INTERNATIONAL COMPARISON ON KEY MATERIAL UTILIZATION EFFICIENCY INDICATORS OF PETROCHEMICAL INDUSTRY

Speaker: ***Ching-Yuan Chang***

Graduate Institute of Environmental Engineering, National Taiwan University

Authors:

Chungfang Ho Chang

Department of International Trade, Chung Yuan Christian University

Chiung-Fen Chang

Department of Environmental Science and Engineering, Tunghai University

Ching-Yuan Chang, Tze-Huei Chan, Chia-Chi Chang, Pei-Hsuan Lin

Graduate Institute of Environmental Engineering, National Taiwan University

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I. INTRODUCTION

- Material utilization efficiency is a management philosophy that encourages the business to enhance the financial and environmental performance and to create more value with less ecological impact. (World Business Council for Sustainable Development, WBCSD, 1996 and 1997)
- Seven elements to demonstrate material utilization efficiency improvement:
  - 1) reduced material intensity,
  - 2) reduced energy intensity,
  - 3) reduced dispersion of toxic substances,
  - 4) enhanced recyclability,
  - 5) maximized use of renewables,
  - 6) extended product life,
  - 7) increased service intensity.

I. INTROODUCTION

- Four types of indicators which are helpful to access companies' material utilization efficiency:
  - Generally applicable value indicators

    e.g., quantity of product/service produced or sold, and net sales.
  - Generally applicable environmental influence indicators

    e.g., energy consumption, water consumption, material consumption, greenhouse gases (GHGs) emissions, and ozone depleting substances (ODS) emissions.
  - Potential generally applicable indicators

    additional financial value indicators, acidification emissions to air, and total waste.
  - Business specific indicators

I. INTRODUCTION

- Petrochemical industry is one of the capital-intensive and highly energy-consumed industries, and strongly associated with many other industries.
- A complete industrial ecology contains material flow, energy flow, and capital flow systems.
- The goal of this study:
  - To investigate the energy consumption and emissions of pollutants of Taiwan's petrochemical industry.
  - To establish and access the material utilization efficiency indicators of Taiwan's petrochemical industry.
  - To compare with other developed countries, such as United States and Japan, and developing countries, such as Korea and China.

II. The Energy Consumption of Petrochemical Industry in Taiwan

Background

- In Taiwan, the items of major materials included in petrochemical industry are raw materials, plastics, chemical fiber, chemical products, and rubber (Ministry of Economic Affairs (MOEA), 1999 and 2001a).
- The energy consumptions of up- and mid-stream processors were calculated and distributed by means of the proportions of the production quantities (e.g., up-stream : mid-stream = 1 : 3) (MOEA, 1992).
- The total energy consumption of the textile industry, which is dependent on the petrochemical industry, was also considered and calculated according to the portion of synthetic fiber contributing to 52.7% of the production value of the textile industry (TCB, 1999).

Production value, quantity and energy consumption

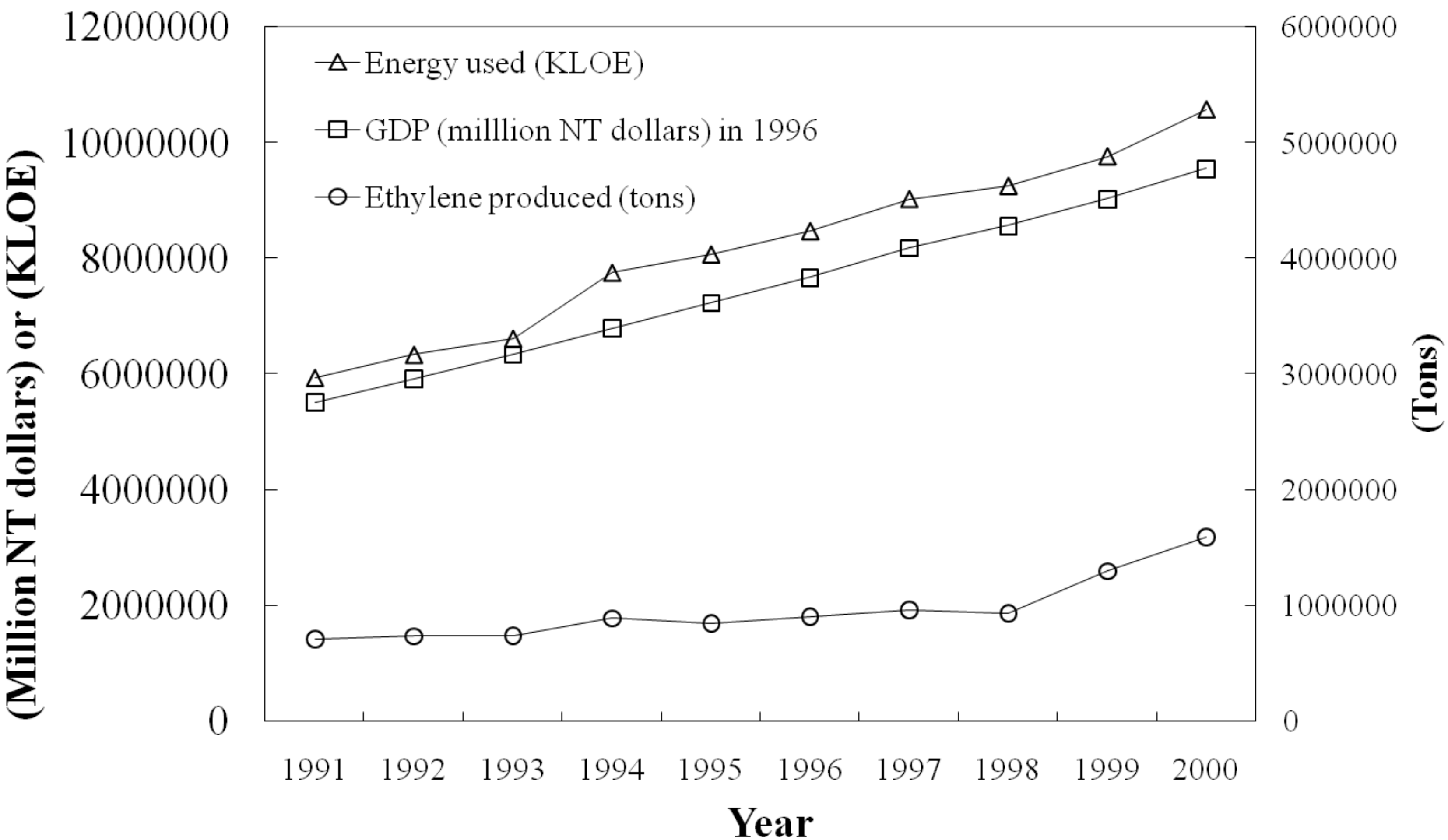

Figure 1. The production value, quantity, and the energy used of petrochemical industry in Taiwan. KLOE: kilo liter oil equivalent. Data sources: MOEA, 2001a.

Energy usage structure

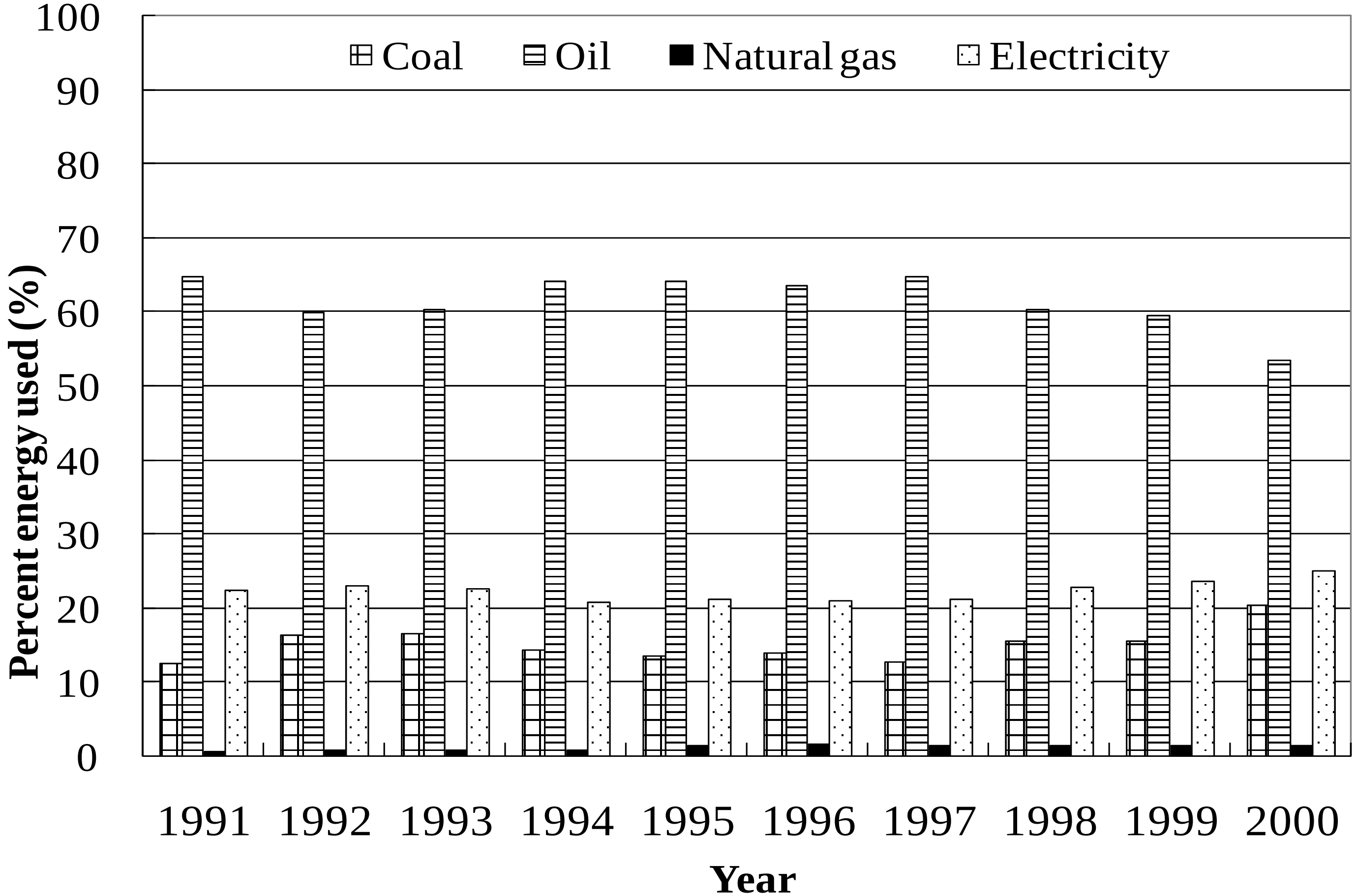

Figure 2. The usage structure of energy resources of petrochemical industry. Data sources: MOEA, 2001.

III. Air Pollution of Petrochemical Industry in Taiwan

Methods and Analyses

- The emissions of the green house gases (CO_2, CH_4, N_2O), NO_X and SO_X were discussed in this study.
- The procedures to calculate the emissions of CO_2 were as follows (Chen, 1998; Yang, 1995):
  1. The heat value of the energy resources in TJ (i.e., tera joule=10^{12} joules) was calculation via the multiplication of the consumed quantity and the specific heat contents of the energy resources.
  2. The carbon content was equivalently equal to the used quantity of energy resources in terms of heat value times the carbon emission coefficient.
  3. The quantity of carbon stored was the carbon content times the fraction of carbon stored.
  4. Finally, the emission quantity of CO_2 can be obtained by the multiplication of the fraction of carbon oxidized (carbon content minus carbon stored) and the conversion factor of 44/12 (the transformation of carbon to CO_2).

Contribution of various greenhouse gases to global warming

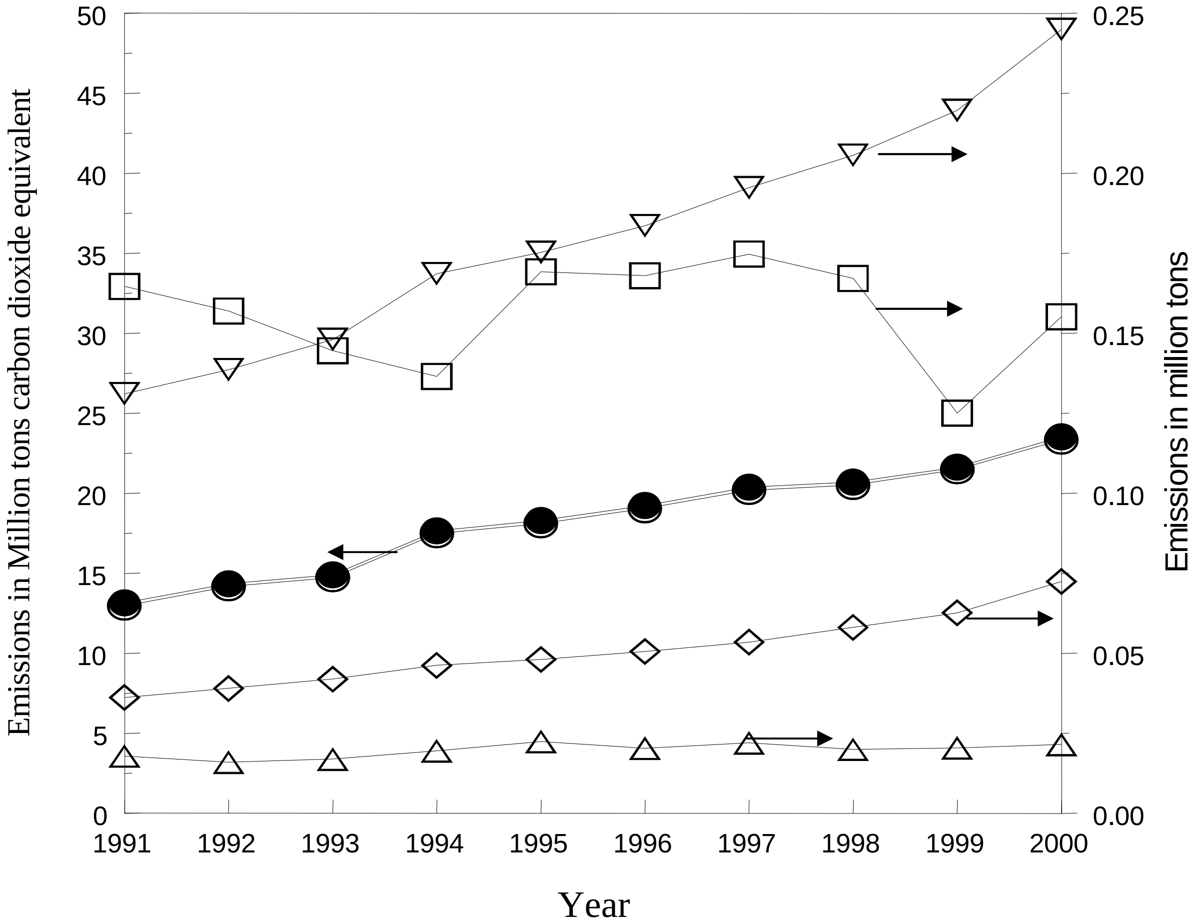

Figure 3. The dependency of emissions of greenhouse gases (●), CO_2 (○), CH_4 (△), N_2O (□), SO_X (▽), NO_X (◇) on year for petrochemical industrial in Taiwan. Data sources: MOEA, 2001.

Comparing the emissions of CO_2, NO_X AND SO_X in different streams

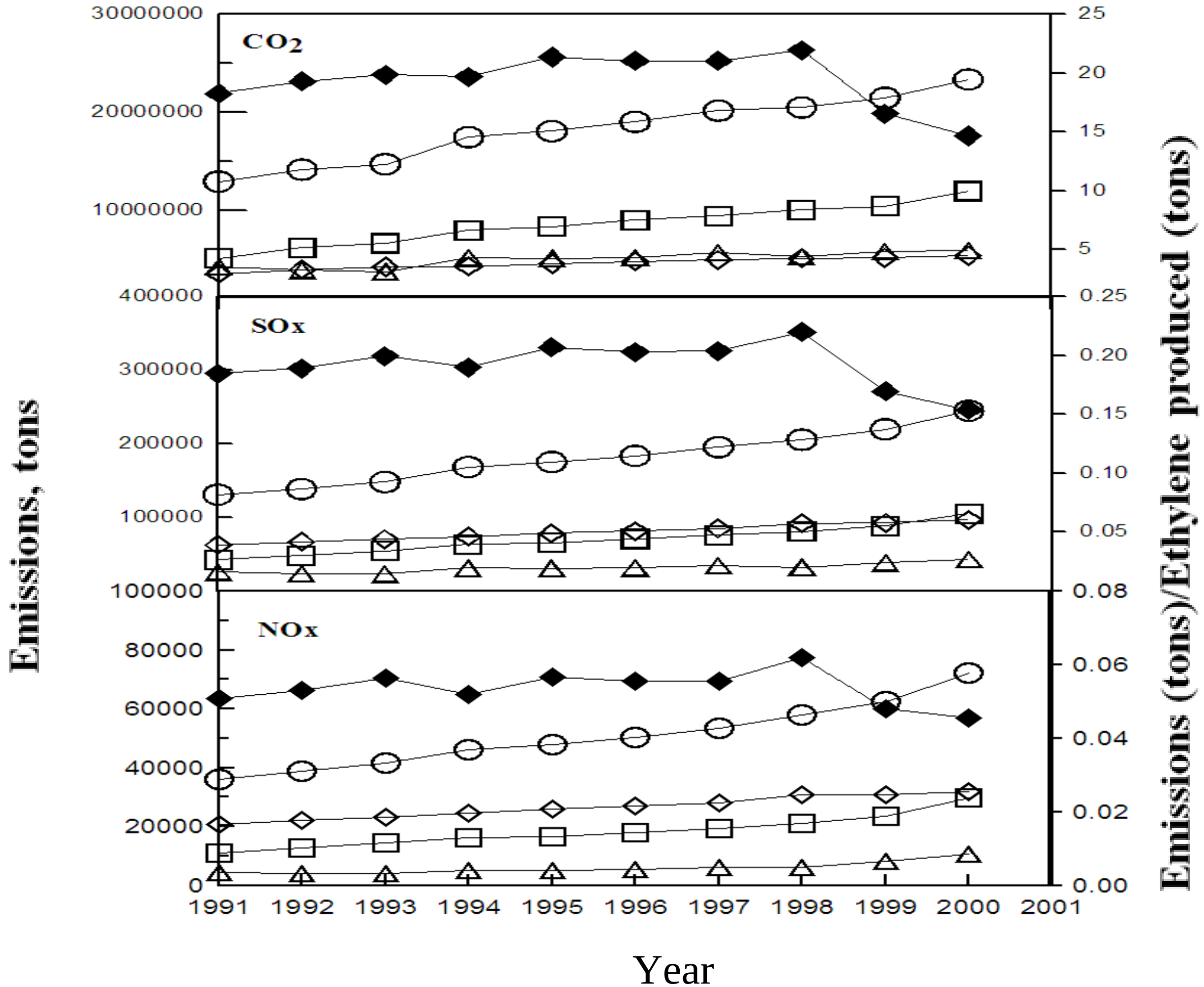

Figure 4. Emissions of CO_2, SO_X and NO_X of up-stream (△), mid-stream (□), down-stream (◇) processors, and the sum (○) of petrochemical industry in Taiwan. ◆: specific gas emissions (i.e., total emissions of CO_2, SO_X, and NOx in petrochemical industry/total ethylene production quantity). Data sources: TEPA, 2002.

IV. Water Consumption and Pollution of Petrochemical Industry in Taiwan

Methods and Analyses

- The quantity of wastewater was calculated by the proportion of industrial production value of petrochemical industry times the whole industrial wastewater quantity (i.e., 35 %) (TEPA, 2002).
- The biochemical oxygen demand (BOD_5) was used to assess the water pollution of petrochemical industry.

Water consumptions in different streams

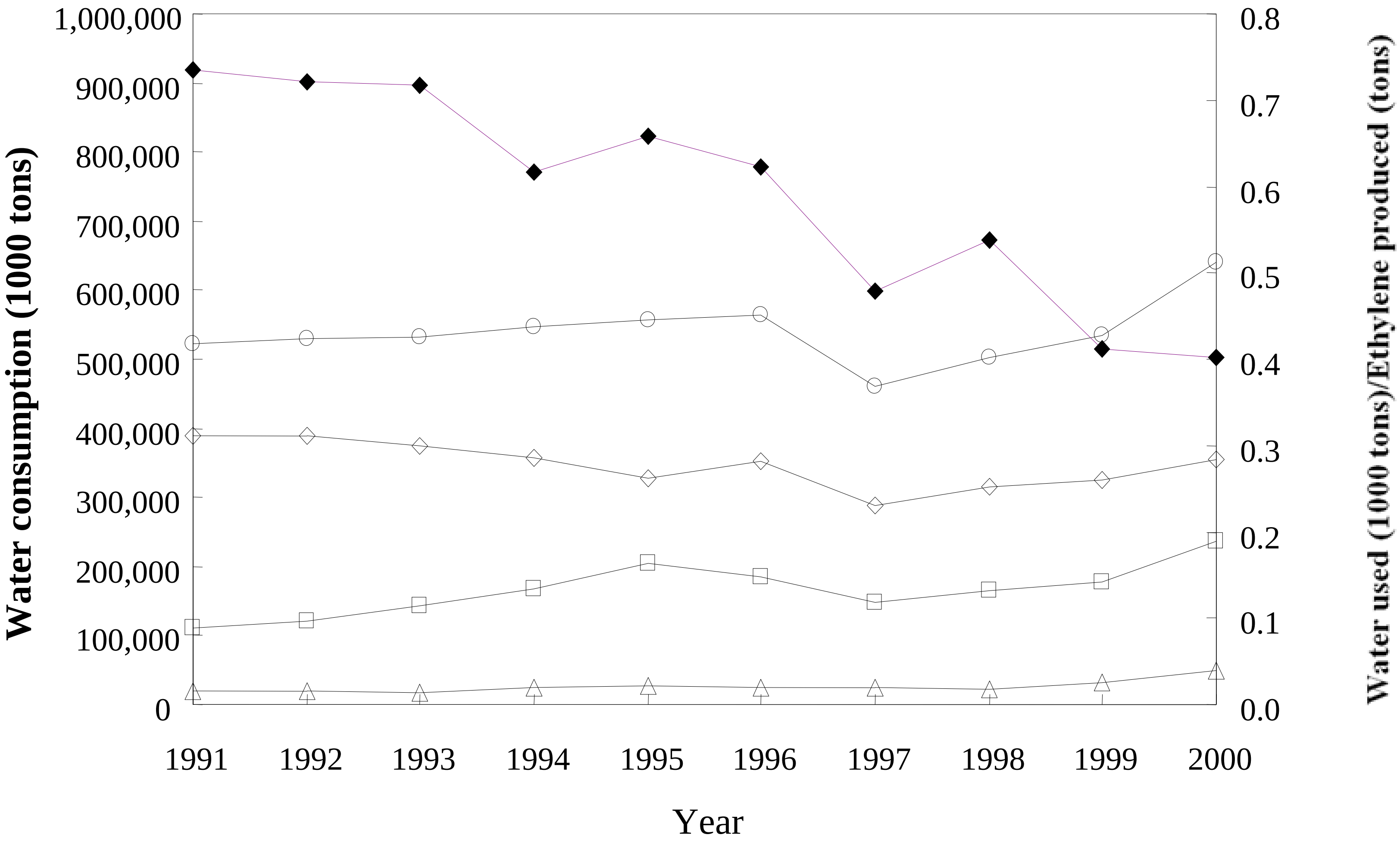

Figure 5. Water consumption of up-stream (△), mid-stream (□), down-stream (◇) processors, and the sum (○) of petrochemical industry. ◆: specific water consumption (i.e., total water consumption in petrochemical industry/total ethylene production quantity). Data source: MOEA, 2001b.

Emissions of water pollutants from different streams

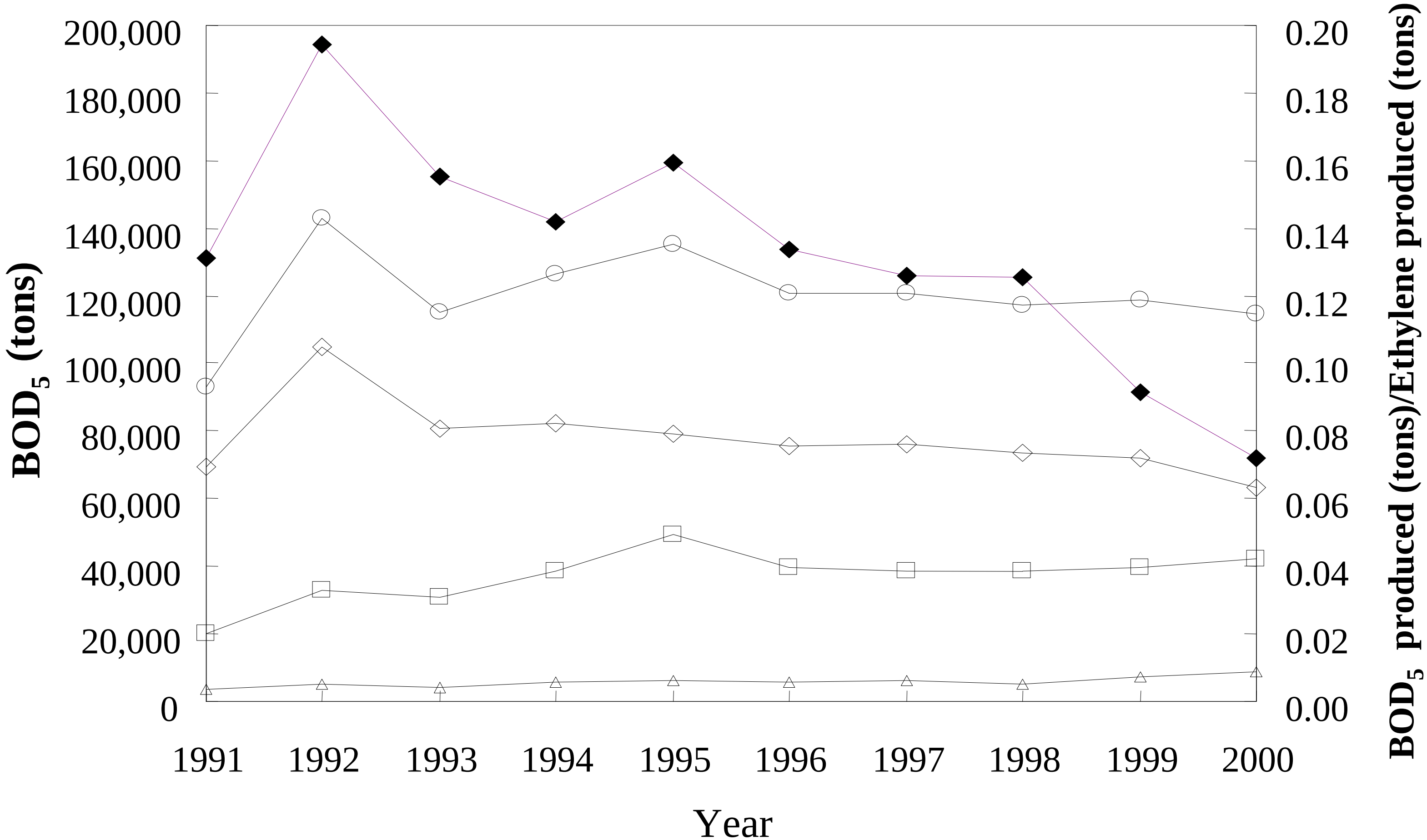

Figure 6. Emissions of water pollutants of up-stream (△), mid-stream (□), down-stream (◇) processors, and the sum (○) of petrochemical industry. ◆: specific water pollutant emission (i.e., total emission of water pollutant in petrochemical industry/total ethylene production quantity). Data source: TEPA, 2002.

V. International Comparison of Material Utilization Efficiency Indicators

Energy, specific energy consumption, and the intensity of energy use.

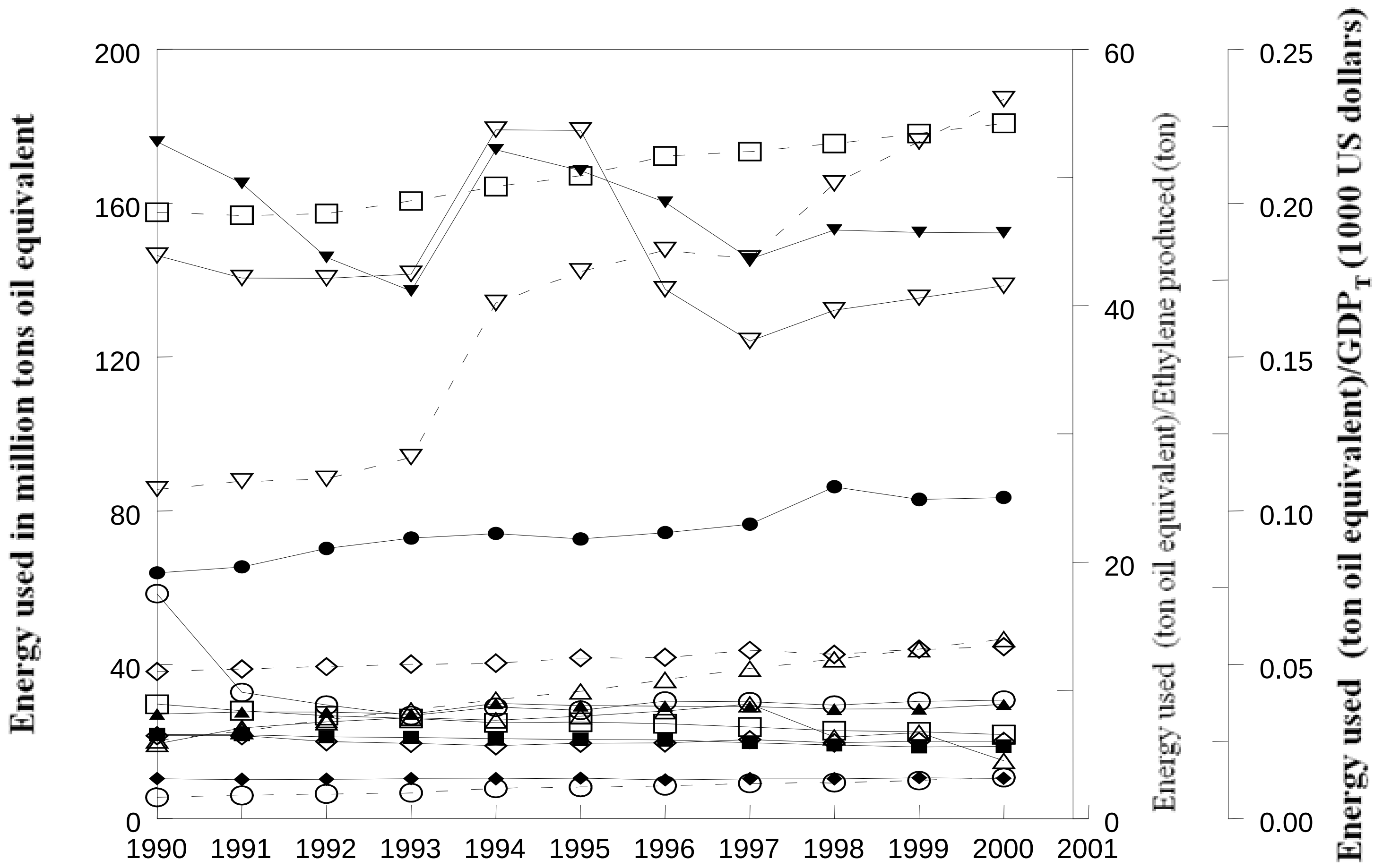

Figure 8. Energy use (broken line with hollow symbol), specific energy consumption (solid line with hollow symbol), and the intensity of energy use (solid line with black symbol) in USA (□), Japan (◇), Korea (△), China (▽) and Taiwan (○). Data sources: IEA, 2002.

Comparison of co_2 emission , specific co_2 emission and co_2 emission intensity

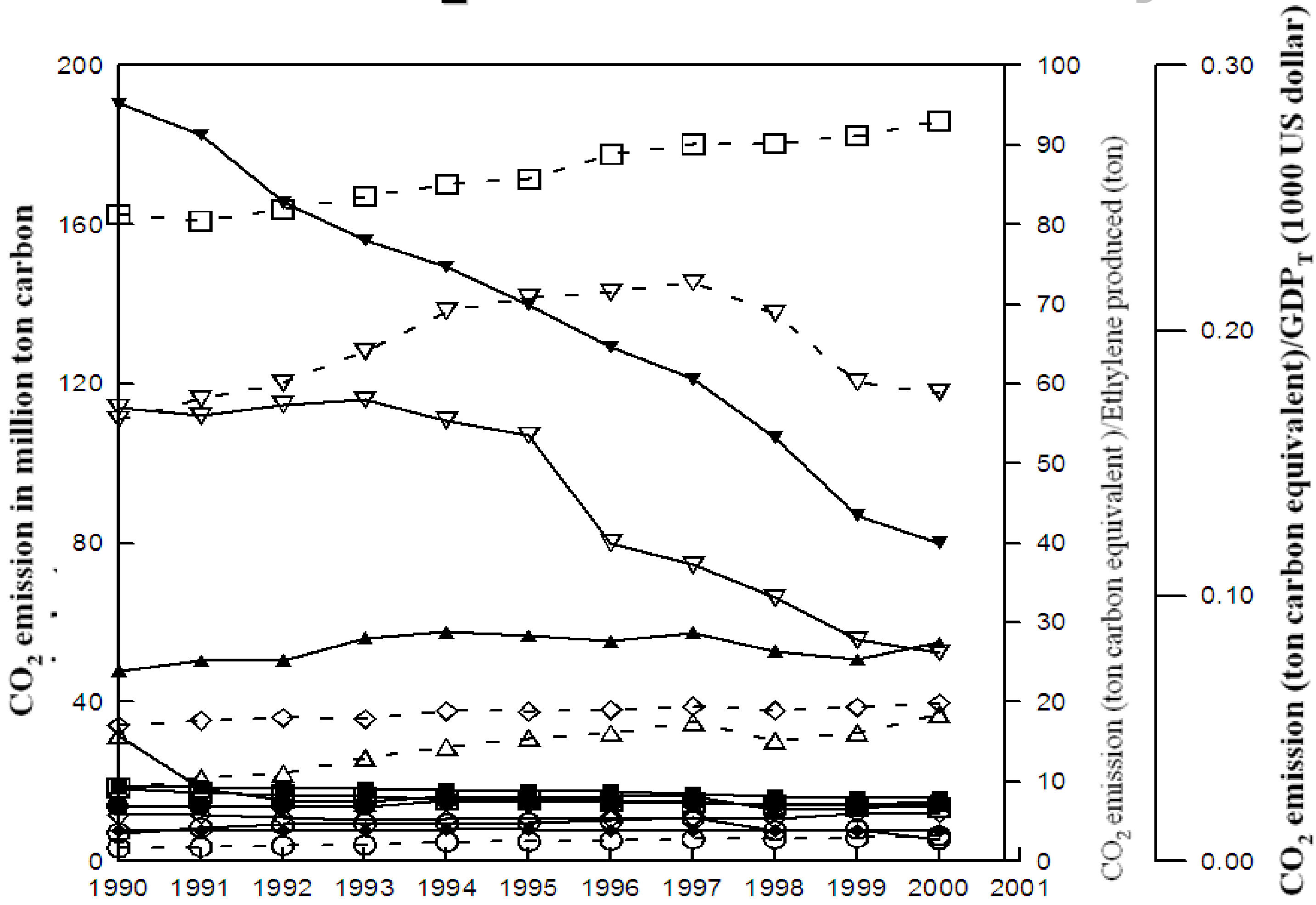

Figure 9. Emission of CO_2 (broken line with hollow symbol), specific CO_2 emission (solid line with hollow symbol), and the intensity of CO_2 emission (solid line with black symbol) in USA (□), Japan (◇), Korea (△), China (▽) and Taiwan (○). Data sources: IEA, 2002.

Comparison of the GDP_T and ethylene production capacity intensity

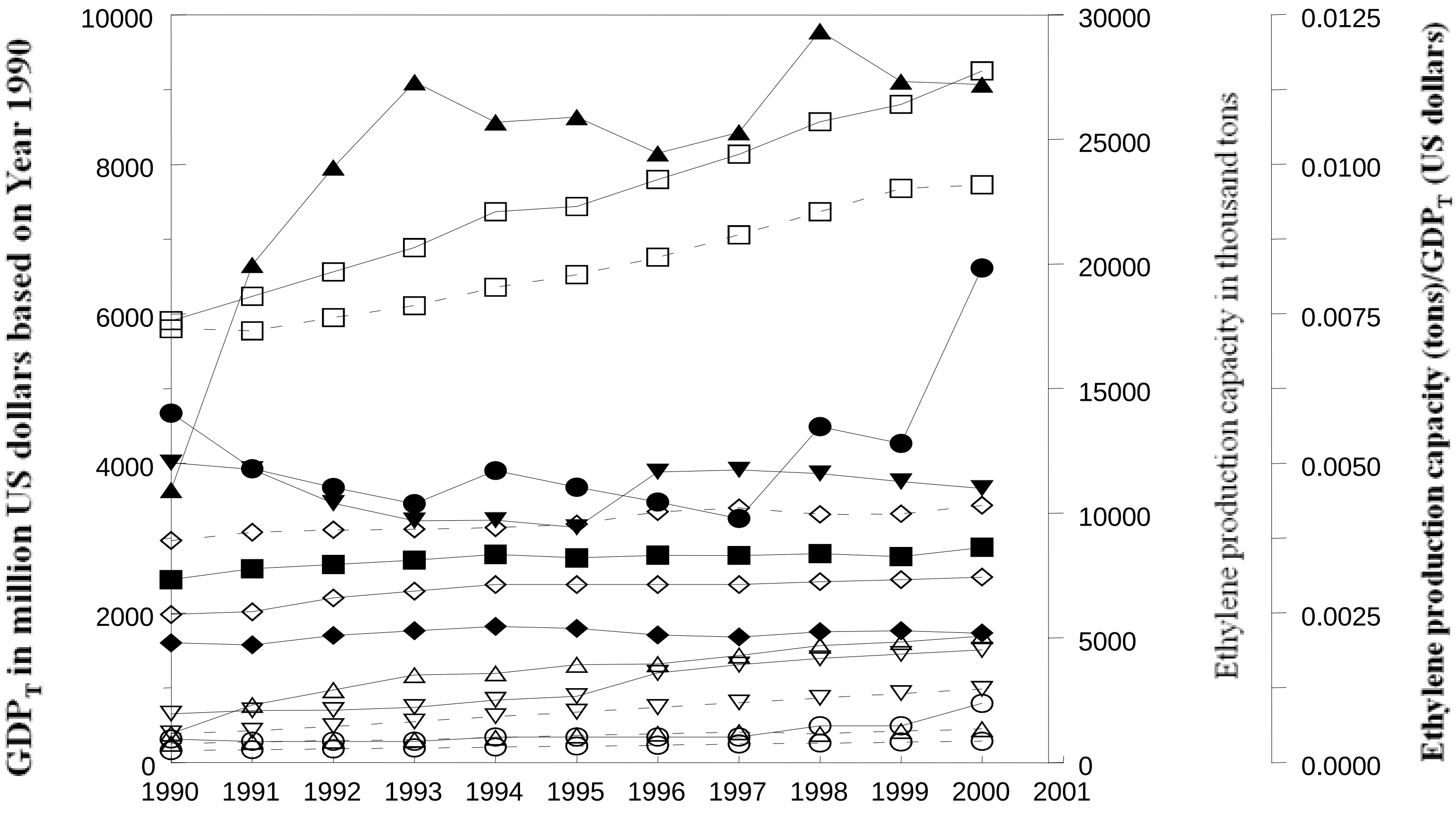

Figure 7. GDP_T (broken line with hollow symbol), ethylene production capacity (solid line with hollow symbol), and the intensity of ethylene production capacity (solid line with black symbol) in USA (□), Japan (◇), Korea (△), China (▽) and Taiwan (○). Data sources: BEA, 2002; BFT, 2002; EIA, 2002; IEA, 2002; MEA, 2001c; NBSC, 2002; The Bank of Korea, 2002; WRI, 2002.

VI. Conclusions

- The energy consumption, air pollutants emission, and water resource consumption of petrochemical industry were approximately one-third to those of all sectors of industries in Taiwan, indicating that the consumption of energy and resources of the petrochemical industry was high.
- A comparison of the specific energy consumption of petrochemical industry of Taiwan to those of other countries, Taiwan is close to Japan and the USA and better than Korea and China.
- The order of intensity of energy use is China＞ Korea＞ Taiwan ＞ USA＞ Japan, indicating that Taiwan is better than Korea and China.

VI. Conclusions

- As for the specific CO_2 emission, Taiwan is the lowest (i.e., the best) among the five nations.
- Regarding the intensity of CO_2 emission, the orders in sequence is China＞ Korea＞ USA＞ Taiwan＞ Japan, revealing that Taiwan is better than USA, Korea and China.

VI. Conclusions

- The intensity of ethylene production capacity follows the order Korea＞ Taiwan＞ China＞ USA＞ Japan, showing that Taiwan is better than China, USA and Japan.
- Overall viewing the above five key material utilization efficiency indicators indicates that Taiwan ranks top 1 to 3 among the five nations regarding the excellency of performance in petrochemical industry.

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