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Analysis of Performance in Release of Non-metallic Minerals' Pollutants in Iran by Non-parametric Directional Distance Output Function Model

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

In this study, the environmental aspects of nonmetallic mineral industries have been evaluated and the amount of pollutants and greenhouse gases from energy sources consumption has been calculated in all the subfields. The results demonstrate that the cement, lime and plaster having the utmost share of the spread of the carbon dioxide (CO_2), involve the maximum share of the social costs. In this research, the technical performance of the mentioned industries has been calculated applying Slacks Based Measure (SBM) approach and the competent industries are specified. However the Directional Distance Output Function reveals that none of them are competent.

Keywords: Environmental evaluation; nonmetallic minerals; directional distance output function.

1. INTRODUCTION

At present, the environmental conservation is one of the most important global challenges, and the economic growth and developments are not reliable unless this subject is considered as a priority. Scientists estimate that more than three to four of the greenhouse gases

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which cause this phenomenon emanate from fossil fuels. Evaluation of the social costs caused by the environmental degradation is of a great importance in order to identify remedial methods which can curtail excessive energy consumption in the country. Total social costs of the resources which are related to energy consumption in Iran have been estimated at 92195 billion Rials. (base year 2002), of which 13.82% was spent by the industry sector. In the year 2011, this figure was in the vicinity of 16%. The increasing energy consumption in the country resulted in increasing emissions of fuel gases. According to the hydro carbon balance report sheets of the past years, the formation of Carbon dioxide was the highest greenhouse gas, which increased from 4.9 tons per person in 2001 to 6.6 tons per person in 2011.

Predicated on the statistics published by the Central Administration of Statistics of Iran, nonmetal mineral industries as well as the regimental metal industries consume more than a moiety of the industrial fuel, and are the most energy consuming industries in the country. This group of industries dominates the highest share of the production costs for energy carriers and plays an important part in the emission of greenhouse gases, thus incurring high costs to the society to a very great extent. According to International Standard Industrial Classification (code ISIC), this group includes manufacturers of non-structural non-refractory ceramic ware (ISIC 2691); refractory ceramic products (ISIC 2692); manufacturers of cement, lime and plaster (2696); manufacturers of bricks (2697); construction fire proof ceramic industries (2698); and manufacturers of other non-metal mineral products (2699).

Considering the fact that during the past years the emission of greenhouse gases in the industrial sector has escalated and the rate of the energy consumption and as a result environmental susceptibility in the non-metal mineral industries is saliently conspicuous, this demands a felicitous orchestrating in order to reduce emissions of the pollutants. In this study, the calculations of the rate of the pollutants in non-metal mineral industries using Directional Distance Output Function are conducted. That is divided into two parts. The first part entails the measurement of the technical efficiency by slacks based measure (SBM) approach, the second part entails the measurement of environmental efficiency using.

2. MATERIALS AND METHODS

After Pittman (1983) who has descried undesirable output for the first time there have been prodigious and perplexed models and studies to evaluate the inefficiency of engenderment due to the ease of undesirable output and to estimate the shadow price by economists of environment [1-8]. One of the basic solutions to evaluate environmental inefficiency was Data Envelopment Analysis (DEA) that had been noticed at first. However there was an abundance of challenges to calculate inefficiency by this method because of the behavior of the pollutant in the production function. In the year 1995, Farc et al. illustrated exchange of the environment quality and the economic development via non-parametric distance functions. Then Chambers et al. taking the idea of benefit function in consumer's function and defect function in producer's function, they provided a competent additive technical calculation method. DDOF model (Directional Distance Output Function) was employed to increase the amount of outputs and decrease the amount of inputs [4]. By increasing the desirable output the author could decrease the undesirable output in this method. This approach has been used in many studies to measure environmental efficiency. The most important foreign and domestic studies done are as follows:

> Kwon and Yun by Distance Output Function and with its dyad during 1990 to 1995 estimated environmental efficiency and the total cost of decreasing pollution of heavy fuel (crude oil) and coal power stations in South Korea and they indicated that the average cost of decreasing Sox pollutants is 310.6 thousand Wons per ton and in decreasing each ton of NOx it is approximately 146.7 thousand Wons and for each ton of TSP (Total Suspended Particles) it is approximately 1548.3 thousand Wons and for each ton of CO_2 it is 3.8 thousand Wons.

Kouwenhoven believed that the industry section plays an important part in air pollution and a mass of the air pollutants considered as hazardous or undesirable output (including Sulfur Dioxide, Nitrogen Oxides, suspended particles, Caron Monoxide and Hydrocarbons) are emitted from it. The author believes that the costs of the emission of each ton of Sulfur, Nitrogen Oxide, suspended particles in air and

Carbon Dioxide vary according to environmental layout and the present rules are not sufficient diminishing costs.

Murty, Kumar and Paul [8,9] evaluated the Distance Input function assuming the substitution of low to high inputs in sugar industry of India and they obtained the shadow price of a variety of water pollutants and the proper and standard tax rate of the pollutants emission and calculated the rate of efficiency and green productivity by Malmquis Productivity Index.

Murty et al. [8,9] investigated the environmental efficiency and the shadow price of undesirable outputs and the elasticity of replacement between desirable and undesirable outputs of production of coal in a province of India by Directional Distance Output Function 1996-2004. The results of this study indicate that the environmental inefficiency of And hara Pradesh province power station equals 0.06 that shows this power station can improve its electricity production with decreasing %6 of production.

3. THEORETICAL FRAMEWORK

3.1 Measurement of Technical Efficiency by SBM Approach

Tune presented the SBM methodology apperceived by "Measurement Free" or "Units Invariant". This methodology has the accompanying qualities:

1. Units Invariant Posit: In this model, inputs and outputs are invariant to the vicissitude of units.
2. Monotone Postulation: Values decrease monotonically for any overabundance inputs and shortage of yields.

The partial nonlinear model of eq. (1) is proposed to measure the proficiency of undertakings by SBM approach.

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

$$s.t.$$
$$x_o = X\lambda + s^-$$
$$y_o = Y\lambda + s^+$$
$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0 \qquad (1)$$

In this model, $X \geq 0$ if $x_{io} = 0$ then we remove $\frac{S_i^-}{x_{io}}$ from the goal function. In the event that $y_{ro} \leq 0$ then we supplant it with a little positive figure. So $\frac{S_i^+}{y_{ro}}$ is a punishment in the objective capacity. In this model an undertaking is productive if just its objective capacity is equivalent to one ($\rho = 1$); therefore abundance and deficiency of inputs and yields are zero.

3.2 Measurement of Environmental Efficiency by Directional Distance Output Function Approach

The function $P(x)$ with x input has the domain $x \in R_+^N$. In addition the input x is a source of a collection of undesirable outputs with the range of $u \in R_+^K$ and desirable outputs with the range of $v \in R_+^M$. In order to measure the environmental efficiency via Distance Function introduced by Shephard. We should have some assumptions. The assumptions are as follows:

1. $(u,v) \in P(x)$ if $0 \leq \theta \leq 1$ then $(\theta v, \theta u) \in P(x)$. In this case the outputs are slightly separable and controllable.
2. It is possible that zero output be produced: $0 \in P(x) \forall x \in R_+^N$
3. - $(u,v) \in P(x)$ If $u = 0$ then $v = 0$ desirable and undesirable output vectors are continuous in source.
4. Inputs are controllable and the producer has no constraints in decreasing and increasing the inputs.

   $$P(x) \subseteq P(x'), if \rightarrow x' \geq x$$

5. The desirable output is controllable.

   $$(v,u) \in P(x) \ and \ v' \leq v \Rightarrow (v',u) \in P(x)$$

6. Null Jointness: Under the following constraint desirable and undesirable outputs can be slightly separable.

   $$\sum_{k=1}^{K} u_{kj} \succ 0, j = 1,...,J,$$
   $$\sum_{j=1}^{J} u_{kj} \succ 0, j = 1,...,K.$$

Separability assumption indicates that via the dearth of undesirable outputs we will face costs. It implies that the decrementing so as to diminish of undesirable yield is just conceivable attractive yield. Withal proposition number 3 signifies that undesirable yield is a by-result of the alluring yield in the engenderment process. In order to measure the efficiency we can use Data Envelopment Analysis as follows:

If we assume the number of the observations (number of the enterprises) $k = 1, 2, ..., K$ Environmental inputs can be formulated in eq. 2.

$$
\begin{aligned}
P(x) = \Big\{ (v,u) : & \sum_{k=1}^{K} \omega_k v_{km} \geq v_m, m = 1,2,...,M, \\
& \sum_{k=1}^{K} \omega_k u_{kj} = u_j, j = 1,...,J, \\
& \sum_{k=1}^{K} \omega_k x_{kn} \leq x_n, n = 1,...,N, \\
& \omega_k \geq 0, k = 1,...,K \Big\}
\end{aligned} \quad (2)
$$

In the above equation $\omega_k, k = 1,...,K$ denotes the non-negative variables and steady return regarding the scale. Also the constraint of imbalance of desirable output and equality of undesirable output restricts us to separate and control the outputs slightly (see [10-12]).

According the mentioned assumption Chung and et al. [4], introduced model called Directional Distance Output Function. This approach is able to increase desirable output by decreasing undesirable output. Directional vector is indicated by $g = (g_v, -g_u)$ and in this vector we have $g_v = 1$ and $-g_u = 1$. Therefore, the environmental efficiency of the enterprise k' by the eq. NO. 2.

$$
\begin{aligned}
& D(x^{k'}, v^{k'}, u^{k'}; g) = \max \beta \\
& s.t. (v^{k'} + \beta g_v, u^{k'} - \beta g_u) \in P(x)
\end{aligned} \quad (3)
$$

The equation no. 3 can be solved by a linear programming model in eq. 4.

$$
\begin{aligned}
& D(x^{k'}, v^{k'}, u^{k'}; g) = \max \beta \\
& s.t. \\
& \sum_{k=1}^{K} \omega_k v_{km} \geq v_{k'm} + \beta g_{vm}, m = 1,...,M \\
& \sum_{k=1}^{K} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1,...,J \\
& \sum_{k=1}^{K} \omega_k x_{kn} \leq x_{k'n}, n = 1,...,N \\
& \sum_{k=1}^{K} \omega_k = 1 \\
& \omega_k \geq 0, k = 1,...,K
\end{aligned} \quad (4)
$$

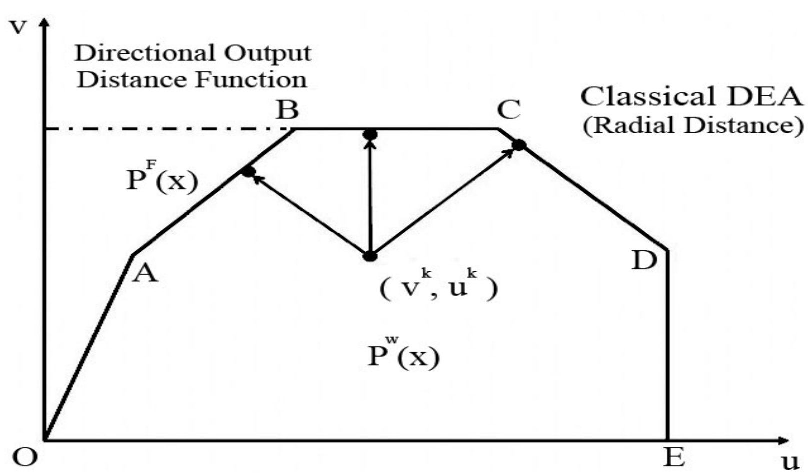

Fig. 1. Environmental efficiency by directional distance output function

If $D(x^{k'}, v^{k'}, u^{k'}; g) = 0$ then the enterprise has been working efficiently; otherwise it has been environmentally inefficient. In fact we use the environmental efficiency of the second stage. This was obtained by Shephard's Distance Output Function, but as Chung et al. [4] said Shephard's Distance Output Function is a special form of Directional Distance Function and the standard value of environmental efficiency is obtained as eq. 5.

$$D(x, v, u) = \frac{1}{\left(1 + D(x^k, v^k, u^k; v^k, u^k)\right)} \quad (5)$$

In eq. 5 if $D(x^{k'}, v^{k'}, u^{k'}; g) = 1$ then the enterprise is efficient; otherwise we have $D(x^{k'}, v^{k'}, u^{k'}; g) \prec 1$ and it is environmentally inefficient.

3.3 Statically Analysis

In order to measure the social costs to compensate for the vulnerability of the pollutants emission and greenhouse gases we should quantify the effects of emission in the environment (human and nature). Environmental social costs of NOx, SO_2, CO2, CO, CH_4 and SPM in the country are shown in the following table.

After adjustment of social costs mentioned in Table 1 by CPI index, and after calculating the pollutant emissions of each unit of energy resources of industries in Table 2, emissions produced by each industrial unit is calculated, then total social costs for NOx, SO_2, CO_2, CO, CH_4 and SPM are calculated for evaluating Environmental Efficiency of each industry and is shown in Table 3.

The above table shows the gregarious costs of non-metal mineral industries of each of the energy resources. By comparing the last column of the table for each non-metal mineral group, it can be concluded that cement, lime and plaster industries (Code 2694) have the highest share of convivial costs among the total costs of non-mineral industry pollutants.

According the above figure cement, lime and plaster industry (Code 2694) share of the total social costs of pollutants of non-metal mineral industries is %61. Manufacture of bricks has the second rank by %33 share of the total social costs of energy resources pollutants.

In perpetuate the pollutant emissions of energy resources in non-metal minerals which have not been categorized in other places (Code 269), have been discussed.

The above tables show the amount of pollutants and greenhouse gases emission by consumption of energy resources of each of the non-metal mineral industries. The comparison of the columns of the tables indicates that the Carbon Dioxide has the most pollutant emission in consumption of energy resources in non-metal mineral groups. It is prominent that the distinguishing proof of key elements in the outflow of Carbon Dioxide is extremely weighty to assess arrangements and techniques of decrement of atmosphere impacts.

4. RESULTS OF THE MODEL

In this section the specialized productivity and the ecological proficiency of the non-metal engenderment commercial ventures, which have not been classified in different spots (Code 269), have been considered. In assessing the specialized effectiveness SPM methodology has been used. This nonlinear model can be figured by GAMS programming. Information was collected from modern workshops with 10 representatives or more. Data and results for technical efficiency were obtained from Table 10.

The data of the last column of Table 10 indicate that manufacture of non-structural non-refractory ceramic ware (2691), manufacture of ceramic, lime and plaster (2694), manufacture of articles of concrete cement and plaster (2695), cutting, shaping and finishing of stone (2696) and manufacture of bricks (2697) are efficient industries.

After measurement of technical efficiency, this study proceeds to calculate environmental efficiency. An integration of the above data, data of convivial costs of energy sector by gas emission and for the amount of emission of industrial sector obtained from the energy balance sheet for energy and the environment were additionally used to evaluate environmental efficiency. In quantifying environmental efficiency Directional Distance Function (DDF) was utilized. Data and results are shown in Table 11.

By comparing the last column of the Tables 10 and 11 it can be concluded that the industries 2691,2694,2696,2697 that are technically efficient are not environmentally efficient decrement of their emission is the only way of reaching the efficient level. For instance if industry 2691 decreases %39 of its pollutants it can increase its desirable production by %36 and achieve the efficient level.

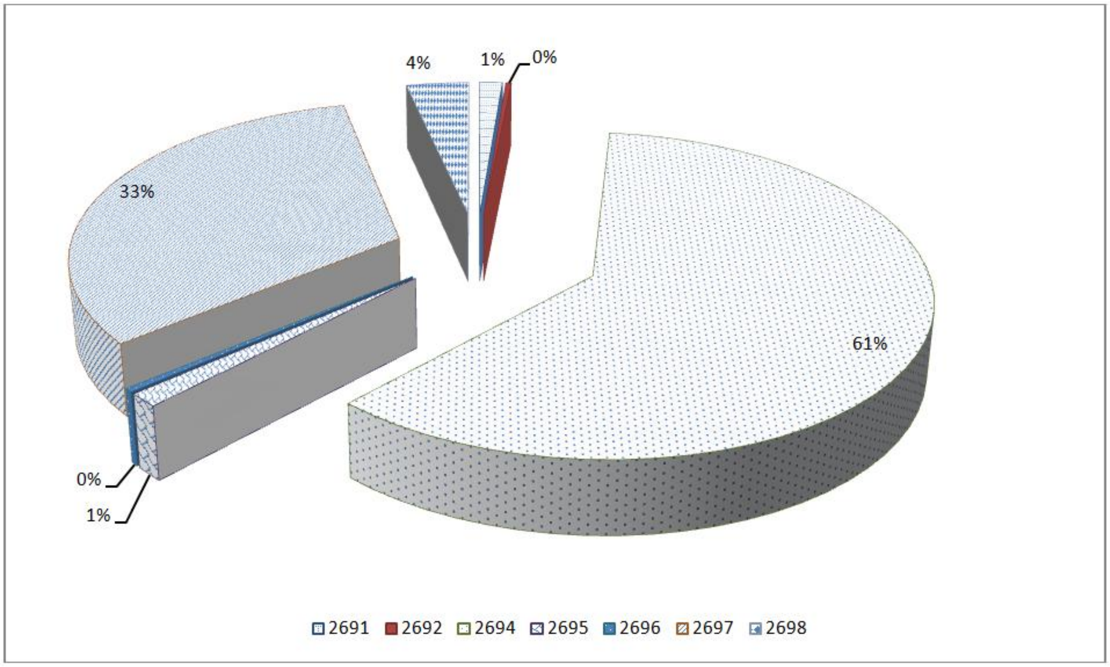

Fig. 2. Non-metal mineral industries share of the total social costs of energy resources pollutants

Source: study achievements

Table 1. Social costs of consumption of energy resources: Pollutants/greenhouse gases (thousand Rials per ton)

Type of gas	N_2O	CH_4	CO_2	SPM	CO	SO_3	SO_2	NOx
Cost	ℵ	1680	80	34400	1500	ℵ	14600	4800

Source: Energy Balance Sheet according the study of the world bank and the Environmental Protection Agency

Table 2. Emission of pollutant and greenhouse gases of industry sector by energy resources (ton)

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

Source: The total energy balance of the country

Table 3. Complete social expense of outflow of non-metal mineral commercial ventures by vital assets

The type of fuel industry code	Natural gas	LPG	Fuel oil	Gas oil	Kerosene	Gasoline	The total social cost of emission for each industry (Rials)
2691	72120581	3589502	5609631	9661132	55026	1354043	92389915
2692	12701124	88450	4369293	4134125	53346	321839	21668177
2694	1160370623	4008872	3182000000	56997314	2789958	6631042	4413025433
2695	10951360	439172	11328186	70930678	691819	6393287	100734501
2696	6943281	597150	987351	10963154	1789824	6106241	27387002
2697	299398194	3304789	1937000000	122000000	1788144	8562075	2371843726
2698	142990825	57326426	29797978	18491804	1068602	3783782	253459416
2699	17273529	591870	174910494	155000000	719122	5313242	353387269

Source: study achievements

Table 4. Pollutants and green house gases of gasoline consumption (kg)

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

Source: study achievement

Table 5. Pollutants and greenhouse gases of Kerosene consumption (kg)

Industry code	CH_4	CO_2	SPM	CO	SO_2	NOx
2691	14	341131	0	102	314	19
2692	13	330714	0	99	304	19
2694	692	17296104	0	5190	15915	969
2695	172	4288871	0	1287	3946	240
2696	444	11095859	0	3329	10210	621
2697	443	11085443	0	3326	10200	621
2698	265	6624705	0	1988	6096	371
2699	178	4458135	0	1338	4102	250

Source: study achievements

Table 6. Pollutants and greenhouse gases of gasoline consumption (kg)

Industry code	CH_4	CO_2	SPM	CO	SO_2	NOx
2691	1213	29960454	15949	2128	166938	53164
2692	519	12820471	6825	911	71435	22750
2694	7157	176756253	94091	12555	984879	313649
2695	8906	219965466	117092	15624	1225639	390323
2696	1377	33998198	18098	2415	189437	60329
2697	15262	376930294	200647	26773	2100241	668852
2698	2322	57345543	30526	4073	319527	101758
2699	19410	479370082	255178	34049	2671032	850629

Source: study achievements

Table 7. Pollutants and greenhouse gases of fuel oil consumption

Industry code	CH_4	CO^2	SPM	CO	SO_2	NOx
2691	400	10310655	3193	12	149863	31930
2692	311	8030879	2487	9	116727	24870
2694	226679	5849021527	1811406	6650	85014357	18113192
2695	807	20821516	6448	24	302637	64480
2696	70	1814779	562	2	26377	5620
2697	137995	3560708503	1102730	4048	51754185	11026767
2698	2123	54769499	16962	62	796064	169610
2699	12459	321490278	99564	366	4672797	995588

Source: study achievements

Table 8. Pollutants and greenhouse gases of LNG consumption (kg)

Industry code	CH_4	CO_2	SPM	CO	SO_2	NOx
2691	398	25004810	0	10837	61	16348
2692	10	616154	0	267	2	403
2694	444	27926176	0	12103	68	18258
2695	49	3059311	0	1326	7	2000
2696	66	4159805	0	1803	10	2720
2697	366	23021469	0	9978	56	15051
2698	6356	399341250	0	173077	978	261082
2699	66	4123019	0	1787	10	2696

Source: study achievements

Table 9. Pollutants and greenhouse gases of NG consumption (kg)

Industry code	CH_4	CO_2	SPM	CO	SO^2	NOx
2691	8127	456151144	60743	28689	1480	722198
2692	1431	80332578	10697	5052	261	127186
2694	130754	7339158633	977318	461583	23815	11619667
2695	1234	69265603	9224	4356	225	109664
2696	782	43915142	5848	2762	143	69528
2697	33737	1893645698	252167	119097	6145	2998100
2698	16113	904394100	120434	56880	2935	1431875
2699	1946	109252306	14549	6871	355	172973

Source: study achievements

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

Industry code	Production (Million rials)	Capital stock (Million rials)	Energy (Million rials)	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

Source: study achievements

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

Industry code	Production (Million Rials)	Emission of pollutants (Million Rials)	Capital stock (Million rials)	Energy (Million rials)	Labor	Level of environmental efficiency
2691	1891919	92	2215730	79629	12328	0.59
2692	1000905	22	446908	27139	2876	0.726
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

Source: study achievements

6. CONCLUSION

Development and growth process of countries is not acceptable and they do not reach a vast development unless considering environmental concerns. Today this topic is the controversial and its importance is emphasized every day. Considering the fact that the fossil fuels emit the most environmental vulnerability especially in emission of pollutants and greenhouse gases. Recognizing its resources and presenting solutions suitable for decreasing the emissions is of great importance. As the industry sector in our country has remarkable share of the emission of pollutants, improving the technical efficiency and the environmental issues is of great importance. In this paper by choosing non-metal minerals as sub-group of industries the technical and environmental efficiency has been investigated. The results indicate that among the industries of this group, cement, lime and plaster have the most shares of the social costs of the pollutants of each unit. By exploring the measure of poison outflows of every industry, it was found that CO2 as a nursery gas has the most divide of the toxins. Assessment of specialized productivity of every industry by SBM methodology betokens that some of non-metal mineral businesses are proficient. However none of them are environmentally efficient by DDF approach.

Since cement plays the most consequential role in engenderment of CO2 between non-metal mineral industries, policy points for decrement of emissions in this industry include: Improvement of industrial units, using substitute fuels, using technologies suitable for decrement of emission of CO2 and encouraging industries to invent an economical method to decrease the emission of CO2.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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