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Environmental Effects of Energy Intensive Industries in Iran

Fazeleh Khadem, Azam Mohamad Bagheri

Senior Researcher of Institute for International Energy Studies (IIES), Ph.D. students of Economics, University of Ferdosi

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ABSTRACT

Environmental issues and emphasis on reduction of damage to environment is essential in policy formulation and developmental planning of countries. In each policy, identification of the source and type of pollutants due to improper use of energy is very important. In this study, we evaluated environmental aspects of Non-Metallic Minerals Industries and calculated the types of emissions resulting from energy consumption in each of these sectors. Results indicated that cement, lime and plaster had the highest share of carbon dioxide emissions and the highest share of social expenditures. In addition, the technical efficiency of these industries is calculated using SBM approach and efficient industry have been identified. However, the directional distance function has shown that these industries are not environmentally efficient friendly.
KEY WORDS: Environmental Effects, Energy Intensive Industries, Energy Consumption, Directed Output Distance Function, CO_2 Emission.

1. INTRODUCTION

Today, environment is one of the most important concerns of the world and international community, thus propounding economic development and growth is not sufficiently addressed without environmental concerns. Since fulfillment of every business requires energy consumption, thus use of energy means a factor for economic motive and improvement in quality of. On the other hand, misuse of energy results in pollutions. Thus, damage to environment though parallel to economic development and growth has impeded the benefits of development with deterioration of environment. So it had put in doubt the belief that production increment results to maximum welfare. This replacement has glorified environment problems and its negative outcomes in designing policies and sustainable development and growth.

Another aspect of environmental vulnerability is manifested, in climate change and global warming in today's world. Scientists estimate that more than three-fourth of greenhouse gases is as a result of, fossil fuels. Consumption

Calculation of social costs due to environment damages is very important in development discussion, and this echoes negative external costs of using energy in economic development process. Total social costs of energy consumption for energy carriers in Iran is Rls.92195 billion (base year 2002), of which 13.82% is for industrial sector. This volume was more than 16% in 2011.In increment of energy consumption in the country, fuel emissions have also increased. According to hydrocarbon balance report, CO2 was the most important greenhouse gas in last couple of years, which has reached from 4.9 ton/person in 2001 to 6.6 ton/person in 2011.

According to the statistics, non-metal mineral industries, which are studied in this study, besides main metal industries consume more than half of industrial fuel and are the most energy intensive industries.in the country This group of industries dominates highest the share of their production costs to energy carriers and they have a high share in production of greenhouse gases, so they incur much social costs to the society. According to the international industrial standard (code ISIC), this group include non-construction fireproof ceramic industries (code 2691); insulation fireproof ceramic industries (code 2692); cement, lime, and gypsum industries (code 2694); concrete, cement, and gypsum products (code 2695); stone preparation industries (code 2696); bricks industries (code 2697); construction fireproof ceramic industries (2698); and other non-metal productions (2699).

Since emission of greenhouse gases in industrial sector has been accelerated in the recent years, and energy consumption in emissions in non-metal mine industries are noticeable, this demands proper planning in order to diminish emissions.

In the particular field of energy and environmental studies, following the survey by Zhou et al. (2008), the assumption used by the traditional DEA models that all the outputs should be maximized might be inappropriate when undesirable, or unwanted outputs are also generated as by-products in the production process. Färe et al. (2001), or Picazo-Tadeo et al. (2005) have been considering Directional Distance Functions (DDF). However, DDF

*** Corresponding Author:** Fazeleh Khadem. Senior Researcher of Institute for International Energy Studies (IIES), Iran. khademiies@gmail.com

approaches have the disadvantage of having to specify a vector of directions which is partly arbitrary. An alternative is provided by the slacks-based efficiency measures, in this vein Jaraite and Di Maria (2011) apply a modified DEA Russell measure in the analysis of the conventional thermal electricity and derived heat production in the EU context over twelve years. Based on the DEA Russell measure, Pastor et al. (1999) and Tone (1997) simultaneously developed a slack based measure which was further studied and complemented by Tone (2001). Nevertheless, both DDF and SBM, share the same principle and base its measure in the slack of the optimized variables, and differ in the objective function definition. The relationship between them has been precisely analyzed by Färe and Grosskopf (2001). The main strengths of these measures relate to the ability of providing a more practical index with higher discriminating power than radial models and independent inefficiency measures for each optimized variable. Jahanshahloo et al. (2014) suggest that a new gradual improvement model used for both inefficient units and efficient units that are not scale efficient.

Thus, this paper studies evaluation of emissions of non-metal industries by Directed Output Distance Function (DODF). The second section reviews Theoretical fundamentals is presented in two parts. Part one expresses measuring technical efficiency by SBM approach. Part two measures environmental efficiency by DODF. Section 3expresses the results. The fourth section is discussion that analyzes the subject. Finally, conclusion is offered.

2. MATERIALS AND METHODS

2-1. Measurement of technical efficiency by SBM approach

SBM approach, which is also recognized by “Dimension Free” and “Units Invariant”, was introduced by Tone (1997, 2007). This approach has the following properties:

1. Units invariant assumption: In this model, input and output are invariant towards units.
2. Monotone assumption: For any excess inputs and dearth of outputs, values decrease monotonically.

The fractional nonlinear model of eq. (1) is suggested to measure efficiency of agencies by SBM approach [12,11].

$$\text{(SMB) Min} \quad \rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}}{1+\frac{1}{s}\sum_{r}^{s}\frac{s_r^+}{y_{ro}}} \tag{1}$$

$$\begin{aligned} & s.t. \\ & x_o = X\lambda + s^- \\ & y_o = Y\lambda + s^+ \\ & \lambda \geq 0, s^- \geq 0, s^+ \geq 0 \end{aligned}$$

In this model, $X \geq 0$. If $x_{io}=0$, then we exit $\frac{s_i^-}{x_{io}}$ from goal function. If $y_{ro} \leq 0$, then we replace it with a small positive number; so $\frac{s_i^+}{y_{io}}$ is a penalty in the goal function. In this model, an agency is efficient if only its goal function is equal to 1 ($\rho=1$); thus excess and dearth of inputs and outputs are zero.

2-2. Measurement of environmental efficiency by DODF

To measure environmental efficiency, we use distance function, which was introduced by Shephard in 1970. Separability assumption indicates that we tolerate cost by undesirable output decrement. It means that decrement of undesirable output is only possible by decrement of desirable output. Another assumption indicates that undesirable output is a peripheral product of desirable output in production process. Date Envelopment Analysis (DEA) can be used to measure efficiency level [10] [3] [4].

By distance function assumptions, Chung et al. (1997) proposed a model called DODF. This model can increase desirable output by decrement of undesirable output [1]. The directed vector is shown by $g=(g_v, -g_u)$, in which $g_v=1$ and $-g_u=1$. Consequently, environmental efficiency of agency k′ by DODF approach is modeled by eq. (2).

(2)

$$D(x^{k'}, v^{k'}, u^{k'}; g) = \max \beta$$
$$s.t.(v^{k'} + \beta g_v, u^{k'} - \beta g_u) \in P(x)$$

Eq. (2) is converted to eq. (3) by a linear programming model.

(3)

$$D(x^{k'}, v^{k'}, u^{k'}; g) = \max \beta$$
$$s.t.$$
$$\sum_{k=1}^{K} \omega_k v_{km} \geq v_{k'm} + \beta g_{vm}, m = 1, \ldots, M$$
$$\sum_{k=1}^{K} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1, \ldots, J$$
$$\sum_{k=1}^{K} \omega_k x_{kn} \leq x_{k'n}, n = 1, \ldots, N$$
$$\sum_{k=1}^{K} \omega_k = 1$$
$$\omega_k \geq 0, k = 1, \ldots, K$$

If $D(x^{k'},v^{k'},u^{k'};g)=0$, then the agency activates efficiently; otherwise, it is inefficient environmentally. In fact, we use environmental efficiency of second stage. This was obtained by Shephard's Output Distance Function, but as Chung et al. (1997) said, Shephard's Output Distance Function is a special form of DODF and the standard value of environmental efficiency is obtained as eq. (4) [1].

(4)

$$D(x, v, u) = \frac{1}{\left(1 + D(x^k, v^k, u^k; v^k, u^k)\right)}$$

In eq. (5), if $D(x^{k'},v^{k'},u^{k'};g)=1$, then the agency activates efficiently; otherwise, it is inefficient environmentally, that is $D(x^{k'},v^{k'},u^{k'};g)<1$.

3. RESULTS

In order to calculate social costs in order to compensate damages of emissions and greenhouse gases, we should quantify the effects of emissions in the environment. Social costs of environment destruction for NOx, SO2, CO2, CO, CH4, and SPM are shown in table 1.

Table 1: The social costs of consumption of energy carriers (thousand rails of tons) [2]

Type of Gas	NOx	SO2	SO3	CO	SPM	CO2	CH4	N2O
Cost	4800	14600	□	1500	34400	80	1680	□
□ Not Available								

After adjustment of social costs mentioned in table 1 by CPI index, and after calculation of produced emissions of industrial unit in table 2, emissions produced by each industrial unit is calculated. Then total social costs for NOx, SO2, CO2, CO, CH4, and SPM are calculated. Environmental efficiency of each industry is shown in table 3.

Table 2: Emission of greenhouse gases of industry sector by energy carrier (ton) [2]

The Type of Fuel	NOx	SO2	SO3	CO	SPM	CO2	CH4	N2O
Gasoline	719	80	-	18652	69	126783	5	1
Kerosene	48	230	-	75	-	249955	10	2
Gas Oil	15514	48715	621	621	4654	8742882	354	71
Fuel Oil	62647	294034	4492	23	6265	20229656	784	157
LPG	534	2	-	354	-	816787	13	1
Natural Gas	76603	157	-	3043	6443	48383622	862	86

Table 3:Total social cost of emissions of non-metal mineral industries by energy carrier

The Type of Fuel (Riyal) / Industrycode (ISIC)	Gasoline	Kerosene	Gas Oil	Fuel Oil	LPG	Natural Gas	The TotalSocialCost ofEmissions for Every Industry
2691	1354.043	55026	9661132	5609631	3589502	72120581	92389915
2692	321839	53346	4134125	4369293	88450	12701124	21668177
2694	6631042	2789958	56997314	3182000000	4008872	1160370623	4413025433
2695	6393287	691819	70930678	11328186	439172	10951360	100734501
2696	6106241	1789824	10963154	987351	597150	6943281	27387002
2697	8562075	1788144	122000000	1937000000	3304789	299398194	2371843726
2698	3783782	1068602	18491804	29797978	57326426	142990825	253459416
2699	5313242	719122	155000000	174910494	591870	17273529	353387269

Table 3 shows total social costs of non-metal mine industries by energy carriers. By comparison of the last column of this table for each non-metal mine group, we see cement, lime and gypsum industry (code 2694) has the highest share in social costs.

The share of cement, lime, and gypsum production industries (code 2694) from total social cost of emissions of non-metal mineral industries is 61%. Brick production industry also is in the second rank. In continue, we discuss about emissions of energy carriers production consuming in non-metal mineral industries that have not been categorized in other places (code 269).

Table 4:Emissions and greenhouse gases due to gasoline consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	12603	1402	326939	1209	2222301	88
2692	2996	333	77709	287	528213	21
2694	61719	6867	1601093	5923	10883090	429
2695	59506	6621	1543686	5711	10492878	414
2696	56835	6324	1474378	5454	10021770	395
2697	79692	8867	2067349	7648	14052367	554
2698	35218	3919	913610	3380	6210071	245
2699	49454	5502	1282905	4746	8720272	344

Table 4 shows emissions and greenhouse gases due to gasoline consumption are in the brick production industry (code 2697). Table 5 also shows that the most of emissions and greenhouse gases due to kerosene consumption are produced by cement, lime, and gypsum industries (code 2694). However, Emissions and greenhouse gases due to gasoil consumption are different. These emissions by other non-metal productions (code 2699) are higher than the other, but brick production industry is in the second rank.

Table 5:Emissions and greenhouse gases due to kerosene consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	19	314	102	0	341131	14
2692	19	304	99	0	330714	13
2694	969	15915	5190	0	17296104	692
2695	240	3946	1287	0	4288871	172
2696	621	10210	3329	0	11095859	444
2697	621	10200	3326	0	11085443	443
2698	371	6096	1988	0	6624705	265
2699	250	4102	1338	0	4458135	178

Table 6:Emissions and greenhouse gases due to gasoil consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	53164	166938	2128	15949	29960454	1213
2692	22750	71435	911	6825	12820471	519
2694	313649	984879	12555	94091	176756253	7157
2695	390323	1225639	15624	117092	219965466	8906
2696	60329	189437	2415	18098	33998198	1377
2697	668852	2100241	26773	200647	376930294	15262
2698	101758	319527	4073	30526	57345543	2322
2699	850629	2671032	34049	255178	479370082	19410

Table 7:Emissions and greenhouse gases due to fuel oil consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	31930	149863	12	3193	10310655	400
2692	24870	116727	9	2487	8030879	311
2694	18113192	85014357	6650	1811406	5849021527	226679
2695	64480	302637	24	6448	20821516	807
2696	5620	26377	2	562	1814779	70
2697	11026767	51754185	4048	1102730	3560708503	137995
2698	169610	796064	62	16962	54769499	2123
2699	995588	4672797	366	99564	321490278	12459

Table 7 shows emissions and greenhouse gases due to fuel oil consumption by different non- metal mineral industries. According to it, the most of emissions are produced by cement, lime, and gypsum industries (code 2694). So that, based on Table 3 indicate that high consumption of fuel oil in the industry.

Table 8:Emissions and greenhouse gases due to LNG consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	16348	61	10837	0	25004810	398
2692	403	2	267	0	616154	10
2694	18258	68	12103	0	27926176	444
2695	2000	7	1326	0	3059311	49
2696	2720	10	1803	0	4159805	66
2697	15051	56	9978	0	23021469	366
2698	261082	978	173077	0	399341250	6356
2699	2696	10	1787	0	4123019	66

Table 9:Emissions and greenhouse gases due to NG consumption (kg)

Industry code	NOx	SO2	CO	SPM	CO2	CH4
2691	16348	61	10837	0	25004810	398
2692	403	2	267	0	616154	10
2694	18258	68	12103	0	27926176	444
2695	2000	7	1326	0	3059311	49
2696	2720	10	1803	0	4159805	66
2697	15051	56	9978	0	23021469	366
2698	261082	978	173077	0	399341250	6356
2699	2696	10	1787	0	4123019	66

Tables 8-9 show emissions and greenhouse gases due to LNG and NG consumption. According to it, the most of emissions are due to construction fireproof ceramic industries (2698) and indicate cleaner fuels like natural gas is the most commonly used in this industry.

By comparison of columns of these tables, we see that CO2 is the gas that has been mostly emitted by consumption of energy carriers in non-metal mineral industries. Obviously, identification of key factors in emission of CO2 is very important to evaluate policies and strategies of decrement of climate-change effects.

4. DISCUSSION

In this section, this study first study technical efficiency and environmental efficiency of non-metal mineral industries that have been not categorized in other places (code 269). To study the technical efficiency, this study used SBM approach. This non-linear model can be calculated by GAMS. Data was gathered from industrial workshops with 10 employees or more. Data and results for technical efficiency were obtained from table 10. The numbers in the last columns of table 10 show that non-construction non-fire ceramic production industries (code 2691); gypsum and lime production industries (code 2694); gypsum, cement, and concrete products industries (code 2695); stone preparation industries (code 2696); and brick industries are efficient industries (code 2697).

Table 10:Technical data and efficiency of non-metal mineral industries uncategorized by SBM approach

Industry code	Production (Million Riyal)	Capital stock (million Riyal)	Energy (million Riyal)	Labor	Level of technical efficiency
2691	1891919	2215730	79629	12328	1
2692	1000905	446908	27139	2876	0.71
2694	16274956	21767663	1735999	23073	1
2695	6216211	8589560	96686	16760	1
2696	2026767	7985071	130899	12066	1
2697	2832964	14368374	557945	41399	1
2698	8224543	11285677	308451	22077	0.88
2699	4879750	8432004	154928	13382	0.99

After measurement of technical efficiency, this study proceeds to calculate environmental efficiency. Rather than the above data, social costs data for energy sector by emitted gases and data for emissions of industrial sector obtained from energy balance sheet for energy and environment were also used to evaluate environmental efficiency. To measure environmental efficiency, Directed Distance Function (DDF) was used. Data and results are shown in table 11.

Table 11:Data and environmental efficiency of non-metal mineral industries by DDOF approach

Industry code	Production (Million Riyal)	Emission (Million Riyal)	Capital stock (million Riyal)	Energy (million Riyal)	Labor	Level of environmental efficiency
2691	1891919	92	2215730	79629	12328	0.59
2692	1000905	22	446908	27139	2876	0.72
2694	16274956	4413	21767663	1735999	23073	0.52
2695	6216211	101	8589560	96686	16760	0.87
2696	2026767	27	7985071	130899	12066	0.82
2697	2832964	2372	14368374	557945	41399	0.51
2698	8224543	253	11285677	308451	22077	0.64
2699	4879750	353	8432004	154928	13382	0.57

By comparison of the last column of tables 10 and 11 we conclude that industries 2691, 2694, 2695, 2696, and 2697 are technically efficient. However, they are not efficient environmentally and they may achieve standard efficiency level by decrement of their emissions. For example, if industry 2691 decreases its emissions by 39%, it may increase its production by 36% and achieve the efficient level.

5. CONCLUSION

In order to diminish environment damages, identification of emission sources and providing suitable strategies to decrease their emissions are very important. Since industry sector in Iran has a significant share in production of emissions, thus noticing discussion of improvement of technical efficiency parallel to the environmental provisions are very important. Therefore, by selecting non-metal mineral industries as one of the industrial sub-groups, we studied technical and environmental efficiencies of this group. The results showed that among the industries in this group, cement, gypsum, and lime production industries have the most shares in social costs of emissions. Also, by study of emissions of each industry, it was found that CO2 has the most shares between greenhouse gases. Evaluation of technical efficiency of each industry by SBM approach indicated efficiency of some non-metal mineral industries. However, despite efficiency of these industries, none of them are efficient environmentally by DDF approach.

Since cement play the most important role in production of CO2 between non-metal mineral industries, policy points toward decrement of emissions in this industry are optimizing industrial units, usage of replaced fuels, usage of related technologies for decrement of production of CO2, and encouraging industrial units to make an economic method to decrease emission of CO2.

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