Optimizing Consumption and Emission in Gas Fuel Consuming Power Applying DEA Model

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Abstract.

In this paper, energy consumption and carbon dioxide emission of the Iran gas generators is studied using Data Envelopment Analysis (DEA) and Goal Programming (GP) to show the importance of CO_2 emission in Iran like most other countries and also conserve fuel as key role of today life and industry. Ramanathan studied energy consumption and carbon dioxide emission as well, from 17 countries of the Middle East and North Africa (MENA) with four indicators for the year 1996. In this paper a simple goal programming model to minimizing carbon dioxide emission and gas consumption is revealed for the year 2004 by employing three main indicators.

First electricity generated by generators, then carbon dioxide emission and at last natural gas consumption as fuel. Albeit there are other factors like generators condition, environmental situation and etc, that could be considered for further studies. The analysis concludes the most and least efficient units and revealed an optimizing model which its optimized results are comparable to international standards for CO_2 emission and fuel consumption.

Key words

Carbon dioxide emission, Data Envelopment Analysis (DEA), Energy consumption, Goal programming.

1. Introduction

In this era more than ever various kind of energy are important for life and industry, one of these kinds is electricity which is made by different kind of fuel, although, in compare to 2003 in 2004 use of gas, wind and water energies as a fuel for generators had increased and made Iran independent in top ten of whole world, however, minimizing the cost and optimizing the use of fuel according to their greenhouse gas emission as a demolition cost are still a goal to achieve.

Energy consumption and carbon dioxide emissions of the world are increasing at alarming rates. Continued carbon dioxide emissions are likely to lead to catastrophic problems such as the greenhouse effect. CO_2 emissions are driven by several factors, the most prominent being energy consumption from fossil fuels and the level of economic activity. Hence, efforts have been made to analyze the energy consumption and CO_2 emissions in Iran.

Patterns in the level of energy consumption, economic activity and CO_2 emissions of many countries of the world have been analyzed in the literature. Ramanathan [1] provided substantial analysis of energy consumption and CO_2 of the countries of the Middle East and North Africa (MENA), using Data Envelopment Analysis and Malmquist Productivity index approach for the period of 1992-1996.Pao [2] used linear and nonlinear statistical models, including artificial neural network (ANN) methods, to investigate the influence of the four economic factors, which were the national income (NI), population (POP), gross of domestic production (GDP), and consumer price index (CPI), on the electricity consumption in Taiwan and then to develop an economic forecasting model. This paper attempts to provide analysis for fuel consumption and CO_2 emissions of gas generators of Iran using Data Envelopment Analysis and Goal Programming. Green house emissions by gas generators in 2004 for NO_x were 11.8%, for SO_2, 17.3 %, for CO_2 25.3%, etc. So on account of the highest one is CO_2 that made the model which is simply extendable for the others.

Based on World Wide Bank and Environment Organization information demolition cost CO_2 is about 2176 million dollar, with this amount of money we could have significant raise in the industry.

2. DEMOLITION COST

A direct cost of environmental effects, such as destroying ecosystem and hygiene effects on people, called demolition cost. In fact, this cost is revealed harmful effects of pollution or a mission on products, ecosystem, and human health that often is an exterior parameter which not counts in pricing. To calculate harm caused by polluted emissions, effects of them should be quantified.

Demolition cost by the name of “Social Cost” is presented by World Wide Bank and Environment Organization studies which based on America EPA coefficients in table I.

Table I- Data on CO2 emission of Iran in 2004

Parts	*CO_2 (Mton)*
Based on World Wide Bank And Environment Organization:	
General, business and house	2574
Industries	1240
Transportation	2333
Agricultural	236
Generators	2176
All	8559
Based on America EPA coefficients:	
Business and houses	17157
Industries	8267
Transportation	15554
Agricultural	1571
Generators	14507
All	57056

3. MODELING

A Reason of choosing gas generators in this paper

Choosing appropriate fuel for generators in order to economic criteria such as fuel cost, geographical regions of generators, availability, environmental pollution of fuel, even long and short term policies have special importance, Hence system and fuel modification could reduce environmental pollution as well as production cost.

In recent years use of gas fuel boost and based on year report of 2004, by replacing gas fuel in national range, three million dollars was saved. Natural gas in compare to other fuels is a clean one and has the minimum pollution emissions rate, although, 46.9% of CO_2 emissions is belong to gas fuel. Under the auspices of minimizing the pollution of generators with the cleanest fuel it may possible to present new approach for energy segment of Iran.

B GP Model

First we introduce parameters and variables are used in models:
S_i: deviation variable from goal limit
X_{CO2}: Carbon dioxide emission (Mton)
X_{elec}: electricity generated by generators in 2004 (MKwh)
Y_{fuel}: gas consumption as a generators fuel (m^3)
U: demolition cost estimated by international bank and environment ministry for CO_2 emission generators in 2004 (the coefficient of 15.03% is because we evaluate demolition cost according to percentage of total product)
P_i: Weight according to importance of goal (P1>P2>P3)
A: Total electricity production in country in 2004 (which was 166917×10^6 KWh that we trying to aimed higher so we replaced it with a higher amount)
B: CO_2 emission by gas generators in 2004 (equal to 9067266 m^3)
C: Consumption of natural gas in 2004 (equal to 885×10^6 m^3)
D: Demolition and social cost in 2004 resulted by CO2 pollution ($)

The presented model tries to achieve explained goals with tools of linear and goal programming. For weighting, DEA is used, that helps to find out the efficient unit and used shadow prices of these units as goal coefficients.

C Input and output of energy balance sheet of 2004

Decision making units, inputs and out puts are revealed in table 2. Since the exact amount of CO_2 emissions of every unit is not accessible the approximate amount are considered as production percentage of total electricity generated by these generators.

D Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a methodology based upon an interesting application of linear programming. It has been successfully employed for assessing the relative performance of set firms, usually called Decision-Making Units (DMU), which use a variety of identical inputs to produce a variety of identical outputs. The basic ideas behind DEA back to Farrel, but the recent series of discussions started with the article by Charnes et al. [3]. The Charnes Model denoted as (1):

$$\max \frac{\sum_{j=1}^{J} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}}$$
$$subjected \quad to \qquad (1)$$
$$0 \le \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}} \le 1 ; n = 1,2,..., N$$
$$v_{jm}, u_{im} \ge \varepsilon ; i = 1,2,..., I ; j = 1,2,..., J$$

The Goal Programming model is denoted as (2) and (3):

$$Min\ P_1 S_3^+ + P_2 S_1^+ + P_3 (S_2^- + S_4^+)$$
$$subjected \quad to$$
$$x_1 \ge B$$
$$x_2 \le A \qquad (2)$$
$$y_1 \ge C$$
$$x_1 + x_2 - y_1 \le 0$$
$$U \ge D$$

In result:

$$Min\ P_1 S_3^{+} + P_2 S_1^{+} + P_3 (S_2^{-} + S_4^{+})$$
$$subjected\quad to$$
$$x_1 - S_1^{+} + S_1^{-} = 90.672668 \quad Mton$$
$$x_2 + S_2^{-} - S_2^{+} = 1000000 \quad Mkwh \qquad (3)$$
$$y_1 - S_3^{+} + S_3^{-} = 885 \quad Mm^3$$
$$x_1 + x_2 = y_1$$
$$U - S_4^{+} = \frac{15.03}{100} 2176 = 327.05 \quad MRial$$

DEA aims to minimize the inputs and maximize the outputs, therefore in this paper, CO_2 emissions and fuel consumption are inputs and electricity production is output of the model which is shown in table II.

E *Efficiency*

DEA found the efficient units which are "Hasa", "yazd C.C." and "Yazdzanbagh" although technical efficiency of every unit is available in table III.

Table II. Inputs and outputs

DMUs	*Fuel (106 m3)*	*Net Production (106 kWh)*	*CO2 (%)*	Percentage of total Production (%)
Shiraz	360.754	806.314	0.453	0.5
Mashhad	299.789	720.352	0.408	0.45
Loshan	89.829	294.180	0.163	0.18
Rey	920.668	3159.942	1.768	1.95
Tabriz	23.932	46.609	0.027	0.03
Zargan	124.301	311.469	0.1723	0.19
Orumieh	37.201	109.212	0.063	0.07
Shirvan	87.655	197.187	0.108	0.12
Shariati	80.182	178.766	0.099	0.11
Sufian	46.568	140.507	0.081	0.09
Hasa	7.761	42.214	0.027	0.03
Shahid Salimi	362.593	101.634	0.607	0.67
Kazerun	1405.059	4635.752	2.593	2.86
Kangan	366.056	737.849	0.417	0.46
Yazd Zanbagj	54.772	165.932	0.091	0.10
Yaz Gas	112.845	320.000	0.181	0.20
Yazd C.C.	259.429	984.620	0.553	0.61
Kerman C.C.	1212.937	4582.592	2.566	2.83
Bandarabaasl	30.212	28.575	0.018	0.02
Abadan C.C.	608.535	2049.709	1.151	1.27
Damavand C.C.	376.402	1235.436	0.689	0.76
Hormozgan	361.885	1191.383	0.671	0.74
Total	7233.049	24314.282	13.628	15.03

Table III. Technical efficiency of every DMU

DMUs Name	*Technical Efficiency*
Orumieh	0.944083273
Damavand C. C.	0.986352737
Bandarabaas	0.861045489
Tabriz	0.936307242
Abadan C. C.	0.982792057
Kerman C. C.	0.999150320
Yazd C. C.	1.000000000
Rey	0.969413832
Zargan	0.982197316
Shariati	0.979404488
Shahid Salimi	0.091045663
Shiraz	0.965424598
Shirvan	0.990300243
Sufian	0.948030348
Kazerun	0.984437241
Kangan	0.959718352
Loshan	0.991704841
Mashhad	0.957628284
Hormozgan	0.978253291
Hasa	1.000000000
Yazd Gas	0.958923065
Yazd Zanbagj	1.000000000

F Primal and Dual model of DEA

As it is shown in (1), the primal model of DEA is complicated and has fractional parts which make it difficult to solve but the dual model of DEA is easier to solve and its results are shadow prices of our variables that could be used as coefficient of goal programming model. In other word the dual model is suitable to solve and use.

G Solving the dual model

Dual amount are shadow prices or equitably prices in other word they are cost of producing one unit more than desired right hand side numbers (table VI). In fact these shadow prices are used for equitably pricing in various industries like electricity industry. The highest shadow price is belonging to efficient unit that for most equitable condition for the lowest demolition cost we used it as coefficient of goal programming function.
"Hasa" is the efficient unit which holds variables of dual model or coefficient of primal model:
P_1= 71.2254
P_2= 29.6873
P_3= 3.1266
In result the goal programming model is as (4).

$$\begin{aligned} &Min \quad 71.2254\, S_3^+ + 29.6873\, S_1^+ \\ &\qquad + 3.1266\,(S_2^- + S_4^+) \\ &subjected \quad to \\ &x_1 - S_1^+ + S_1^- = 90.672668 \times 10^6 \quad ton \qquad (4) \\ &x_2 + S_2^- - S_2^+ = 10^{12} \quad kwh \\ &y_1 - S_3^+ + S_3^- = 885 \times 10^6 \quad m^3 \\ &x_1 + x_2 = y_1 \\ &U - S_4^+ = 35548.9 \quad \$ \end{aligned}$$

4. Solve the GP Model

Attending to described goals and their relation with goal model variables:
1. Minimizes the deviation of first goal (71.2254 S_3^+)
2. Minimizes the deviation of third goal (29.6873S_1^+)
3. Minimizes the deviation of second and forth goal (3.1266 (S_2^-+S_4^+))
To solve the model Lingo Program is employed.

4. CONCLUSION

Model is attempted to minimize the cost and shows that a new management approach is vital and with replacing the clean fuel the demolition cost decrease. According to the model results, "Hasa" is rated efficient unit, although there are some other indicators to refer to, such as environmental and technical factors, age of machines, primary investment, repair and maintenance expenses, and efficiency of process, etc that could be considered for future papers and required to develop the model to compass the new and acceptable factors.

For further works it could be convenient to consider on replacing fuel, which needs an expert. And focusing on altering demolition and other harmful cost to profit is appropriate.

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Table IV- Dual quantity of DEA model

DMUs Name	*Fuel (Mm^3)*	*CO_2*	*Net Production*
Shiraz	0.1735	0.0371	0
Mashhad	0.1927	0.0412	0
Loshan	0.2471	0.2611	0
Rey	0.0444	0.0095	-6.9E-18
Tabriz	209115	0.6221	0
Zargan	0.4570	0.0977	0
Orumieh	0.6335	0.6697	0
Shirvan	0.7279	0.1555	0
Shariati	0.7941	0.1696	-1.11E-16
Sufian	0.4945	0.5227	2.22E-16
Hasa	71.2255	296787	3.1266
Shahid Salimi	0.0656	0.0694	-2.7E-17
Kazerun	0.0156	0.0164	0
Kangan	0.1885	0.0402	-2.78E-17
Yazd Zanbagh	0.8734	0.1866	-1.11E-16
Yazd Gas	0.4343	0.0928	0
Yazd C.C.	0.0742	0.0784	0
Kerman C.C.	0.0160	0.0168	0
Bandarabass	2.3E-27	0.0540	6.13E+231
Abadan C.C.	0.0351	0.0371	0
Damavand C.C.	0.0585	0.0618	2.78E-17
Hormozgan	0.0602	0.0636	2.78E-17