so as to provide the Production License to the projects has evaluated all these data. In our analysis we took into consideration:

- The produced energy will be sold to the Grid Administrator for at least 20 years according to contracts that is signed (Greek Law N.3468/06 and N. 3851/2010).
- We used tax rate 25% according to the Greek Law N. 3296/2004.
- We used inflation rate 3.0%.

The operational costs are:

1. The needed labor force (wage costs and Employer's social security contribution).

2. Insurance costs.
3. Returning Charges to the State and Municipalities for the Land usage.
4. Maintance and Service contracts.
5. Consumables and equipment.
6. Other charges and costs.
7. Energy Source Material (where is needed).

4.1 Wind Farm 18 MW – "Aioliki Pnoi LtD"

All the data has been approved by the Greek Regulatory Authority of Energy so as to provide the Production Licence. We studied a wind farm 10 MW power, at the area "Agios Ioannis", municipality of Distomo at Viotia.

The Total Sum of the Operational Cost of the Wind Farm for 20 years is 21.126.346€.

The available energy to be used by the Grid Administrator for the next 20 years is 1.291.392.260 KWh (1.291.392 MW) with energy capacity 30%. The final operational/productive cost of the wind farm is 16,36 €/ MWh.

The social footprint is a flag, which can be calculated by comparing the produced MWh to the number of the labor force units, are needed. The social footprint at the wind farm is : $5/1291392=0.39 * 10^{-5}$.

Table 1

Operational Costs

Year	Wage Costs (5 employees)	Energy Source Material	Insurance	Returning Charges to the State	Maintenance and Service	Consumables and equipment	Other charges and costs	TOTAL SUM
		No Source Material	24455042	5165569	40000	1500	10000	
			0.45%	3%	9 Turbines	9 Turbines	9 Turbines	
1	80531		116750	154967	0	14322	95481	462050
2	82947		120252	158686	0	12908	98345	473139
3	85435		123860	162495	381924	9496	101296	864505
4	87998		127575	166395	393382	7825	104335	887510
5	90638		131403	170388	405183	8060	107465	913137
6	93357		135345	174477	417339	8302	110689	939509
7	96158		139405	178665	429859	8551	114009	966647
8	99043		143587	182953	442755	8807	117430	994574
9	102014		147895	187344	456037	9071	120952	1023314
10	105074		152332	191840	469718	9344	124581	1052889
11	108227		156902	196444	483810	12511	128318	1086212
12	111473		161609	201159	498324	15860	132168	1120593
13	114818		166457	205987	513274	19399	136133	1156067
14	118262		171451	210930	528672	23136	140217	1192668
15	121810		176594	215993	544532	27079	144424	1230432
16	125464		181892	221176	560868	32354	148756	1270511
17	129228		187349	226485	577694	35623	153219	1309598
18	133105		192969	231920	595025	40243	157816	1351078
19	137098		198758	237486	612876	45108	162550	1393877
20	141211		204721	243186	631262	50228	167427	1438035

Table 2

Energy Production of the Wind Farm (18 MW)

	Energy	**Energy Losses**	**Available Energy**	**Grid Penetration**	**Available Energy**
	KWh/year	**%**	**%**	**%**	**KWh/year**
Year 1	0	2	98	100	0
Year 2	67232000	2	98	100	64569613
Year 3	67232000	2	98	100	64569613
Year 4	67232000	2	98	100	64569613
Year 5	67232000	2	98	100	64569613
Year 6	67232000	2	98	100	64569613
Year 7	67232000	2	98	100	64569613
Year 8	67232000	2	98	100	64569613
Year 9	67232000	2	98	100	64569613
Year 10	67232000	2	98	100	64569613
Year 11	67232000	2	98	100	64569613
Year 12	67232000	2	98	100	64569613
Year 13	67232000	2	98	100	64569613
Year 14	67232000	2	98	100	64569613
Year 15	67232000	2	98	100	64569613
Year 16	67232000	2	98	100	64569613
Year 17	67232000	2	98	100	64569613
Year 18	67232000	2	98	100	64569613
Year 19	67232000	2	98	100	64569613
Year 20	67232000	2	98	100	64569613

Table 3

The quality/finance parameters for the Wind Farm 18 MW

Productive Cost (€/ MWh)	**Environmental Footprint (0-1)**	**Reliability (0-1)**	**Social Footprint**
16.36	0.1	0.3	0.39

4.2 Photovoltaic (PV) Park 1 MW

The Greek Regulatory Authority of Energy has approved all the data. We studied a photovoltaic park 1 MW power, at the area "Arkalohori", municipality of Iraklion at Crete.

The Total Sum of the Operational Cost of the PV Park for 20 years is 877.262 €.

Table 4

Operational Costs

Year	Wage Costs	Energy Source Material	Insurance	Returning Charges to the State	Maintenance and Service	Consumables and equipment	Other charges and costs	TOTAL SUM
	0	0	2000000	0	2000000	2000000	627274	
			0.45%	3%	0.3%	0	0	
1			9548	0	0	4244	13309	27101
2			9835	0	0	4371	13709	27914
3			10130	0	6365	4502	14120	35117
4			10433	0	6556	4637	14544	36171
5			10746	0	6753	4776	14980	37256
6			11069	0	6956	4919	15429	38373
7			11401	0	7164	5067	15892	39525
8			11743	0	7379	5219	16369	40710
9			12095	0	7601	5376	16860	41932
10			12458	0	7829	5537	17366	43190
11			12832	0	8063	5703	17887	44485
12			13217	0	8305	5874	18423	45820
13			13613	0	8555	6050	18976	47194
14			14022	0	8811	6232	19545	48610
15			14442	0	9076	6419	20132	50069
16			14876	0	9348	6611	20736	51571
17			15322	0	9628	6810	21358	53118
18			15782	0	9917	7014	21999	54711
19			16255	0	10215	7224	22659	56353
20			16743	0	10521	7441	23338	58043

The available energy to be used by the Grid Administrator for the next 20 years is 27.244.000 KWh (27.244 MWh).

The final operational/productive cost of the wind farm is 32,2 €/ MWh.

The social footprint is a flag, which can be calculated by comparing the produced MWh to the number of the labor force units, are needed. The social footprint at the PV Park is : 0.1

Table 5

Energy Production of PV Park (1 MW)

	Energy	Energy Losses	Available Energy	Grid Penetration	Available Energy
	KWh/year	%	%	%	KWh/year
Year 1	0	2	98	100	0
Year 2	1390000	2	98	100	1362200
Year 3	1390000	2	98	100	1362200
Year 4	1390000	2	98	100	1362200
Year 5	1390000	2	98	100	1362200
Year 6	1390000	2	98	100	1362200
Year 7	1390000	2	98	100	1362200
Year 8	1390000	2	98	100	1362200
Year 9	1390000	2	98	100	1362200
Year 10	1390000	2	98	100	1362200
Year 11	1390000	2	98	100	1362200
Year 12	1390000	2	98	100	1362200
Year 13	1390000	2	98	100	1362200
Year 14	1390000	2	98	100	1362200
Year 15	1390000	2	98	100	1362200
Year 16	1390000	2	98	100	1362200
Year 17	1390000	2	98	100	1362200
Year 18	1390000	2	98	100	1362200
Year 19	1390000	2	98	100	1362200
Year 20	1390000	2	98	100	1362200

Table 6

The quality/finance parameters for the Wind Farm 18 MW

Productive Cost (€/ MWh)	Environmental Footprint(0-1)	Reliability (0-1)	Social Footprint
32.2	0.1	0.8	0.1

4.3 Biomass Energy Plant 2.3 MW

The Greek Regulatory Authority of Energy has approved all the data. We studied a biomass energy plant 2.3 MW power, at the area "Kalimnos", Aegean Island.

The Total Sum of the Operational Cost of the Biomass Plant for 20 years is 56.847.550 €.

The available energy to be used by the Grid Administrator for the next 20 years is 367.225.600 KWh (367.226 MWh).

The final operational/productive cost of the wind farm is 154,8 €/ MWh. The necessary labor units are 8 and the social footprint is 8/367226=2.1 * 10^{-5}.

Table 7

Operational Costs

Year	Wage Costs (8 employees)	Energy Source Material	Insurance	Returning Charges to the State	Maintenance and Service	Consumables and equipment	Other charges and costs	TOTAL SUM
		23919 tn	7306228	0	7306228	7306228	3278800	
		70euros/tn	0.45%	3%	0.3%	0	0	
1	200000	1776297	34880	0	0	14612	69570	2095359
2	206000	1829586	35927	0	0	15051	71657	2158220
3	212180	1884473	37005	0	23254	15502	73806	2246220
4	218545	1941007	38115	0	23951	15967	76021	2313607
5	225102	1999238	39258	0	24670	16446	78301	2383015
6	231855	2059215	40436	0	25410	16940	80650	2454505
7	238810	2120991	41649	0	26172	17448	83070	2528140
8	245975	2184621	42898	0	26957	17971	85562	2603985
9	253354	2250160	44185	0	27766	18511	88129	2682104
10	260955	2317664	45511	0	28599	19066	90773	2762567
11	268783	2387194	46876	0	29457	19638	93496	2845444
12	276847	2458810	48282	0	30341	20227	96301	2930808
13	285152	2532574	49731	0	31251	20834	99190	3018732
14	293707	2608552	51223	0	32188	21459	102165	3109294
15	302518	2686808	52760	0	33154	22103	105230	3202573
16	311593	2767412	54342	0	34149	22766	108387	3298650
17	320941	2850435	55973	0	35173	23449	111639	3397609
18	330570	2935948	57652	0	36228	24152	114988	3499537
19	340487	3024026	59381	0	37315	24877	118438	3604524
20	350701	3114747	61163	0	38435	25623	121991	3712659

Table 8

Energy Production of Biomass Plant (2.3 MW)

	Energy	Energy Losses	Available Energy	Grid Penetration	Available Energy
	KWh/year	%	%	%	KWh/year
Year 1	0	2	98	100	0
Year 2	18736000	2	98	100	18361280
Year 3	18736000	2	98	100	18361280
Year 4	18736000	2	98	100	18361280
Year 5	18736000	2	98	100	18361280
Year 6	18736000	2	98	100	18361280
Year 7	18736000	2	98	100	18361280
Year 8	18736000	2	98	100	18361280
Year 9	18736000	2	98	100	18361280
Year 10	18736000	2	98	100	18361280
Year 11	18736000	2	98	100	18361280
Year 12	18736000	2	98	100	18361280
Year 13	18736000	2	98	100	18361280
Year 14	18736000	2	98	100	18361280
Year 15	18736000	2	98	100	18361280
Year 16	18736000	2	98	100	18361280
Year 17	18736000	2	98	100	18361280
Year 18	18736000	2	98	100	18361280
Year 19	18736000	2	98	100	18361280
Year 20	18736000	2	98	100	18361280

Table 9

The quality/finance parameters for the Biomass Plant 2.3 MW are:

Productive Cost (€/ MWh)	Environmental Footprint (0-1)	Reliability (0-1)	Social Footprint
154.8	0.4	0.9	0.21

4.4 Energy Production with Lignite Units

In Greece this moment the energy production with lignite by PPC is actually enforced by the state through the free usage by the PPC of the lignite mines. So in the following data are not included such costs. Thanks to this the average production cost at lignite units is about 0.05 €/ KWh.

According to a Booz Allen Hamilton Study, there is the highest operational cost at the old technology lignite units : Megalopolis I (91,3 €/MWh) and Megalopolis II (80,1 €/MWh). Units not located in Greece has operational cost 41,9 €/MWh respectively. In Greece the unic with the lowest operational cost is located at Florina (26,6 €/MWh).

According to the European union software ExternE (http://www.externe.info/results.html) there is an external cost which includes environmental and health footprint cost. This cost is about 46 €/MWh and according to this Megalopoli unit has a cost of 75 €/MWh.

Table 10
Power Lignite Units

Power Station	Total External Cost (million €/yr)	Marginal External Cost (€/MWh)
Kozani-Agios Dimitrios	392.6	34.19
Keratsini	18	10.87
Aliveri	46.4	34.1
Aminteon	164.6	42.73
Kozani-Kardia	293.1	32.19
Komotini	23.3	8.76
Lavrio	94.9	17.23
Megalopoli	518.7	93.15
Ptolemaida	151.3	39.99
Florina	60.2	27.15
Rhodes	43.3	62.82
Crete-Linoperamata	48.3	39.95
Crete-Chania	35	36.29
TOTAL	1889.8	37.77

Source: Georgakellos (2007).

Table 11
The quality/finance parameters for Lignite Units are:

Productive Cost (€/ MWh)	Environmental Footprint (0-1)	Reliability (0-1)	Social Footprint
41.9	1	0.9	6

4.5 CO_2 tariff

Each country trades permissions (TN Crights) at the international environmental stock exchange. Each country has the right to sell these rights at its factories or enterprises or sell them to another country. When a country produce green energy has a big stock of rights to sell at the global environmental stock exchange so as have profit.

On the other hand, countries with heavy industry and lack of green energy production have the need to buy rights from the environmental stock exchange.

5. Java Application Runs

We developed an application so as to study and present some cases of implied policies by the major and the minor players. In our future work we will imply dynamic memory and feedback dynamic models so as to find the Nash and Stackelberg equilibrium. We present you 20 static cases. We change our system inputs / policies and we study the systems outputs /players gains.

Figure 1
Snapshot of the application

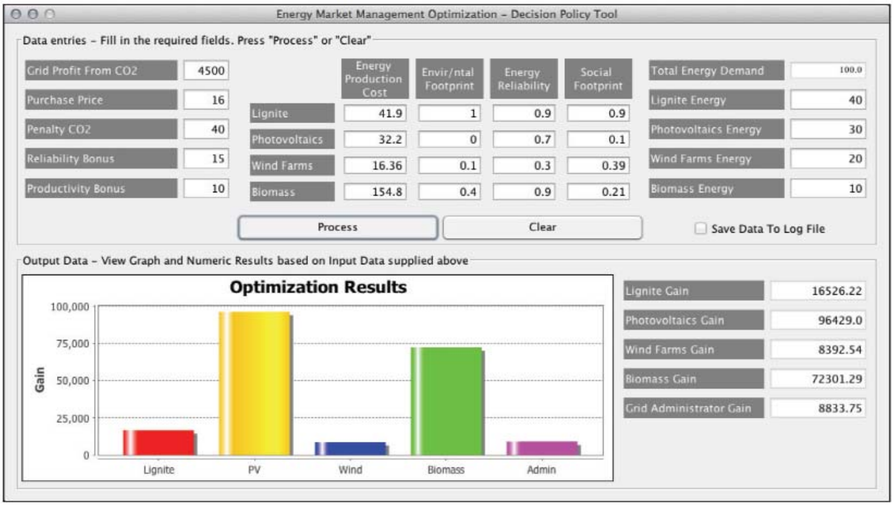

Table 12

Energy Market Management Optimization Log File

Input Data	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Grid Profit From CO_2:	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0
Purchase Price:	16.0	18.0	22.0	25.0	22.0	26.0	15.0
Penalty CO_2:	40.0	40.0	25.0	30.0	20.0	20.0	35.0
Reliability Bonus:	15.0	15.0	15.0	30.0	15.0	20.0	25.0
Productivity Bonus:	10.0	10.0	10.0	5.0	10.0	25.0	20.0
Lignite Energy Prod. Cost:	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Lignite Env. Footprint:	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lignite Energy Reliability:	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Lignite Social Footprint:	0.9	0.9	0.9	0.9	0.9	0.9	0.9
PV Energy Production Cost:	32.2	32.2	32.2	32.2	32.2	32.2	32.2
PV Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PV Energy Reliability:	0.7	0.7	0.7	0.7	0.7	0.7	0.7
PV Social Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Prod. Cost:	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Wind Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Reliability:	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wind Social Footprint:	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Biomass Energy Prod. Cost:	154.8	154.8	154.8	154.8	154.8	154.8	154.8
Biomass Env. Footprint:	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass Energy Reliability:	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Biomass Social Footprint:	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Total Energy (estimation):	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(to be continued)

Lignite Energy:	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Photovoltaic Energy:	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Wind Farms Energy:	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Biomass Energy:	10.0	10.0	10.0	10.0	10.0	10.0	10.0
OUTPUT							
Lignite Gain:	16526.22	16606.22	17366.22	8515.11	17566.22	45839.56	35668.44
Photovoltaic Gain:	96429.0	96489	96609	48714	96609	241734	193209
Wind Farms Gain:	8392.54	8432.54	8542.54	4487.67	8552.54	21247.16	16832.29
Biomass Gain:	72301.29	72321.29	72421.29	35709.14	72441.29	183097.71	146115.57
Grid Administrator Gain:	8833.75	8633.75	7543.75	105056.87	7313.75	-289435.63	-189342.5

Table 12 (Cont.)
Energy Market Management Optimization Log File

Input Data	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14
Grid Profit From CO_2:	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0
Purchase Price:	16	16	16	16	16	16	16
Penalty CO_2:	40	40	40	40	40	40	40
Reliability Bonus:	10	10	10	10	10	10	10
Productivity Bonus:	10	10	10	10	10	10	10
Lignite Energy Prod. Cost:	41.9	35	35	25	20	23	30
Lignite Env. Footprint:	1.0	1.0	0.7	0.7	0.7	0.8	0.9
Lignite Energy Reliability:	0.9	0.9	0.9	0.9	0.9	0.9	0.7
Lignite Social Footprint:	0.9	0.9	0.9	0.6	0.5	0.7	0.9
PV Energy Production Cost:	32.2	32.2	32.2	32.2	32.2	32.2	32.2
PV Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PV Energy Reliability:	0.7	0.7	0.7	0.7	0.7	0.7	0.7
PV Social Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Prod. Cost:	16.36	16.36	16.36	16.36	16.36	16.36	16.36

(to be continued)

Wind Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Reliability:	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wind Social Footprint:	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Biomass Energy Prod. Cost:	154.8	154.8	154.8	154.8	154.8	154.8	154.8
Biomass Env. Footprint:	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass Energy Reliability:	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Biomass Social Footprint:	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Total Energy (estimation):	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lignite Energy:	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Photovoltaic Energy:	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Wind Farms Energy:	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Biomass Energy:	10.0	10.0	10.0	10.0	10.0	10.0	10.0
OUTPUT							
Lignite Gain:	16346.22	13555.56	14035.56	15546.67	15080	11942.86	11613.33
Photovoltaic Gain:	96324	96324	96324	96324	96324	96324	96324
Wind Farms Gain:	8362.54	8362.54	8362.54	8362.54	8362.54	8362.54	8362.54
Biomass Gain:	72256.29	72256.29	72256.29	72256.29	72256.29	72256.29	72256.29
Grid Administrator Gain:	9193.75	12260.42	-42219.6	-43330.7	-42664.03	-21646.89	-3597.36

Table 12 (Cont.)
Energy Market Management Optimization Log File

Input Data	Case 15	Case 16	Case 17	Case 18	Case 19	Case 20	Case 21
Grid Profit From CO_2:	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0
Purchase Price:	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Penalty CO_2:	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Reliability Bonus:	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Productivity Bonus:	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Lignite EnergyProd. Cost:	41.9	41.9	41.9	41.9	41.9	41.9	41.9
Lignite Env. Footprint:	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lignite Energy Reliability:	0.9	0.9	0.9	0.9	0.9	0.9	0.9

(to be continued)

Lignite Social Footprint:	0.9	0.9	0.9	0.9	0.9	0.9	0.9
PV Energy Production Cost:	32.2	32.2	32.2	32.2	32.2	32.2	32.2
PV Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PV Energy Reliability:	0.7	0.7	0.7	0.7	0.7	0.7	0.7
PV Social Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Prod. Cost:	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Wind Env. Footprint:	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wind Energy Reliability:	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wind Social Footprint:	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Biomass Energy Prod. Cost:	154.8	130	130	154.8	154.8	154.8	154.8
Biomass Env. Footprint:	0.4	0.4	0.5	0.7	0.4	0.4	0.4
Biomass Energy Reliability:	0.9	0.9	0.8	0.9	0.9	0.9	0.9
Biomass Social Footprint:	0.21	0.21	0.15	0.7	0.21	0.21	0.21
Total Energy (estimation):	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lignite Energy:	40.0	40.0	40.0	40.0	40.0	30.0	15.0
Photovoltaic Energy:	30.0	30.0	30.0	30.0	30.0	30.0	35.0
Wind Farms Energy:	20.0	20.0	20.0	20.0	20.0	20.0	15.0
Biomass Energy:	10.0	10.0	10.0	10.0	10.0	20.0	35.0
OUTPUT							
Lignite Gain:	16526.22	16526.22	16526.22	16526.22	16526.22	12394.67	6197.33
Photovoltaic Gain:	96429.0	96429.0	96429.0	96429.0	96429.0	96429.0	112500.5
Wind Farms Gain:	8392.54	8392.54	8392.54	8392.54	8392.54	8392.54	6294.41
Biomass Gain:	72301.29	60739.76	85446.67	20581.29	72301.29	144602.57	253054.5
Grid Administrator Gain:	8833.75	20643.27	436.37	74053.75	8833.75	-87464.98	-248215.6

6. Conclusions – Future Work

Observing the outcomes of out model we notice that the gravity of its parameter is different. The administrator can imply a friendly to the environment policy. This leads the producers to invest more money in order to succeed a bigger market share but this increase their productive cost (Balasko and Shell, 1980). In other cases the Grid Administrator implies a social friendly policy minimizing the environmental factor influence.

Many benefits can be earned by the development of a dynamic decision policy tool like this. The majority of relevant papers take into consideration financial and capacity constraints. In our work we formulate and count politics parameters such as the social and environmental footprint. Software based on our model could be a useful tool to a manager of a private energy plant so as to increase the market share of his company by taking the proper decisions.

In our previous work we developed a dynamic feedback model implying game theory tools (Nash and Stackelberg equilibriums). Our aim in our future research is to develop a decision making tool implying our game theory model in a liberalized energy market, taking into consideration all the quality and quantity parameters and restrictions of an electrical distribution grid. Also our model will be completely dynamic with feedback information and we will include stochastic parameters. Each player has his own policy vector. The Grid Administrator defines the policy that he will follow to rank and buy energy from the producers. Each producer has the options to improve his energy profile and be more "attractive" to be selected by the system.

All the policies that are implied by the players we intend to use memory and feedback dynamic models so as to find the Nash and Stackelberg equilibrium in our future work.

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