行政院國家科學委員會專題研究計畫　成果報告

產業能源與二氧化碳減量之永續決策關連模式之建立與應用

計畫類別： 個別型計畫
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執行期間： 92 年 08 月 01 日至 93 年 07 月 31 日
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行政院國家科學委員會補助專題研究計畫成果報告

產業能源與二氧化碳減量之永續決策關連模式之建立與應用
Sustainable Decision Model Development and Application of Linkage Effects between Industry, Energy and CO_2 Reduction

計畫類別：■個別型計畫□整合型計畫
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計畫主持人：張翊峰 嘉南藥理科技大學環境資源與管理系
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執行單位：嘉南藥理科技大學環境資源與管理系

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中文摘要

本文目的在於結合投入產出法與乘數分析，探討國內產業關聯度及能源耗用與污染排放量之乘數效應，且針對產業的能源與環境乘數特性進行群落分析，以評析主要產業之能源與環境效益及探討產業的發展策略。由乘數分析之結果得知，其他化工原料、石化原料、陸上運輸、水泥業、鋼鐵業及人造纖維等產業的能源效益最差，即這些產業所需的直接與間接單位能源需求量最大。在環境方面，CO2污染乘數較高的產業包括其他化工原料、水泥、陸上運輸、鋼鐵、其他非金屬及造紙業等產業，群落分析結果顯示，鋼鐵業與造紙業產業總關聯效果較高，屬重要產業，未來應持續改善能源效益及加強污染防治措施，至於其他非金屬礦物製品業則可考量逐年降低其產業配比。紡織及成衣業、橡膠製品業及營造業對帶動相關產業仍有相當程度之重要性，而油氣煉製業、石化原料業及塑膠原料業對其他產業之影響度較小，另外，由於塑膠原料業的產業關聯效果偏低，不宜繼續擴充此產業的配比。商業及其他服務業之能源與環境效益極佳，為值得鼓勵與擴展的產業。

關鍵詞：能源與環境關聯效應、乘數分析、產業關聯分析、群落分析

Abstract

This study aims to assess the linkage effects of energy consumption and CO_2 emissions for 34 major industries in Taiwan by using multiplier analysis and cluster analysis. Results indicate that there is a strong linkage between energy consumption and pollution emission. Industries such as iron & steel, power generation, paper & product and petro-chemical materials will continue to play important roles in Taiwan's economic development, yet they need to be improved for better energy and environmental bases. Other industrial chemicals, highway, cement, artificial fibers and non-metallic mineral products should not be encouraged to expand in the future. Also, sectors such as public service & others and commercial sector are worthy for further promotion. This study indicates that industry development should be integrated with environmental and energy policies, in order to assure environmental sustainability, energy security and economical gains.

EYWORDS: energy and environmental linkage; multiplier analysis; interindustry linkage; cluster analysis

研究內容

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ENERGY AND CO_2 EMISSION LINKAGE ANALYSIS OF TAIWAN INDUSTRY

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ABSTRACT

This study aims to assess the linkage effects of energy consumption and CO_2 emissions and NOx) for 34 major industries in Taiwan by using multiplier analysis and cluster analysis. Results indicate that there is a strong linkage between energy consumption and pollution emission. Industries such as iron & steel, power generation, paper & product and petro-chemical materials will continue to play important roles in Taiwan's economic development, yet they need to be improved for better energy and environmental bases. Other industrial chemicals, highway, cement, artificial fibers and non-metallic mineral products should not be encouraged to expand in the future. Also, sectors such as public service & others and commercial sector are worthy for further promotion. This study indicates that industry development should be integrated with environmental and energy policies, in order to assure environmental sustainability, energy security and economical gains.

KEYWORDS: energy and environmental linkage; multiplier analysis; interindustry linkage

1. INTRODUCTION

Taiwan has very limited indigenous energy sources on land, since energy plays a vital role in national economic development. The total amount of Taiwan's energy supply increased from 31.78 million kiloliters of oil equivalent in 1982 to 113.23 million kiloliters of oil equivalent in 2002, for an annual average growth rate of 6.6%. Security of energy supply has been the top priority in Taiwan's energy policy. Yet, there are growing environmental concerns among the public over energy activities. Also, the government in Taiwan is becoming more aware of energy-related regional and global environmental problems. Therefore, it is important to understand the interrelationships between energy and environment in order to seek mutual gains for energy security and environmental sustainability.

A number of studies (Huang,1994; Hawdon,1995; Proops, 1996; Caster,1998;Chang, 1998; Sun,1999; Chen, 2001) have been conducted in dealing with energy and environmental analysis. This study uses the multiplier analysis and cluster analysis to assess the linkage effects between energy consumption and air pollutant emissions in order to provide insight for relevant policy making in Taiwan.

2. METHODOLOGY

As pollution is regarded as the "externality" of regular economic activities, many forms of pollutant emissions can be related in a measurable way to energy consumption or production processes. In this study, CO_2 are used as pollution indices to evaluate relationships between energy consumption and pollutant emissions.

The multiplier analysis, derived from the input-output model is frequently applied to estimate the inter-industry relationships and the direct and indirect impact of industry. Most of studies use the energy and pollution multipliers to quantify the total impacts of the energy input and pollution output associated with interindustry activities, and they can be formulated as the following:

$$\overline{R} = R(I-A)^{-1} = \sum_{i=1}^{n} (r_{ki} \times b_{ij}) \quad \text{.......(1)}$$

$$\overline{Q} = Q(I-A)^{-1} = \sum_{i=1}^{n} (q_{pi} \times b_{ij}) \quad \text{.......(2)}$$

where

$\overline{R}$:[$\overline{r}_{kj}$]$_{1xn}$, energy multiplier, total impact of energy coefficient which specifies the amount of energy k required directly and indirectly by per million dollars(US) worth of output of industry j ,

$\overline{Q}$:[$\overline{q}_{pj}$]$_{1xn}$, pollution multiplier, total impact of pollution coefficient which specifies the amount of pollutant p emitted directly and indirectly caused by per million dollars(US) worth of output of industry j,

$(I-A)^{-1}$: Leontief inverse matrix, based on technical matrix of Taiwan domestic transaction,

b_{ij} : element of Leontief inverse matrix,

R: $[r_{kj}]_{1xn}$, direct energy coefficient of energy k (eg. Coal & its products, oil & its products, natural gas & liquefied natural gas) for industry j (10^7Kcal/US\$$10^6$),

Q: $[q_{pj}]_{1xn}$, direct pollutant coefficient of pollutant p (eg. CO_2) from industry j (ton pollutant/US\$$10^6$),

r_{ki} : consumption of energy k by the industry i per million dollars worth of output,

q_{pi} : emissions of pollutant p of industry i per million dollars worth of output.

The concept of interindustry linkage effect was developed by Hirschman (1985). It was based on the assumption that the economy could be promoted by adopting an imbalanced investment policy to generate an equilibrium growth among the related industries. In other words, economy in related industries can be boosted through linking input and output activities.

In general, linkage effect is classified into "forward linkage effect" and "backward linkage effect". The former indicates that the output of certain industry productivity may be used as input to other industries, while the latter means that production activities of a certain industry may induce more uses of other industries as input. The calculation of the interindustry linkage effect was constructed by Bear and Kerstenetzky(1964). It can be presented as the following:

$$Ui^f = \frac{\sum_{j=1}^{n} b_{ij}}{\frac{1}{n}\sum_{i=1}^{n} b_{ij} \sum_{j=1}^{n} b_{ij}} \quad (3) \qquad Uj^b = \frac{\sum_{i=1}^{n} b_{ij}}{\frac{1}{n}\sum_{i=1}^{n} b_{ij} \sum_{j=1}^{n} b_{ij}} \quad ....(4)$$

where

Ui^f = sensibility index of dispersion, denoting the forward linkage effect,
Uj^b = power index of dispersion, indicating the backward linkage effect,
b_{ij} = element of Leontief inverse matrix,
$\sum_{j=1}^{n} b_{ij}$ = sum of elements in row i of Leontief inverse matrix,
$\sum_{i=1}^{n} b_{ij}$ = sum of elements in column j of Leontief inverse matrix.

In addition, the hierarchical cluster analysis approach was selected to measure the similarity among various industries in order to demonstrate the characteristic distribution pattern of energy and pollution multipliers.

3. DATA CONSOLIDATION

The basic input-output Table for 1999 and the final demand sectors used in this study were originally developed by the Accounting Office of the Executive Yuan in Taiwan (2001). The energy consumption of various industries is based on the data from the "Taiwan Energy Balance Sheets" (Taiwan Energy Commission, 2002). Because the sector classifications of the basic input-output table and the "Taiwan Energy Balance Sheets" are not identical, we combined them into a 34-sector table (Lin, 1996). Since the focus of this study is on the domestic industry productivities, CO_2 was selected as pollution indices, since the global climate changes received most of the attention among other environmental problems. The CO_2 emission of thirty-four industries are estimated according to the IPCC guidelines(10), while emissions caused by the electricity and power generation sectors are allocated to various industries according to the rate of electricity consumption.

4. RESULTS AND DISCUSSION

Coupling Effects of Energy and Pollution Coefficients

The energy coefficients for all 34 sectors are computed and listed in Table 1. Because of high coal and oil coefficients, the electricity & power generation sector has the highest energy coefficient. During 1999 in Taiwan. The Taiwan government intends to increase the share of coal to meet the increasing demand in power generation as part of its strategy for energy diversification. Other industrial chemicals, petro-chemical materials, highway and cement are among the top five in energy coefficient compared to other industries. These sectors also have high rankings regard to CO_2 emission coefficient, which delineates the coupling relationship between energy consumption and CO_2 emission.

Relationships of Energy and Pollution Multipliers

The total (direct and indirect) impacts of energy and pollution coefficients analysis for all 34 sectors are displayed in Table 2. Again, the results indicate that electricity & power generation ranks the highest for CO_2 multiplier due to its very high energy coefficient.

Comparing Table1 and Table 2, results of energy multiplier analysis indicate that the cement sector has more indirect impacts compared to the highway sector. As a result, it changes the order in ranking for the energy multiplier. Similarly, artificial fibers and plastic material are ranked higher in the energy multiplier(Table 2) compared to energy coefficient(Table 1). On the other hand, sectors such as storage & communication, commercial sector and public service & others rank fairly low in energy multiplier compared to rankings of those energy coefficient.

As for pollution multiplier, the top five CO_2 multiplier include electricity & power generation, other industrial chemicals, cement, highway, and iron & steel. Coincidently, these industries are identified as the most significant industries causing the greenhouse effect in Taiwan(7). Also, it is noticeable that the cement and the iron & steel sectors rank higher in the CO_2 multiplier compared to energy multiplier due to their large share of coal consumption. On the other hand, petro-chemical materials and non-metallic mineral products have lower ranks in the CO_2 multiplier compared to the energy multiplier due to their higher natural gas multiplier. Sectors such as storage & communication, commercial sector and public service & others rank consistently low in energy multiplier, as well as in CO_2 multiplier. The above results indicate a significant linkage between energy consumption and CO_2 emission.

Highlights of Significant Industries

In this study, the cluster analysis was used to demonstrate the characteristic distribution pattern of energy and pollution multipliers. Table 3 highlights results of the cluster analysis, total interindustry relationships, and rankings of energy and pollution multipliers. Highlights of some major industries are summarized the following:

Electricity & power generation

As shown in Table 3, power generation ranks the highest for coal energy multiplier and CO_2 multipliers. According to the current energy policy in Taiwan, the share of electricity supply will continue to increase in the future. It indicates that power generation will continue to play a very important role for economical and industrial activities in Taiwan. For future improvement, Taiwan needs to have a larger share of natural gas and non-fossil fuel for electricity generation and continue to improve facilities for pollution control and for better energy efficiency.

Other industrial chemicals

Other industrial chemicals ranks the second CO_2 multiplier and the third energy multiplier as shown in Table3. Also, Result of overall interindustry linkage analysis indicate that this sector has little effects to overall industry development, therefore it is suggested that total investment and productivity of this sector be cut in the future for better energy and environmental bases.

Cement

As shown in Table 3, the cement sector ranks the third for CO_2 multiplier, and the sixth for energy multipliers. As for overall interindustry relationships, this sector has a larger backward linkage effect and relatively small in forward linkage effect. It ranks the twelfth in overall interindustry linkage. Future mitigations may include upgrading industry processes, substitution to clean fuels, enhancing regulation for better coal efficiency and pollution control.

Highway

The highway sector ranks the fourth CO_2 multipliers, and the fifth for CO_2 pollution multiplier. Also, the characteristic distribution pattern of the highway sector ranks the second for energy cluster and the fourth for environmental cluster due to the rapid growth of transportation and the lack of effective control devices for CO_2 emission in Taiwan. Control measure to abate transportation impacts in Taiwan may include upgrading the public transportation system, phasing out old motors, substitution to clean fuels, improvement in motor thermodynamic and mechanical devices to better energy efficiency.

Iron & steel

Results of cluster analysis indicate that the iron & steel sector ranks the fifth for CO_2 multiplier and demonstrate similar attributes with the cement sector in the energy clusters. However, the iron & steel ranks the third in overall interindustry relationships, while the cement sector ranks the 29th as listed in Table 3. It indicates that the iron & steel sector plays much more important role than the cement sector in Taiwan’s economic development. For the future, mitigations may include upgrading industry process, enhancing regulation for better coal efficiency and pollution control.

Electric machinery, Storage & communication, Commercial and Public services & others

All these four sectors have similar attributes from cluster analysis. They rank very low in energy multipliers as well as pollution multipliers. Among these, the public service & others sector has the highest ranking in overall interindustry relationships, which implies that this sector would do very well to expand in terms of economical gains as well as sound energy and environmental bases. Also, the commercial sector shares similar conditions with higher ranking in overall interindustry linkage effects. On the other hand, sector of storage & communication has low rankings for energy and pollution coefficients, yet this sector has lowest value in both forward and backward linkage effects. It is suggested that this sector could be expanded to have larger share in overall industry development to meet mutual benefits in energy and environmental gains.

5. CONCLUSIONS

This study aims to assess the linkage effects of energy consumption and air pollutant emissions for 34 major industries in Taiwan during 1999 by using multiplier analysis and cluster analysis. Results indicate that power generation, other industrial chemicals, petro-chemical materials, cement, highway, and artificial fibers are among the highest in energy multiplier, which also imply that these industries have lower energy efficiency compared to other industries. The above-mentioned industries also hold high rankings in CO_2 multipliers, which proves that there is a strong linkage between energy consumption and pollution emission.

Results of this study also indicate that iron & steel, power generation, paper & product and petro-chemical materials are identified as high energy demand, high pollution emission, and high rankings in overall interindustry linkage effects. This means that the above-mentioned industries will continue to play important roles in Taiwan's economic development, yet they need to be improved for better energy and environmental bases. On the other hand, other industrial chemicals, highway, cement, artificial fibers and non-metallic mineral products are identified as high energy demand and high pollution with low rankings in overall interindustry relationships; therefore, these industries should not encouraged to expand further in the future. Also, this study indicates that sectors such as public service & others and commercial sector are worthy for promotion because these industries have very high rankings in overall interindustry relationships with low energy demand and low pollution emission. In order to cope with growing concerns of environmental impacts from energy activities in Taiwan, energy policy has to be integrated with environmental policy. It is anticipated that stringent environmental standards and regulations will play important roles in Taiwan, which may have impacts on energy policy makings and the energy structure of Taiwan. The methodology and results of this study can be valuable in further application for integrating energy and environmental policies.

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Table 1 Coupling Effects of Energy and CO_2 Coefficients

Unit*: 10^7Kcal/US$$10^6$ Unit**: ton/US$$10^6$

Sector	Electricity* Coefficient	Rank	Coal* Coefficient	Rank	Oil* Coefficient	Rank	Natural Gas* Coefficient	Rank	Energy* Coefficient	Rank	CO2** Coefficient	Rank
1.Agricultural, Forestry & Fishery	13.09	22	0.00	12	48.50	12	0.00	20	61.6	18	149.3	16
2.Energy-related Sector	11.33	24	0.00	12	15.67	20	23.79	5	50.8	20	85.9	19
3.Foods & Products	14.02	20	0.00	12	23.50	17	0.57	13	38.1	22	62.7	20
4.Textiles & Products	35.92	13	2.16	10	66.02	10	1.10	12	105.2	15	182.5	15
5.Leather & Products	17.51	19	0.00	12	34.11	14	0.00	20	51.6	19	89.7	18
6.Lumber & Products	18.50	18	0.00	12	4.29	25	0.00	20	22.8	26	11.0	27
7.Paper & Products	59.25	6	49.42	8	66.01	11	0.39	16	175.1	12	331.5	11
8.Printing	7.28	28	0.00	12	1.42	29	0.00	20	8.7	32	3.3	31
9.Oil & Gas Refineries	26.39	16	0.00	12	210.72	6	57.81	2	294.9	7	560.8	9
10.Coal Products	73.34	3	0.00	12	84.37	9	0.00	20	157.7	13	218.5	13
11.Petro-Chemical Materials	50.40	10	107.03	4	780.14	1	18.28	6	955.8	2	734.4	7
12.Plastic Materials	59.05	7	58.38	6	2.04	28	0.00	20	119.5	14	190.3	14
13.Artificial Fibers	162.65	1	94.13	5	0.18	34	0.00	20	257.0	10	300.1	12
14.Plastic Products	6.47	31	0.00	12	9.06	22	0.53	14	16.1	27	24.8	24
15.Rubber Products	133.68	2	0.00	12	148.68	7	5.22	8	287.6	8	397.0	10
16.Other Industrial Chemicals	63.17	5	7.50	9	460.23	4	0.00	20	530.9	4	1,233.3	4
17.Chemical Products	31.87	14	0.00	12	27.13	15	31.52	4	90.5	16	112.2	17
18.Cement	53.96	9	390.25	2	21.83	18	0.00	20	466.0	5	1,264.4	3
19.Non-Metallic Mineral Products	43.58	12	54.21	7	119.58	8	57.51	3	274.9	9	860.0	5
20.Iron & Steel	46.56	11	242.20	3	37.59	13	7.59	7	333.9	6	796.7	6
21.Non-Ferrous Metal	11.14	25	0.00	12	16.08	19	0.00	20	27.2	25	41.4	22
22.Metal Products	30.52	15	0.00	12	10.80	21	1.55	10	42.9	21	30.5	23
23.Machinery	6.82	30	0.00	12	1.14	31	0.11	18	8.1	33	3.1	32
24.Electric Machinery	11.59	23	0.00	12	1.32	30	1.46	11	14.4	29	6.2	30
25.Transport Equipments	7.39	27	0.00	12	3.40	26	0.45	15	11.2	30	9.4	28
26.Misc. Manufactures	10.25	26	0.00	12	25.16	16	0.03	19	35.4	23	55.5	21
27.Electricity & Power Generation	56.33	8	1661.08	1	624.11	3	300.45	1	2,642.0	1	7,400.3	1
28.Gas & Water Supply	69.62	4	0.00	12	0.89	32	0.00	20	70.5	17	1.9	34
29.Construction	1.26	33	0.00	12	5.55	23	0.00	20	6.8	34	14.5	26
30.Highway	0.64	34	0.00	12	744.57	2	0.00	20	745.2	3	1,791.2	2
31.Railway, Ship & Aviation	7.11	29	0.00	12	235.06	5	0.00	20	242.2	11	577.0	8
32.Storage & Communication	13.75	21	0.00	12	0.84	33	0.00	20	14.6	28	2.1	33
33.Commercial Sector	24.58	17	0.00	12	4.43	24	2.55	9	31.6	24	16.3	25
34.Public Service & Others	6.12	32	0.00	11	3.33	27	0.17	17	9.6	31	8.7	29

Table 2 Coupling Effects of Energy and CO_2 Multipliers

Unit*: 10^7Kcal/US$$10^6$ Unit**: ton/US$$10^6$

Sector	Electricity* Multiplier	Rank	Coal* Multiplier	Rank	Oil* Multiplier	Rank	Natural Gas* Multiplier	Rank	Energy* Multiplier	Rank	CO2** Multiplier	Rank
1.Agricultural, Forestry & Fishery	25.72	28	29.74	31	96.86	18	7.22	31	159.5	30	419.8	24
2.Energy-related Sector	21.24	30	59.30	24	66.75	25	38.67	6	186.0	24	421.5	23
3.Foods & Products	31.66	20	45.67	26	94.15	20	10.20	26	181.7	25	395.5	26
4.Textiles & Products	100.49	3	137.58	11	222.80	10	24.24	13	485.1	12	928.4	12
5.Leather & Products	30.55	23	37.10	28	93.21	21	7.79	30	168.7	29	348.3	30
6.Lumber & Products	31.01	21	62.15	23	66.42	26	12.49	22	172.1	28	368.7	29
7.Paper & Products	88.21	6	242.58	5	183.49	12	35.67	8	550.0	9	1,295.9	8
8.Printing	29.33	26	73.67	18	60.85	28	13.14	20	177.0	26	404.8	25
9.Oil & Gas Refineries	30.60	22	63.34	21	249.75	9	71.42	3	415.1	13	880.8	13
10.Coal Products	83.45	9	52.96	25	149.59	13	11.67	24	297.7	17	562.4	19
11.Petro-Chemical Materials	71.65	11	228.75	6	1012.60	1	50.53	4	1,363.5	2	1,486.4	6
12.Plastic Materials	91.61	4	212.68	7	387.49	5	31.77	11	723.5	8	1,086.0	10
13.Artificial Fibers	206.26	1	276.69	4	363.20	6	34.45	9	880.6	4	1,286.7	9
14.Plastic Products	39.27	16	121.84	12	148.71	14	22.51	14	332.3	15	654.7	15
15.Rubber Products	166.19	2	85.08	16	271.64	8	21.76	15	544.7	10	969.3	11
16.Other Industrial Chemicals	84.91	8	191.33	8	651.75	4	36.49	7	964.5	3	2,249.3	2
17.Chemical Products	51.24	15	62.72	22	136.22	15	46.44	5	296.6	18	521.0	21
18.Cement	80.15	10	583.25	2	131.79	17	26.92	12	822.1	6	2,187.9	3
19.Non-Metallic Mineral Products	61.00	13	154.01	9	213.78	11	82.69	2	511.5	11	1,464.8	7
20.Iron & Steel	85.76	7	474.79	3	132.46	16	32.87	10	725.9	7	1,772.7	5
21.Non-Ferrous Metal	34.61	17	116.41	15	86.52	22	15.89	18	253.4	19	593.0	18
22.Metal Products	58.53	14	139.33	10	83.68	23	18.41	16	299.9	16	652.5	16
23.Machinery	34.02	18	117.60	14	64.70	27	12.83	21	229.1	22	529.0	20
24.Electric Machinery	23.31	29	39.19	27	42.86	31	9.01	28	114.4	31	234.8	31
25.Transport Equipments	29.48	25	76.55	17	58.15	30	10.68	25	174.9	27	384.7	28
26.Misc. Manufactures	32.02	19	68.68	19	95.95	19	12.01	23	208.7	23	438.7	22
27.Electricity & Power Generation	70.03	12	1900.45	1	747.32	3	350.09	1	3,067.9	1	8,552.0	1
28.Gas & Water Supply	88.48	5	68.03	20	59.67	29	18.19	17	234.4	21	387.5	27
29.Construction	28.17	27	119.04	13	80.44	24	14.43	19	242.1	20	595.5	17
30.Highway	8.20	34	20.39	34	798.02	2	9.06	27	835.7	5	1,996.7	4
31.Railway, Ship & Aviation	12.86	32	24.91	32	295.35	7	6.69	32	339.8	14	810.9	14
32.Storage & Communication	17.97	31	30.01	30	22.41	34	5.63	33	76.0	33	159.5	33
33.Commercial Sector	30.15	24	30.15	29	33.62	32	8.75	29	102.7	32	192.2	32
34.Public Service & Others	11.85	33	24.10	33	24.53	33	4.95	34	65.4	34	143.4	34

Table 3 Results of Cluster And Multiplier Analyses And Overall Industry Linkage For Major Sectors in Taiwan (1999)

Sector	Cluster Analysis	CO_2 Multiplier ranking[1]	Energy Multiplier ranking[1]				Linkage Effect		
			Total	Coal	Oil	Natural Gas	Forward (Ui^b)	Backward (Uj^f)	Total effect ranking
27.Electricity & Power Generation	1	1	1	1	3	1	1.28	0.80	11
16.Other Industrial Chemicals	2	2	3	8	4	7	0.98	1.04	13
30.Highway	3	4	5	34	2	27	0.85	0.66	26
18.Cement	3	3	6	2	17	12	0.55	0.94	29
20.Iron & Steel	4	5	7	3	16	10	2.00	1.25	3
11.Petro-Chemical Materials	5	6	2	6	1	4	2.14	1.22	2
4.Textiles & Products	7	12	12	11	10	13	0.78	1.22	14
15.Rubber Products	7	11	10	16	8	15	0.53	1.03	25
24.Electric Machinery	12	31	31	27	31	28	1.33	1.23	5
32.Storage & Communication	12	33	33	30	34	33	0.64	0.58	34
33.Commercial Sector	12	32	32	29	32	29	1.75	0.61	7
34.Public Service & Others	12	34	34	33	33	34	3.32	0.61	1

Notations: 1. results are taken from Table 2

計畫成果自評

本計畫所預期完成之具體研究成果及效益包括策劃研究並蒐集國內外文獻資料，作為研究之基礎。根據國內產業經濟與能源消費資料，推估各產業相關的CO_2排放量，建立各項3E系統指標。建立3E系統永續指標資料庫，提供快速的查詢及連結之介面。以群落分析法建立產業在3E系統下之屬性，作為評量產業定性分析之基礎。以投入產出結構因素分析法分析前十大產業CO_2排放量的變動趨勢及確認影響CO_2排放增減量之關鍵因素，作為研擬削減方案之參考。

本研究所建立產業經濟、能源與環境相關之永續決策指標資料庫，可累計歷年資料並進行趨勢分析，提供國內產業之相關3E系統數據指標之查詢，有助於相關研究分析時之基礎。資料庫介面未來則可逐步擴充至其他污染物資料之建立，甚或應用至其他環境層面，例如產業耗水資料、廢棄物產量等領域。研究並以群落分析配合專家系統邏輯法則定位產業之屬性，可多層面並客觀分析產業之定性分析。

此外對於參與之碩士班研究生及相關工作人員可訓練其獨立思考與群體合作之能力，並有助於培養能源與環境規劃人才之養成。上述之研究成果已發表於國內之學術研討會及期刊，將持續投稿於國外期刊，且完成碩士人才之培訓，整體而言，本項補助計畫所得之成果可堪稱豐碩。