RIETI Discussion Paper Series 10-J-026

Evaluation and Verification of Limestone and Dolomite origin CO_2 emissions using I/O table and Industrial Statistics data in Japan

April, 2010

Kainou Kazunari (C)[*0]

Abstract

Among present Japanese Greenhouse Gas Emission quantification methodologies, the methodology for Limestone and Dolomite origin carbon dioxide quantification is pointed out that there may be some duplication, oversight and estimation error due to the present methodology mixes up industrial and technological classifications.

The author tried to verify and evaluate the present methodology developing new methodology applying estimation methodology used in Japanese General Energy Statistics with I/O table and industrial statistics' data, comparing the emission amount with present one by time series from 1990.

The author quantified the total Limestone, Dolomite and their derivatives' end-use side demand with non-equivalent price input table by industrial sector classification at first, and examined whether carbon dioxide emission happens or not sector by sector alongside the industrial classification.

As a result, the author found that present methodology resulted in similar level in 1990 base year with the new methodology, but after 1995 they show large and unstable discrepancies. At the end, the present methodology proved to be over estimate to the new methodology around one million metric tons of carbon dioxide in average from 2005 to 2007.

The author analyzed causes for such a large and unstable over estimation and found that present methodology double counted Limestone and Quick lime consumption produced by end-use side in iron and steel industry and over sighted several Limestone and Dolomite uses such as paint and earthenware materials, or flue gas sulfur oxide recovery materials. And the author found that such errors offset each other and resulted in one million tons of over estimation.

Hence the author recommends re-calculation to replace the present methodology after revising necessary statistics by cooperation with related organizations.

Key words: I/O table, Greenhouse Gas Emissions, Limestone and Dolomite
JEL Classification: C82, Q51, L72

*0 The analysis and simulation in this paper solely represent the author's view and opinions; they DO NOT represent RIETI IAA, Osaka University, KEIO University and/or other institute's view or opinions.

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1. Present situations and Issues

1-1. Present methodology for Limestone and Dolomite origin CO2 emission estimation

1-1-1. Limestone and Dolomite origin CO2 emission

Limestone, Dolomite[*1] or other carbonate minerals emit CO2 when their carbonate acid; CO3 parts are dissolved by strong heat or chemical reactions. For example, when we make intermediate product ″Clinker″ for Portland cement from incinerated Limestone, CO2 – a typical greenhouse gas – is emitted.

- $CaCO_3$ (Limestone) → (Heat) → CaO (Quick Lime) + $\boxed{CO_2}$ ↑
- $CaMg(CO_3)_2$ (Dolomite) → (Heat) → CaO + MgO (Incinerated Dolomite) + $\boxed{2CO_2}$ ↑
- $CaCO_3$ (Limestone) + H_2SO_4 (Sulfic Acid) → $CaSO_4$ (Gypsum) + H_2O + $\boxed{CO_2}$ ↑

But Limestone and Dolomite use does not always accompany CO2 emission; a part of Limestone and Dolomite are used directly for Building stone materials or pulverized materials for non-organic white color paints. In such cases, no CO2 emission happens.

In some cases, Limestone is once dissolved its carbonate acid part and CO2 is emitted, but they are re-combined and equal amount of CO2 is captured in the final products; for example, Calcium carbonate powders for toothpaste or other detergent chemicals are made by such re-combination process. Similarly, Soda ash[*2] for industrial detergent chemicals or food additives are made by dissolution of Limestone and emission of CO2 once happen but equal amount of CO2 is captured in Soda ash by re-combination of Sodium oxide and CO2 in the process.

- $CaCO_3$ (Limestone) →(Heat)→ CaO (Quick Lime) + $\boxed{CO_2}$ ↑

  CaO (Quick Lime) + H_2O → $Ca(OH)_2$ (Slaked Lime)

  $Ca(OH)_2$ (Slaked Lime) + $\boxed{CO_2}$ → $CaCO_3$ (Calcium carbonate powder)

Hence, when we try to quantify Limestone and Dolomite origin CO2 emission accurately, we need to identify detailed use of Limestone, Dolomite and their derived chemical substances such as Soda ash, and we need to identify CO2 emitted in the atmosphere from the CO2 remained in the Limestone and Dolomite or CO2 captured in the final products as far as possible.

1-1-2. Reporting mandates under UNFCCC and Kyoto Protocol

Limestone and Dolomite origin CO2 emissions are andropogenic greenhouse gas emissions under the UNFCCC and the Kyoto Protocol, so countries are required to report their annual emission quantity as a part of national greenhouse gas inventory in accordance with the IPCC 1996 guideline. More precisely, UNFCCC and Kyoto Protocol's reporting format has five Limestone and Dolomite related categories at present; 2A1. ～ 2A4., 2B4.

2. Industrial Process

2A. Mineral Products

- 2A1. Cement (CO_2 emission)
- 2A2. Quick Lime (CO_2 emission)
- 2A3. Other Limestone and Dolomite use (CO_2 emission)
- 2A4. Soda ash production and use (CO2 emission)

2B. Chemical Industry

- 2B4. Calcium Carbide production (CO2 emission)

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*1 Dolomite is a mineral that Ca in the Limestone is partly replaced by Mg by infiltration of sea water and high pressure.

*2 ″Soda ash″ is the name for Na2CO3. Soda ash is used for glass materials, industrial detergent chemicals and food additives,

1-1-3. Abstract of present Limestone and Dolomite origin CO2 emission quantification methodology in Japanese GHGs inventory

Japanese GHGs inventory as of 2009 quantify Limestone and Dolomite origin CO2 emission based on various official statistics as follows*3; those are conforming with the UNFCCC and Kyoto Protocol's reporting format and IPCC 1996 methodology.

(1) 2A1. Cement production

2A1. Cement production quantification uses the Clinker production quantity as activity level because CO2 is emitted in the production process of the Cement's intermediate product Clinker. The emission factor is quantified by two stages; at first, they estimate CaO share in the Clinker for Limestone origin CaO and other waste origin CaO, and then they estimate emission factor multiplied by share of the Limestone origin CaO and CO2 emission factor of Limestone dissolution per CaO production.

The statistical basis for Clinker production is the Limestone consumption and Clinker production quantity in the METI industrial statistics for Cement and Ceramic Products. And the share of Limestone origin CaO in the total CaO in the Clinker is quantified and reported by the Japan Cement Association.

(2) 2A2. Quick Lime production

2A2. Quick Lime production uses Quick Lime (CaO) production quantity and Incinerated Dolomite (CaO･MgO) production quantity as activity level. They use CO2 emission factor of Limestone and Dolomite dissolution per CaO and MgO production.

The statistical basis for the Quick Lime production level are the METI industrial statistics for Chemical Products. And the basis for the Incinerated Dolomite production are reported quantity by Japan Quick Lime Association.

(3) 2A3. Other Limestone and Dolomite use

2A3. Other Limestone and Dolomite use uses Limestone consumption quantity for the Iron and Steel industry and Glass industry as the activity level. And they uses CO2 emission factor of Limestone dissolution per their weights.

The statistical basis for the Limestone consumption quantity of the Iron and Steel industry and Glass industry are the METI industrial statistics for Mineral Materials; they use sales amount of Limestone with Steel and Smelting Grade and Soda and Glass Grade.

(4) 2A4. Soda ash production and use (– a; production, –b; use)

In accordance with the 2A4a. Soda ash production, Japanese GHGs inventory repots that both Solvay Process and Rubran Process used in Japan for the Soda ash production*4 re-combine Limestone origin CO2 and Sodium oxide, and CO2 are captured in the Soda ash; hence no CO2 emission happens.

$2NaCl + \underline{CaCO_3} \rightarrow (NH_3) \rightarrow CaCl_2 + Na_2\underline{CO_3}$ (Solvay Process)

$2NaCl + H_2SO_4 + \underline{CaCO_3} + 2C(Coke) \rightarrow Na_2\underline{CO_3} + 2HCl + CaS + 2CO_2$(Coke Origin) (Rubran Process)

In accordance with the 2A4b. Soda ash use, they use total Soda ash consumption quantity as the activity level, and they uses CO2 emission factor of Soda ash dissolution per their weights.

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*3 More precise explanations are available in the Japanese GHGs inventory reports.

*4 Besides Solvay and Rubran process, Trona process is known as the Soda ash production process and the Trona process accompanies CO2 emission from Trona ore dissolution. But in Japan no company uses the Trona process because there are no Trona ore resources.

The statistical basis for the Soda ash consumption quantity is domestic sales reported by Japan Soda Industry Association and imported quantity of Soda ash based on Japan Trade Statistics by MOF.

(5) 2B4. Calcium Carbide production (A part of 2B4.)

2B4a. Calcium Carbide production uses its production quantity as the activity level and CO2 emission factor of Limestone dissolution per weight.

The statistical basis for the Calcium Carbide production is based on the reported quantity by Japan Carbide Industry Association, but the data are classified as secret.

1-1-4. Limestone and Dolomite origin CO_2 emission with the present methodology

Japanese GHGs inventory 2007 reports that Limestone and Dolomite origin CO_2 emission as 50.2 Mt CO2 that corresponds 3.7 per cent to the total Japanese GHGs emission.

The emission decreases around 7.2 Mt CO2 to the 1990 level in 2007, mainly due to the decrease of cement production caused by decreases of public infrastructure investment.

[Table-2-1-1. 1990・2007 CY Limestone and Dolomite origin CO_2 emission and their share]

	1990		2007		2007-1990
Total Emission	1,261.338 $MtCO_2$*	(100 %)	1,374.254 $MtCO_2$	(100 %)	+112.918
2. Industrial Process	62.318 $MtCO_2$	4.94 %	53.730 $MtCO_2$	3.91 %	-8.588
2A. Mineral Materials	57.448	4.55	50.219	3.65	-7.229
2A1. Cement Production	37.966	3.01	30.076	2.19	-7.920
2A2. Quick Lime Production	7.371	0.58	7.799	0.57	+0.428
2A3. Other Limestone Use etc.	11.527	0.91	12.004	0.87	+0.477
2A4. Soda ash production etc.	0.584	0.05	0.340	0.02	-0.244
2B4. Calcium Carbide production			(Classified as secret)		

Note; For comparison purpose, 1990 data is based on the base year emission quantity.

1-2. Major issues of Present methodology and Focus of this Discussion Paper

1-2-1. Issues of Present methodology

(1) Issues pointed out

Present Japanese Limestone and Dolomite origin CO2 emission quantification methodology shown in 1-1-3 are pointed out several accuracy issues by MOE greenhouse gas quantification methodology committee and industrial process working group under the committee as follows. A part of the issues are already under consideration for further improvement.

But among the issues, the possibility of the Limestone consumption level duplication and over sight are serious; that means Japanese Limestone origin CO2 emissions may change many thousand tons and large uncertainty remains.

So it is necessary to verify and re-calculate the Japanese Limestone and Dolomite origin CO2 emissions as soon as possible.

- Possibility of the Limestone consumption level duplication (2A3, 2A2, 2A4)

The statistical basis for the Other Limestone and Dolomite use (2A3) are the sales amount of Limestone with Steel and Smelting Grade and Soda and Glass Grade, but they may be double counted with the Limestone consumption quantity in the Quick Lime production (2A2) or Soda ash production (2A4a) or other parts.

- Possibility of the over sight of Limestone consumption (2A3etc.)

Some Limestone consumption such as flue gas sulfur recovery materials use may be ignored by present methodology.

- Possibility of over estimation of Soda ash related emission (2A4)

A part of Soda ash use does not accompany CO2 emission though present methodology assumes that all Soda ash shall emit CO2.

(2) Root cause for the issues

The author estimates that the root cause for the issues pointed out here are the 1996 IPCC guideline for the Limestone and Dolomite origin CO2 emission that uses both end-use categorization and technological categorization part by part, which may lead some confusion when they apply the guideline methodology without deep understandings.

Especially in the Japanese GHGs inventory case, they paid too much attention for following 1996 IPCC guideline methodology as it is in detail, but ignored the principles that GHGs inventory shall identify the complete amount of the Limestone and Dolomite origin CO2 emission from both end-use categorization and technological categorization at the same time so as to avoid duplication or over sight.

1-2-2. Major Existing Research

(1) Bottom-up approach for Limestone and Dolomite origin CO2

The 1996 IPCC guideline for the Limestone and Dolomite origin CO2 emission are typical bottom-up type quantification methodology and present Japanese GHGs inventory follows the guideline. But the guideline itself is regarded as the cause of the issues as the author discussed previously, so the guideline does not contribute the issues.

(2) Top-down Limestone and Dolomite origin CO2 estimation by I/O table and industrial statistics

There are many existing research that take "Top-down" approach that estimate CO2 emissions using I/O table and industrial statistics, most of them estimates a part of Limestone origin CO2 emission such as cement production.

The typical example is "3E-ID"; data book for environment burden intensity using I/O table by Japanese National Institute of Environment, IAA that integrates I/O table data and industrial statistics data and estimates Limestone origin CO2 with 5 year interval.

The "3E-ID" includes not only Limestone origin CO2 but its derived substances such as Quick Lime and so on and estimates the total amount of the emission in detail. But it uses material balance table annexed with the I/O table under single price assumption, it has no intermediate year data, and it has some over sight such as Dolomite origin CO2 or Limestone use for flue gas sulfur recovery materials.

Kainou (2005) has estimated energy origin CO2 emission for General Energy Statistics of Japan Residential and Commercial Sector using I/O table and industrial statistics with non-unique price material I/O table, but he did not applied the methodology for the Limestone and Dolomite origin CO2 emission,

1-2-3. Focus of this discussion paper

This research tries to develop new methodology for the Limestone and Dolomite origin CO2 emission quantification using I/O table and industrial statistics with non-unique price material I/O table; it enables complete end-use categorization base Limestone and Dolomite consumption by industrial classification, so emission quantity shall be estimated by identifying whether the emission happens or not for each industrial classification using technological categorization.

And this research tries to compare the Limestone and Dolomite origin CO2 emission quantity with the Present methodology and the new methodology above from 1990 to recent year to verify and evaluate the Japanese Limestone and Dolomite origin CO2 emission at present.

Through such comparison, evaluation and verification, this research aims to improve Japanese Greenhouse Gas inventory accuracy and aims to develop new Limestone and Dolomite origin CO2 emission quantification methodology.

2. New methodology for Limestone and Dolomite origin CO2 emission estimation using I/O table and Industrial Statistics

2-1. Methodological issues for Limestone and Dolomite origin CO2 emission estimation

2-1-1. Basic concepts of new methodology

(1) Technological categorization for Limestone and Dolomite and their derived substances consumption by industrial sector whether CO2 emission happens or not

In order to estimate complete Limestone and Dolomite origin CO2 emission including their derived substances without duplication or over sight, it is necessary to identify Limestone, Dolomite and their derivatives consumption by industrial sector and categorize them into following four categories from the viewpoint whether CO2 emission happens (E) or not (N).

E. CO2 emission happens

E-1. Carbonate acid part is dissolved at the point of intermediate product
(ex: Limestone for Cement Clinker, Incinerated Dolomite for Steel making)

E-2. Carbonate acid part is not dissolved at the point of intermediate product, but shall be dissolved at its final product
(ex: Limestone for earthenware clay, Soda ash for Glass production)

N. CO2 emission does NOT happen

N-1. No dissolution process
(ex: Limestone for building stone use, Dolomite for concrete sand)

N-2. Carbonate acid part is dissolved at the point of intermediate product, but equal CO2 shall be re-combined during the following process or at its final product
(ex: Limestone for Calcium carbonate powder, Soda ash for industrial detergent or food additives)

[Table 2-1-1. Categorization concept of Limestone and its derived substance by technological categorization by industrial sector whether CO2 emission happens or not]

Source	Intermediate Products		Final Products	Categorization
Indigenous Limestone				
Imported Limestone				
	Building Material Use			
		Building stone	Building Materials	N-1
		Quarried gravel and sand	Building Materials	N-1
	Other Use	Flue Gas Sulfur Recovery	Limestone Slurry	E-2
		Earthenware Clay	Earthenware	E-2
		White Color Paint Material	Non-organic Paints	N-1
		Exported Limestone		(N-1)
	Chemical Material Use			
	Cement Use			
		Cement Clinker	Portland Cement	E-1
	Quick Lime and Fireproof Materials Use			
		Quick Lime: CaO	Gypsum, Firebricks	E-1
		Slaked Lime: Ca(OH)2	Building Materials	E-1
		Calcium Carbonate Powder		N-2
	Smelting Use			
		Limestone and Dolomite	Smelting Slug Materials	E-1
	Soda Ash and Glass Use			
		Glass Grade Soda Ash	Plate Glass	E-2
		Low Grade Soda Ash	Industrial Detergent	N-2
		Food Grade Soda Ash	Food Additives	N-2
Imported Soda Ash		Exported Soda Ash		(N-1)

Note: Same as Dolomite.

(2) Quantitative estimation of Limestone and Dolomite and their derived substances consumption by industrial sector using non-unique price material I/O table

In order to estimate Limestone and Dolomite and their derived substances consumption by industrial sector, we can apply non-unique price material I/O table method. The method uses available consumption information from industrial statistics and estimates consumption by I/O table for the rest industrial sector where no information available from industrial statistics.

Non-unique price material I/O table is a kind of extended I/O tables that is made from comparing material flow quantity by various Industrial Statistics and input table of I/O tables, estimating trading price of each industry with consideration of the difference of quality and difference of trading conditions that causes differentiated trading price.

Most of the material I/O tables made as an annex for the I/O table are unique price material I/O table that assume unique trading price, and so difference of the quality or price such as effect of volume discount causes estimation error for material consumption. But in case of the non-unique price material I/O table, such error are corrected as far as relevant industrial statistics are available.

(3) Technical estimation of emission or non-emission determination for Limestone and Dolomite and their derived substances

If non-unique price material I/O table for Limestone and Dolomite and their derived substances are successfully constructed, we can estimate the Limestone and Dolomite origin CO_2 emission determining whether each classified industrial use amount corresponds emission or non-emission category in 2-1-1 (1) .

Limestone and Dolomite origin CO_2 emission occur in case that their carbonate acid part dissolved such as high temperature more than 500 degree Cercius which most organic substances dissolves or chemically reacted with strong acid such as sulfonic acid; but such high temperature or heavy chemical process exist in the Chemical, Cement and Ceramics, Iron and Steel, Non-ferrous Metals, Metal wares and Power Generation and so on.[**5]

And Limestone and Dolomite and their derivative substances that once dissolved but absorbs CO_2 again at the final product process; "N-2" are mostly Limestone for Calcium carbonate powder, Soda ash for industrial detergent or food additives, so these production and/or consumption quantities are obtained from I/O table or Industrial Statistics.

Hence, we can estimate the Limestone and Dolomite origin CO_2 emissions with certain accuracy and without duplication when we sum up Limestone or Dolomite consumption for the 6 industrial classifications above that have high-temperature and/or heavy chemical process, identifying "E-1","E-2" and "N-2" classifications using information obtained from non-unique price material I/O table; because the rest can be deemed as "N-1".

2-1-2. Reverse estimation of Limestone quantity used for SOx scrubber from quantity of scrubbed sulfur

The Limestone use for SOx scrubber is typical "E-2" case that the emission occurs in the final consumption stage but not in the intermediate material stage.

But direct estimation from the I/O table and/or Industrial Statistics are very difficult due

5 Besides these industry, waste treatment or other industries may have similar process such as waste acid treatment or metal recycle smelting, but because there are no statistics for these industry, this paper do not estimate emissions from such industries.

to the following reasons;

- It is very hard to identify whether the Limestone is used for SOx scrubber or other purposes in the industry from the information of I/O table or Industrial Statistics.
- It is impossible to estimate Limestone amount used for SOx scrubber when the industry does not produce Limestone powder or slurry by itself but purchases from other one as "Chemical materials" because there are no such statistics.
- Limestone powder or slurry purchase quantity are often cancelled with the production of other by-products such as fry ash.

Hence we can apply reverse estimation for the Limestone consumption for SOx scrubber from the quantity of to be scrubbed sulfur; because in recent days most part of the power generation plants and large scale industrial boilers use similar "Wet scrubbing" technology that converts SOx into Gypsum using Limestone powder colloidal solution in the water. So we can assume that all recovered sulfur quantity from the power generation plants and large scale industrial boilers had been applied the same "Wet scrubbing" technology and then we can estimate the Limestone consumption for SOx scrubber from the total sulfur amount included in the coal or C grade heating oil consumed in these plants.

Practically, we can easily estimate coal and C grade heating oil consumption from the General Energy Statistics for each industrial classification that equips power generator or large scale industrial boiler[*6]. And when we assume sulfur content ratio as 0.5 wt% for coal and 1.5 wt% for C grade heating oil and recovery efficiency coefficient as 99.0 %[*7] in accordance with General Energy Statistics and/or recent technology trends, we can estimate the total sulfur quantity to be scrubbed and the Limestone consumption for SOx scrubber.

2-2. How to make non-unique price material I/O table using original I/O table and Industrial Statistics and how to identify emission or non-emission use

2-2-1. Data availability for the Limestone, Dolomite and related derivative substances in I/O and Industrial Statistics

(1) Industrial Statistics -1 Mineral Resource Production Statistics[*8]

Mineral Resources Production Statistics by government of Japan provides Limestone and Dolomite indigenous mineral production quantity and sales quantity for major uses.

But the survey items of sales quantity in the statistics had been gradually abolished by budget rationalization policy of the government of Japan around the year 1990 and 2000, so only a few items are consistent from 1990 up to recent years.

And because the sales statistics are based on the statistical survey for the supply side mining industry, it is not sure that the sales statistics classification correctly reflects the final consumption figures.

Hence, due to the reasons above, this paper gives priority for the end-use side statistics if

*6 In case of coal or C grade heavy oil used in industrial furnace such as blast furnace of iron and steel industry, Limestone may be used from other purpose besides SOx scrubbing, sulfur may be recovered by some other process technology or sulfur may consist as feed stock for the products; so we should exclude coal or C grade heating oil use in industrial furnaces.

*7 Most of the "Wet scrubbing" technology based SOx scrubber has recovery efficiency around 95.0 % to 99.0 %. Here in order to avoid underestimation of the Limestone consumption, let us allow to use the higher number.

*8 Besides the statistics, some industrial association issue Limestone related production statistics. But due to the reliability issues, I do not use them.

possible, and use supply side statistics only if end-use side statistics are not available.

Practically, Limestone and Dolomite use for public works such as road construction or reinforced concrete material are based on this supply side statistics[*9].

Available statistical items;

- Limestone

  Production and Major Sales; Cement, Iron, steel and other smelting, Soda and Glass, Road construction, Reinforced concrete materials

- Dolomite

  Production and Major Sales; Iron, steel and other smelting, Soda and Glass, Road construction, Reinforced concrete materials

(2) Japan Trade Statistics

Japan Trade Statistics provides import and export quantity and payment for Limestone, Dolomite and related derivatives[*10] at monthly basis; (number shows HS classification code)

- Limestone and related derivatives
  - 2521.00 Limestone
  - 2522.10 CaO 2522.20 Ca(OH)2 2522.30 Lime hydration 2523.10 Cement clinker
  - 2849.10 Calcium Carbide 3102.9010 Calcium Cyanamid
  - 2836.20 Na2CO3 (Soda Ash)
  - 2836.30 NaHCO3 2836.50 CaCO3
- Dolomite and related derivatives
  - 2518.10 Dolomite
  - 2518.20 Calcinated Dolomite 2519.10 Magnesite

(3) Input / Output Table (I/O table)

(Limestone, Dolomite and related derivatives)

Japanese I/O table includes in its basic trading table following 4 data about Limestone, Dolomite and related derivatives by total expenditure basis for 1990, 1995, 2000 and 2005 calender year. (The number corresponds to the I/O classification number.)

0621-011 Limestone
0621-019 Other Ceramic raw material Minerals (Dolomite, Silica stone, Clay etc.)
2021-011 Soda Ash
2599-099 Other Stone, Mineral and Ceramic Products (CaO, Ca(OH)2 etc.)

Thus, I/O table provides detailed Limestone and Soda Ash domestic consumption data, but it is not available for Dolomite. So we need to estimate Dolomite data from aggregated data with other products in I/O table which means lower accuracy.

And in case of the road construction or concrete material use of Limestone and/or Dolomite, an accurate industrial classification for such use are not sure, so expenditure data for such use are not classified for Construction industry but classified as "Other use / No industrial classification applicable".

(Limestone for SOx including gas after treatment use)

Limestone for SOx including gas after treatment use are not classified for Electric Power Generation (#5111-02), but sub-zero values for "Other raw material for Ceramic Products"

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*9 Some sales statistics items are abolished and are not available at present, so I estimated that by trend regression analysis and extrapolation.

*10 The Japan Trade Statistics includes other carbonate acid substances such as SrCO3 that may dissolve and emit CO2 by strong heating or chemical reaction, but their quantity are small and detailed informations are not available, so this paper does not quantify that.

Similarly, the statistics has NaHCO3 trade statistics, but the are quantified in #5111-02 instead, for example.

The value is estimated as a net value for pulverized Limestone purchase and Fly-Ash and/or Gypsum by-product sales (sub-zero), so we can deem that I/O table classifies Limestone for SOx including gas after treatment use in "Other raw material for Ceramic Products (0621-019)".

(4) Industrial Statistics -2 Chemical Industry Statistics, Iron and Steel Statistics, Cement and Ceramic Products Statistics

In Industrial Statistics such as Chemical Industry Statistics, Iron and Steel Statistics, Cement and Ceramic Products Statistics, there are some raw material production and consumption statistics for Limestone and/or Dolomite related derivatives.

But, similar to other statistics, most of the survey items in the statistics had been abolished by budget rationalization policy of the government of Japan in the year 2000, so quantities of Limestone and/or Dolomite related derivatives used for Iron and Steel or Cement and Ceramic Products are unknown after that.

Moreover, the number of Soda Ash manufacturers get less than two company, so the statistics data are not available due to the commercial confidentiality rules of the statistics.

So in this paper, the author estimates consumption quantities by regression analysis of Limestone and/or Dolomite related derivatives using crude iron or glass production quantities as explanation variables in order to make up those missing statistics values[**11]

- Chemical statistics
  - (1990-) CaO Ca(OH)2 CaCO3 (Production, Trade and Stockpile, same as follows)
  - (1990-1997) Calcium carbide, Calcium nitride
  - (1990-2000) Soda ash (-2001 Soda ash for material use)
- Cement and Ceramics statistics
  - (1990-) Limestone use for cement feed stock, Clinker production[**12]
  - (1990-1999) Limestone and Dolomite use for float glass and glass fiber feed stock
- Iron and Steel statistics
  - (1990-) (None)
  - (1990-2003) Limestone, Quicklime, Dolomite and Calcined Dolomite use for feed stock

2-2-2. Making non-equivalent price material input table for Limestone and estimation for emission and/or non-emission use

Limestone and related derivatives except Soda Ash material consumption and emission quantities by industrial classifications are estimated by non-equivalent price material input table for the year 1990, 1995, 2000 and 2005.

For the purpose of easy-understandings, all Limestone related derivative are converted into the quantity of Limestone equivalent.

(1) Supply quantity

Sum of indigenous production quantity by Mineral resource production statistics and import quantity by Japan trade statistics are estimated as total supply quantity of

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11 The result of the regression analysis are shown in Appendix A.
But in practices, it is necessary to ask related industry to provide their internal statistical analysis for the purpose of quantifying the greenhouse gas emissions. And if such internal statistics are not available, we need to consider to resume necessary statistics.

12 As for Cement clinker production, the statistical survey covered only Portland cement clinker before the year 2006, but it is expanded for total clinker production after that for the purpose of improving greenhouse gas inventory quantification.

Limestone.

(2) Specified consumption

Following consumption by industrial classification are defined as "specified consumption" that both consumption quantities by industrial statistics and consumption expenses by I/O table are known.

- Flue Gas Sulfur Recovery (Estimated by General energy statistics)
- Soda Ash production (Chemical statistics and regression analysis extrapolation)
- Quick lime production (Chemical statistics)
  - Calcium carbonate powder (Chemical statistics)
  - Other use (= Quick lime production - Calcium carbonate powder)
- Glass material use (Cement and Ceramics statistics and regression analysis extrapolation)
- Cement material use (Cement and Ceramics statistics)
- Iron and Steel use (Iron and Steel statistics and regression analysis extrapolation)
- Gravel use for road construction or concrete material (Mineral resource production statistics)
- Export (Japan Trade Statistics)

(3) General consumption

Consumption except the "specified consumption" above, which consumption expenses by I/O tables are known, are estimated from the "general price" estimated by subtracting "specified consumption" from total supply quantity and expenditure; consumption quantities for each industrial classification are estimated by dividing the amount of expenditure by the "general price".

(4) Emission / Non-emission estimation

Emission / Non-emission distinctions for "0621-011 Limestone" of I/O table are estimated as follows by industrial classification and their major industrial process.

(Limestone / Emission Use)

0621-01 Mining - Cement and Ceramics material	E-2 Flue Gas Sulfur Reduction
2011-02 Chemical - Chemical fertilizer	E-1 Chemical material
2022-09 Chemical - Other non-organic material	E-1 Chemical material
2039-09 Chemical - Other organic	E-1 Chemical material
2511-01 Cement and ceramics - Float Glass	E-1 Glass material
-09 - Other Glass	
2521-01 Cement and ceramics - Cement	E-1 Cement material
2531-01 Cement and ceramics - Ceramics	E-2 Ceramics material
2599-01 Cement and ceramics - Refractory	E-1 Refractory material
-09 Quick Lime and Slaked Lime (except Calcium carbide powder)	E-1 Chemical material
2611-01 Iron and Steel - Pig iron	E-1 Smelting slag material
-04 - Crude steel / Galvanic Furnace	E-1 Smelting slag material
2631-02,03 Iron and Steel - Die cast Products	E-1 Smelting slag material
2711-01 Non ferrous metals - Copper	E-1 Smelting slag material
-02,03 Non-ferrous metals - Lead, Zinc	E-1 Smelting slag material

(Limestone / Non-Emission Use)

1811-01 Pulp and Paper - Pulp	N-1 Paper coat and filler material
-09 - Other paper products	
2021-01 Chemical - Soda products	E-2 Chemical material / N-2 Food Additives
2022-01 Chemical - Non organic pigment materials	N-1 Paint and pigment materials
2072-01 Chemical - Paint materials	N-1 Paint and pigment materials
2072-02 Chemical - Ink materials	N-1 Paint and pigment materials
2311-01 Rubber products - Rubber tire	N-1 Rubber filler materials
2311-09 Rubber products - Other rubber products	N-1 Rubber filler materials
2072-01 Chemical - Non organic paint materials	N-1 Paint materials
2521-01 Cement and Ceramics - Ready-mixed concrete	N-1 Sand and gravel
2523-01 Cement and Ceramics - Cement products	N-1 Sand and gravel

2599-01 Cement and Ceramics - Polisher materials	N-1 Polisher materials
2599-09 Cement and Ceramics - Other materials - Calcium carbonate powder	N-2 Calcium carbonate powder material
4131-02 Public construction works	N-1 Sand and gravel
8111-01 Central Government	N-1 Sand and gravel
9000-01 Classification unknown	N-1 Sand and gravel

2-2-3. Making non-equivalent price material input table for Soda Ash and estimation for emission and/or non-emission use

Consumption and emission quantities of Soda Ash - a typical Limestone derivative products - by industrial classification is estimated by non-equivalent price material input table for the year 1990, 1995, 2000 and 2005.

For the purpose of easy-understandings, all Soda Ash quantities are converted into the quantity of Limestone equivalent.

(1) Supply quantity

Sum of Soda Ash production quantity by Chemical statistics and Soda Ash import by Japan Trade Statistics are estimated as total supply of Soda Ash.

(2) Specified consumption

Following consumption by industrial classification are defined as "specified consumption" that both consumption quantities by industrial statistics and consumption expenses by I/O table are known.

- Soda Ash material consumption (Chemical statistics and regression analysis extrapolation)
- Glass material consumption (Cement and Ceramic statistics and regression analysis extrapolation)
- Export (Japan Trade Statistics)

(3) General consumption

Same as 2-2-2. (3) above.

(4) Emission / Non-emission estimation

Emission / Non-emission distinctions for "2011-011 Soda Ash" of I/O table are estimated as follows by industrial classification and their major industrial process.

(Soda Ash / Emission Use)

2011-02 Chemical - Chemical fertilizer	E-1 Chemical material
2021-01 Chemical - Soda products	E-1 Chemical material
2022-09 Chemical - Other non-organic products	E-1 Chemical material
2061-01 Chemical - Medical supplies	E-1 Chemical material
2074-01 Chemical - Agrichemicals	E-1 Chemical material
2079-09 Chemical - Other chemical products	E-1 Chemical material
2511-01 Cement and Ceramics - Float Glass	E-1 Glass material
2519-09 Cement and Ceramics - Other Glass products	E-1 Glass material
2531-01 Cement and Ceramics - Ceramics	E-1 Ceramics material
2599-09 Cement and Ceramics - Other products	E-1 Chemical material
2611-01 Iron and Steel - Pig iron	E-1 Smelting slag material
-04 - Crude steel / Galvanic Furnace	E-1 Smelting slag material
2711-02 Non-ferrous metal - Zinc	E-1 Smelting slag material
3421-03 Electronic devices - Light bulb	E-1 Chemical material
8222-01 Research and development	E-1 Chemical material

(Soda Ash / Non-Emission Use)

1113-09 Food - Other fishery products	N-1 Food additives
1117-06 Food - Seasoning	N-1 Food additives
1514-01 Fiber and textiles - Dye and arrangements	N-1 Industrial detergent
1811-01 Pulp and paper - Pulp	N-1 Industrial detergent

1812-02 Pulp and paper - Board paper	N-1 Industrial detergent
2032-02 Chemical - Cyclic compound	N-1 Industrial detergent
2039-09 Chemical - Other organic chemical product	N-1 Industrial detergent
2041-01 Chemical - Thermosetting resin	N-1 Industrial detergent
2051-01 Chemical - Rayon and acetate	N-1 Industrial detergent
2071-01 Chemical - Soap and detergents	N-1 Industrial detergent
2073-01 Chemical - Photograph printing paper	N-1 Industrial detergent
2079-01 Chemical - Adhesive material	N-1 Industrial detergent
2111-01 Petroleum products - Petroleum products	N-1 Industrial detergent
2411-01 Leather products - Leather products	N-1 Industrial detergent
2623-01 Iron and Steel - Cold rolling steel plate	N-1 Industrial detergent
2623-02 Iron and Steel - Galvanized steel plate	N-1 Industrial detergent
3611-01 Machinery - Ship maintenance	N-1 Industrial detergent
3629-01 Machinery - Automobile manufacturing	N-1 Industrial detergent
3921-09 Other manufacturing	N-1 Industrial detergent
5211-01 Water purification	N-1 Industrial detergent
8629-01 Household service - Cleaning	N-1 Industrial detergent
8111-01 Central Government	N-1 Industrial detergent
9000-01 Classification unknown	N-1 Industrial detergent

2-2-4. Making non-equivalent price material input table for Dolomite and estimation for emission and/or non-emission use

Consumption and emission quantities of Dolomite by industrial classification is estimated by non-equivalent price material input table for the year 1990, 1995, 2000 and 2005.

For the purpose of easy-understandings, all Dolomite derivative products quantities are converted into the quantity of pure Dolomite equivalent.

(1) Supply quantity

Sum of indigenous Dolomite production quantity by Mineral resource production statistics and Dolomite import by Japan Trade Statistics are estimated as total supply of Dolomite.

(2) Specified consumption

Following consumption by industrial classification are defined as "specified consumption" that both consumption quantities by industrial statistics and consumption expenses by I/O table are known.

- Glass material consumption (Cement and Ceramic statistics and regression analysis extrapolation)
- Iron and Steel material consumption (Iron and steel statistics and regression analysis extrapolation)
- Export (Japan Trade Statistics)

(3) General consumption

Same as 2-2-2. (3) above.

(4) Emission / Non-emission estimation

Emission / Non-emission distinctions for "0621-019 Other Cement and Ceramic material mineral" of I/O table are estimated as follows by industrial classification and their major industrial process.

Be careful that there are some errors due to the estimation that "0621-019 Other Cement and Ceramic material mineral" of I/O table corresponds Dolomite demand and supply because statistics for the Dolomite is not available.

(Dolomite / Emission Use)

0621-01 Mining - Ceramic material minerals	E-1 Refractory material
0621-09 Mining - Other non metallic minerals	E-1 Refractory material
2021-01 Chemical - Chemical fertilizer	E-1 Chemical material

2022-09 Chemical - Other non-organic products	E-1 Chemical material
2039-02 Chemical - Oil processed products	E-1 Chemical material
2039-09 Chemical - Other organic products	E-1 Chemical material
2061-01 Chemical - Medical supplies	E-1 Chemical material
2079-09 Chemical - Other chemical products	E-1 Chemical material
2511-01 Cement and Ceramics - Float Glass	E-1 Glass material
2521-01 Cement and Ceramics - Cement	E-1 Cement material
2531-01 Cement and Ceramics - Ceramics	E-1 Ceramics material
2599-09 Cement and Ceramics - Other products	E-1 Chemical material
2611-01 Iron and Steel - Pig iron	E-1 Smelting slag material
-2631-01 - Iron Casting Products	E-1 Smelting slag material
2711-01,02 Non-ferrous metal - Lead, Zinc	E-1 Smelting slag material
2811-01 Metallic wares - Construction parts	E-1 Refractory material
- 2899-09 - Other parts and products	E-1 Refractory material
8611-09 Household service - Other amusement	E-1 Ceramics material

(Dolomite / Non-Emission Use)

1812-01 Pulp and paper - Paper	N-1 Paper coat and filler materials
-1829-09 Pulp and paper - Other products	N-1 Paper coat and filler materials
2022-01 Chemical - Non organic pigment materials	N-1 Paint and pigment materials
2072-01 Chemical - Paint materials	N-1 Paint and pigment materials
2079-01 Chemical - Adhesive materials	N-1 Paint and pigment materials
2121-01 Coal Products - Pavement materials	N-1 Sand and gravel
2311-01 Rubber products - Rubber tire	N-1 Rubber filler materials
2311-09 Rubber products - Other rubber products	N-1 Rubber filler materials
2412-02 Leather products - Other products	N-1 Polisher materials
2599-01 Cement and Ceramics - Polisher materials	N-1 Polisher materials
3031-02 Machinery - Textile machine	
- 09 Other machine parts	N-1 Polisher materials
3711-01 Precision machinery - Optical machines	N-1 Polisher materials
-3719-03 - Other medical machines	N-1 Polisher materials
9000-01 Classification unknown	N-1 Sand and gravel

3. Limestone and Dolomite origin CO2 emission estimated by the new methodology

3-1. Limestone and Dolomite origin CO2 emission estimated by the new methodology

3-1-1. Demand and Supply of Limestone for emission use and non-emission use

Table 3-1-1-1. and Figure 3-1-1-1 to -4 show the estimated demand and supply quantity of Limestone and associated CO2 emission from the year 1990 to 2007 in accordance with the methodology described in 2-2. above.

About 70 per cent of the emission use is for cement material consumption and about 80 per cent of the non-emission use is for sand and gravel consumption. The reason why total Limestone use are decreasing is that both of those consumption are related to the level of Japanese domestic constructions and public works investments those are decreasing in these years.

In the emission use besides the cement material use, mining, porcelain and quick lime material use have been increased, but smelting and chemical use have been largely decreased and caused about 14 per cent decrease of total emission use from 1990 to 2007.

In the non-emission use besides gravel and concrete material use, pulp and paper and chemical use have been steeply decreased and caused about 21 per cent decrease from 1990 to 2007.

Hence, in 2007 calendar year, Limestone origin CO2 emission from emission use are estimated around 47.51Mt-CO2, 14.4 per cent and 7.985Mt-CO2 decrease from the 1990 calendar year.

[Table 3-1-1-1. Limestone demand and supply by emission and non-emission use classification and Limestone origin CO_2 emission]

1000t$CaCO_3$	1990CY	2000CY	2005CY	2006CY	2007CY	90-07	07/90 ratio
(Limestone Supply)	196280	182734	162217	163428	163200	-33080	-0.169
(Consumption/Emission)	126206	117996	108112	108471	108047	-18159	-0.144
Cement	89070	85051	76073	75832	74071	-14999	-0.168
Quick lime etc.	15417	14113	15500	15770	16392	+ 645	+0.041
Iron and Steel	13387	13082	12489	12578	12740	- 1148	-0.083
Chemical	4074	1723	703	885	998	- 3076	-0.755
Mining *	1951	2052	2423	2227	2494	+ 542	+0.278
Non-ferrous metal	1092	941	453	589	686	- 405	-0.371
Porcelain	315	1009	439	559	639	+ 324	+1.028
(Consumption/Non-emission)	70074	64738	54105	54957	55153	-14922	-0.213
Gravel, concrete	58814	55738	50084	50141	49830	- 8984	-0.153
Pulp and paper	8026	7323	3001	3779	4264	- 3761	-0.469
Chemical/Soda ash	2573	1074	570	588	599	- 1973	-0.767
Calcium carbonate	459	499	410	398	404	- 56	-0.121
(CO_2 emission ktCO_2)	55494	51884	47538	47696	47510	- 7985	-0.144

3-1-2. Demand and Supply of Soda ash for emission use and non-emission use

Same as 3-1-1, the table 3-1-2-1 and Figure 3-1-2-1 to -4 show the estimated demand and supply quantity of Soda ash and associated CO2 emission quantity from the year 1990 to 2007 in accordance with the methodology described in 2-2. above[**13].

In these years, imported Soda ash increase their share due to the cost competitiveness, and imported quantity of Soda ash get larger than the domestic produced one after calender year 2000.

13 The demand and supply quantity of the Soda ash here are converted into the Limestone weight equivalent.

In Soda ash final consumption, we can observe that non-emission use quantity are larger than emission use quantity. And we can also observe that around 50 per cent of emission use quantity is covered by glass material use, and more than 80 per cent of non-emission use quantity is covered by industrial detergent, not food seasoning.

Soda ash consumption for glass material use is decreasing due to the decrease of float glass production and increase of glass recycling in Japan. Soda ash consumption for industrial detergent use[**14] is also decreasing due to the decrease of the production of large scale industrial detergent consumer industry such as leather products and textile dye and arrangement.

CO_2 emission associated with the Soda ash emission use are 0.191Mt-CO_2 in calendar year 2007 and 27.0 per cent and 0.071Mt-CO_2 decrease compared to the calendar year 1990.

3-1-3. Demand and Supply of Dolomite for emission use and non-emission use

Same as 3-1-1, the table 3-1-3-1 and Figure 3-1-3-1 to -4 show the estimated demand and supply quantity of Dolomite and associated CO_2 emission quantity from the year 1990 to 2007 in accordance with the methodology described in 2-2. above[**15].

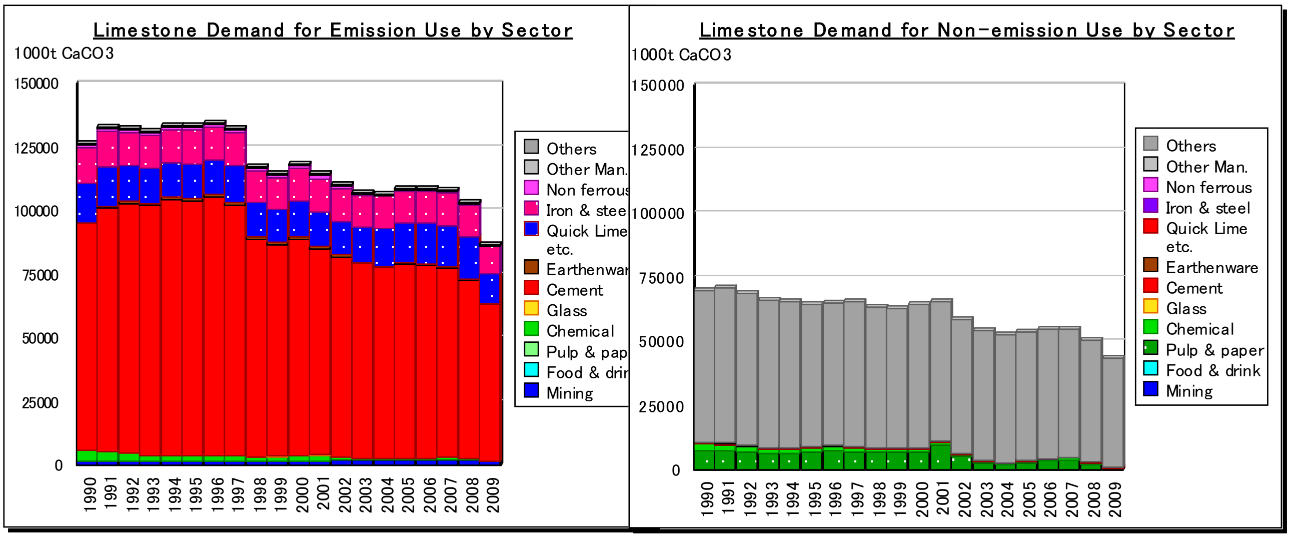
In these years, imported Dolomite is gradually increasing its supply share and its share reached to 50 per cent recently.

In Dolomite final consumption, emission use and non-emission use are almost equal in their quantity in these years. Almost 50 per cent of the emission use is slag formation material for Iron and Steel industry and most of the rest is refractory material for Cement and Ceramics industry. And more than 90 per cent of the non-emission use is building material such as gravel and sand.

Dolomite consumption for the emission use keeps almost the same level because the increase of slag formation use and decrease of refractory material cancelled out. Dolomite consumption for the non-emission use is decreasing due to the decrease of the domestic demand of building material.

CO_2 emission associated with the Dolomite emission use are 1.693 Mt-CO_2 in calendar year 2007 and 0.4 per cent and 0.007 Mt-CO_2 decrease compared to the calendar year 1990.

[Figure 3-1-1-3, -4. Limestone demand for emission and non-emission use by sector]



14 Non-emission use of Soda ash in the Iron and steel industry is also a kind of industrial detergent; Soda ash is used as alkaline defatter in the pre treat process of rolled steel or plated steel.

15 The demand and supply quantity of the Soda ash here are converted into the Limestone weight equivalent for simplicity.

3-2. Comparison of the newly estimated CO2 emission level with the present one

3-2-1. Uncertainty level evaluation of the new methodology

Before comparing the CO2 emission level of new methodology described in 2-2 with the emission level of present methodology, it is necessary to evaluate the uncertainty level of the new methodology and ensure that the uncertainty level of the new methodology is enough low in order to evaluate and verify the present CO2 emission level.

Emission factors for both new methodology and present methodology are almost same, but activity levels are totally differs. So hereafter let us compare the uncertainty level of activity level.

In new methodology, supply quantity and specified consumption are based on entire survey such as trade statistics or mineral resource production statistics those are high reliable statistics; so uncertainty level of these statistics are very low and estimated to be less than 5 per cent.

In case of extrapolation by the regression estimation for the missing statistics value are applied, additional uncertainties are added that corresponds to the regression estimation errors.

In case of Limestone use for SOx scrubber where reverse estimation from the quantity of sulfur is applied, maximum uncertainty factor "40 per cent" for low reliable statistics is applied.

And in case of the general consumption quantity that is estimated from subtracting total specified consumption from the supply and emission or non-emission estimation are applied, the author assumed and quantified the impact of 50 per cent of the emission or non-emission estimation are wrong at random manner and added the impact to the uncertainty level.

As a result of these assumptions, uncertainty level of the new methodology are estimated as 5.5 per cent in calendar year 1990 and 6.2 per cent in calendar year 2007 and proved that uncertainty level is fairly low though regression analysis are so frequently applied.

The uncertainty level of present methodology "2A Mineral products" are estimated as 6.3 per cent in calendar year 2007, so uncertainty level of the new methodology is almost equal to the present level.

The reason why such a low uncertainty level is ensured in the new methodology is as follows; most part of the CO2 emissions in the new methodology are estimated directly from the specified consumption based on reliable statistics and share of the estimated CO2 emissions such as SOx scrubber or I/O tables are very small especially from calendar year 1990 to 2000.

Thus, we can assume that the CO2 emission level of new methodology and present methodology are directly comparable.

[Table 3-2-1-1. Uncertainty level evaluation for the activity level of new methodology and comparison with the present methodology]

	1990CY	2000CY	2005CY	2006CY	2007CY
(New methodology)	0.055	0.056	0.062	0.062	0.062
Limestone	0.057	0.058	0.065	0.065	0.065
Soda ash	0.274	0.303	0.256	0.256	0.256
Dolomite	0.117	0.088	0.091	0.091	0.091
(Present methodology)	--	--	--	--	0.063
Cement	--	--	--	--	0.100
Quick Lime	--	--	--	--	0.050
Other use	--	--	--	--	0.047
Soda Ash	--	--	--	--	0.063

(Note) Evaluation and synthesis of the uncertainty level of present methodology is done by the author, 3-2-2. Comparison of estimated CO2 emission value of new and present methodologies

After ensuring the result of uncertainty level evaluation, the author compared the estimated CO2 emission quantity with new methodology and present methodology.

The CO2 emission level in calendar year 1990 are observed that both are almost the same level.

But from the calendar year 1991 to 2003, estimated CO2 emission level with new methodology passes around 1.0 Mt-CO2 higher level than the level with present methodology. And after the calendar year 2003, the situation reverses and estimated CO2 emission level with new methodology passes around 1.0 Mt-CO2 lower level than the level with present methodology.

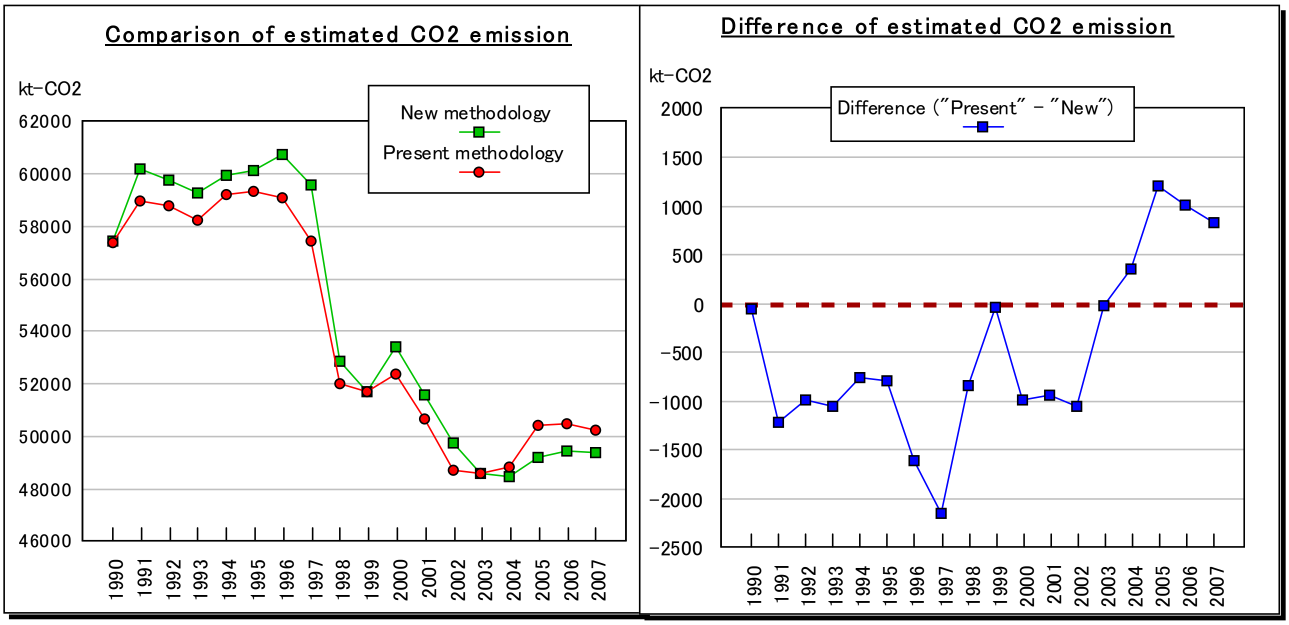
The relationship of estimated CO2 emission quantity with new methodology and present methodology are not stable by time and wide discrepancy are observed.

Let me discuss the reason why such instability and discrepancy are observed in the next chapter in detail.

[Table 3-2-2-1. Comparison of estimated CO2 emission quantity with new and present methodology]

kt-CO_2	1990CY	2000CY	2005CY	2006CY	2007CY	90-07	07/90 ratio
New methodology	57456	51577	49231	49461	49394	− 8062	− 0.140
Limestone	55494	51884	47538	47696	47510	− 7985	− 0.144
Soda Ash	262	225	212	195	191	− 71	− 0.270
Dolomite	1700	1290	1480	1570	1693	− 7	− 0.004
Present methodology	57399	52412	50431	50464	50219	− 7180	− 0.125
Cement	37966	34434	31654	31376	30076	− 7890	− 0.125
Quick Lime	7322	6419	7175	7428	7799	+ 478	+ 0.065
Other use	11527	11124	11245	11330	12004	+ 476	+ 0.041
Soda Ash	584	435	357	541	566	− 18	− 0.031
[Present − New]							
Discrepancy	− 57	− 987	+ 1201	+ 1002	+ 825	(+ 882)	
			+ 1009 (2005-07 average discrepancy)				

[Figure 3-2-2-1. ,-2. Comparison of estimated CO2 emission quantity with new and present methodology]



4. Results and Recommendations

4-1. Evaluation and verification results of present Limestone and Dolomite origin CO2 emissions[*16]

4-1-1. Evaluation and verification for Limestone use for Cement material

(1) Difference of Limestone consumption quantity for Cement material and present methodology, relationship with the Cement like earth solidifier

Present methodology for "2A1 Cement" takes clinker production quantity as activity level because clinker is made from calcination of Limestone or other materials, and it takes weight share of Limestone origin CaO to the total CaO in the clinker as correction coefficient for the activity level. Then Limestone origin CO2 emission from the Cement production sector is estimated by multiplication of the activity level, correction coefficient and CO2 emission factor of Limestone.

But the author's new methodology approaches assuming that all Limestone consumption in the Cement industry are calcinated or dissolved and taking Limestone consumption as activity level without correcting coefficients[*17].

When we compare the CO2 emission level of Cement industry with present and new methodology, present methodology is smaller than new by 1.0 to 4.0 Mt-CO2 per year (around 3 to 10 per cent to the total Limestone material consumption). The discrepancy is not counted as emission at present and may be omitted.

But the author estimates that the discrepancy part is caused by the "Non-clinker" Limestone calcination and dissolution as a material for the Cement like earth solidifier[*18], and estimates that the discrepancy should be categorized as an emission as well as the clinker. The reason of the author's estimation is that the Cement like earth solidifier creates Etringite ($3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$) crystal by hydration reaction, but that mean that carbonate acid part of the original Limestone shall be dissolved anyway.

Moreover, Cement like earth solidifier production statistics by Japan Cement manufacturer's Association shows that the production trend of the general grade Cement like earth solidifier is quite similar with the discrepancy of the CO2 emission level of Cement industry with present and new methodology.

(2) Correlation analysis with clinker, present CO2 emission estimation and Limestone origin CO2 emission

In order to verify the present methodology, the author checked the correlation with clinker production, Limestone consumption by Cement and Ceramic Products Statistics as follows;

a) Correlation coefficient of clinker production trends with the present CO2 emission estimation trends and Limestone consumption trends

b) Correlation coefficient of CO2 emission estimated from the clinker's chemical composition and its production amount trends with the present CO2 emission

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*16 Hereafter the quantity of Limestone, Dolomite and related derivative are converted into CO2 emission quantity in order to simplify the discussion.

*17 The author's approach had been used as Japanese original methodology until fiscal year 2005, but forced to amend into the present methodology by the strong and frequent pressure of the UNFCCC review.

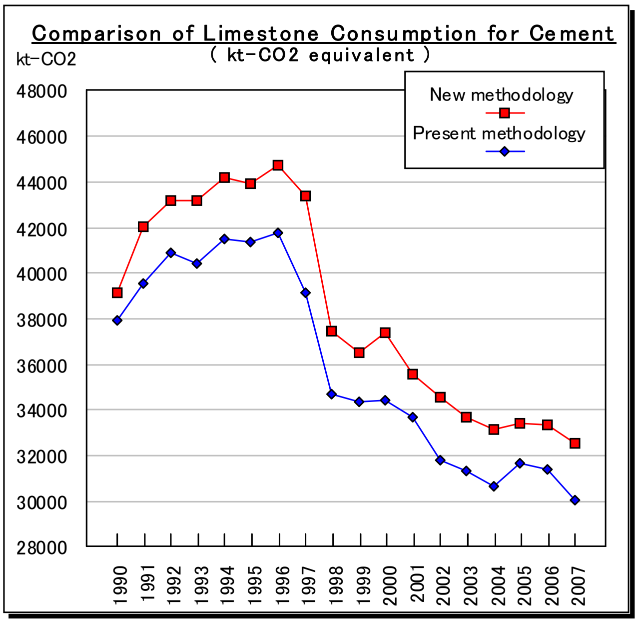
*18 The Cement like earth solidifier is used for muddy earth strength improvement or groundwater migration control for the hazardous materials. The earth solidifier are mixed with the earth on site, and hydration reaction causes rapid growth of pillar like crystals of Etringite that causes solidification of the muddy earth.

estimation trends and Limestone consumption trends

As a result, both a) and b) shows that correlation of clinker production with Limestone consumption is better than the correlation of clinker production and present CO2 emission though present CO2 emission is estimated from the clinker production.

The author cannot achieve further in depth analysis because the present methodology uses secret parameters submitted by Japan Cement manufacturer Association, but the result implies that present methodology may have some latent problems.

[Figure 4-1-1-1. Comparison of Limestone consumption for Cement (CO_2 equivalent) by CO_2 emission equivalent with new and present methodology]



[Table 4-1-1-1. Correlation analysis for Clinker production, present CO2 emission estimation and Limestone origin CO2 emission, 1990-2007CY]

(Correlation Coefficient)	Present CO2 emission estimation	Limestone material consumption
Clinker production a)	0.9623	0.9807
CO2 emission estimated from Clinker production b)	0.8911	0.9202

4-1-2. Evaluation and verification for Limestone and Dolomite use for Iron and Steel industry

(1) Duplication of Limestone and Dolomite consumption for Iron and Steel industry

Present methodology for 2A2 Quick Lime is based on the Quick Lime production by Chemical Statistics and Calcined Dolomite production by the survey of Japan Quick Lime Association. Similarly, 2A3 Other Limestone and Dolomite use is based on the sales quantity for Iron and Steel industry and Soda and Glass industry by Mineral Resource Production Statistics.

But when the author compared the Limestone and Dolomite sales amount for the Iron and Steel industry including fello-alloy by Mineral Resource Production Statistics with the Limestone and Dolomite consumption amount by the Iron and Steel Statistics, the author found very wide discrepancy there; sales amount constantly exceeds the consumption amount by 4.0 Mt-CO2 equivalent per year. (See Figure 4-1-2-1 (1).)

The discrepancy is almost the same level of Limestone and Dolomite origin CO2 emission for Quick Lime and Calcined Dolomite production, so the sales amount by Mineral

Resource Production Statistics includes both directly used Limestone and Dolomite and indirectly used Limestone and Dolomite those are entrusted to some associated company or their internal division to be calcined into the Quick Lime or Calcined Dolomite after their purchase. (See Figure 4-1-2-2 (2).)

But all of the Iron and Steel company and their associated company are subject to the mandate of the Chemical Statistics and members of Japan Quick Lime Association, so they declare Quick Lime and Calcined Dolomite production quantity including the amount of indirectly used Limestone and Dolomite as Quick Lime and Calcined Dolomite.

Thus, present 2A3 Other Limestone and Dolomite use based on Mineral Resource Production Statistics includes duplication with the 2A2 Quick Lime based on Chemical Statistics and so on, at least 4.0 Mt-CO2 that corresponds the amount of indirectly used Limestone and Dolomite entrusted to be calcined into Quick Lime and Calcined Dolomite.

(2) Quantitative contradiction under the "No duplication" assumption

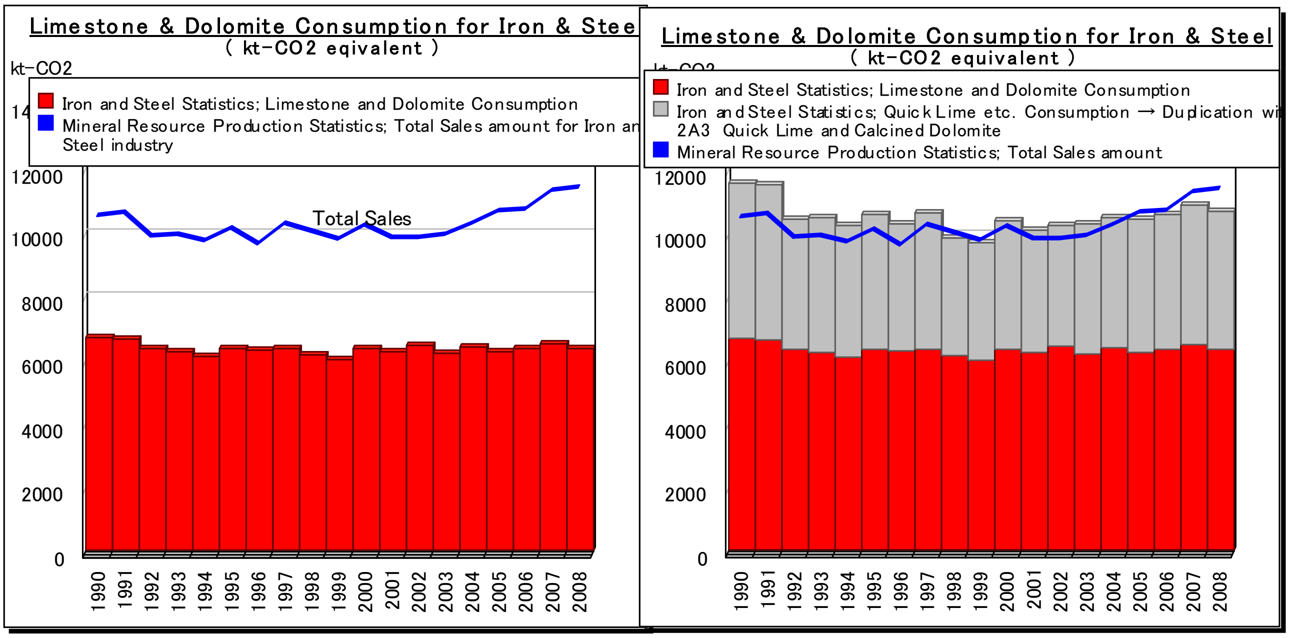
On the contrary, if we assume that there are "No duplication" above, we shall face the following contradiction.

From calendar year 1990 to 2000, almost 50 pre cent of the Quick Lime is purchased by Iron and Steel industry by the Japan Quick Lime association statistics, that means Iron and Steel industry purchases around 9.0 Mt-CaCO3 equivalent per year.

Then if we assume the Quick Lime above has no duplication with the sales amount of Limestone by Mineral Resource Production Statistics; that is around 20.0 Mt-CaCO3 in average, so that means Iron and Steel industry purchases 29.0 Mt-CaCO3 per year in total.

But the level 29.0 Mt-CaCO3 per year is around 50 per cent over to the average Limestone and Quick Lime consumption (20 Mt-CaCO3 per year in average) of Iron and Steel industry by Iron and Steel Statistics; there are no reason for the Iron and Steel industry to purchase such an excess Limestone or Quick Lime and we can conclude that "No duplication" assumption is wrong.

[Figure 4-1-2-1.,-2 Comparison of Limestone and Dolomite consumption in Iron and Steel industry and sales amounts by Mineral Resource Production Statistics; (1) and (2)]



(Note) Limestone and Dolomite consumption after the 2004CY are estimated by regression with explanatory parameters such as crude steel production and so on.

4-1-3. Evaluation and verification for Limestone and Dolomite use for Soda and Glass materials

At present methodology, 2A3 Other Limestone and Dolomite use is based on the sales quantity for Iron and Steel industry and Soda and Glass industry by Mineral Resource Production Statistics.

But when the author compared the sales amount by the Mineral Resource Production Statistics for the Soda and Glass materials with the Soda Ash production amount and Limestone and Dolomite consumption for Glass material by Cement and Ceramics Statistics, the author found wide discrepancy of the amount.

One reason is that Limestone itself is directly used as material for the Soda Ash, so Limestone consumption for Soda Ash is double counted by 2A3 Other Limestone and Dolomite use via Soda and Glass material sales and 2A4 Soda Ash.

Moreover, sales amount for Soda and Glass industry by Mineral Resource Production Statistics is too large and fluctuated compared to the Soda Ash production amount and Limestone and Dolomite consumption for Glass material by Cement and Ceramics Statistics, and almost 50 per cent of sales amount (0.3 to 0.5 MtCO2 equivalent) are estimated to be used by other industry or stockpiled somewhere.

In accordance with the Dolomite, trends of sales statistics for Soda and Glass industry by Mineral Resource Production Statistics matches well to the trends of consumption for Glass material by Cement and Ceramics Statistics. The discrepancy with the sales and consumption are estimated to be covered by the imported Dolomite.

At present methodology, there are no way to identify the secondary trade of Limestone and Dolomite or stockpile change at the consumer side. Moreover, present methodology have no idea with the import and export of the Limestone and Dolomite origin derivatives that is not yet emitted CO2. So these problems consist the reason for the discrepancy and estimation errors.

4-1-4. Impact of not estimated emission and non-emission use of Limestone, Dolomite and their derivatives by present methodology

The author quantified the impact of major emission and non-emission use that estimated under the new methodology but not under the present methodology as follows with CO2 emission quantity in 2007.

- Emission Use that is not estimated by the present methodology; present methodology is "Under estimate"
  - Limestone origin Calcium carbonate powder for SOx scrubber (E-2) 1.1 Mt-CO2
  - Limestone for earthenware and chemical material (E-1) 1.0 Mt-CO2
  - Dolomite for refractory and chemical material (E-1) 0.7 Mt-CO2
- Non-emission Use that is not excluded in emission by the present methodology; present methodology is "Over estimate"
  - Soda Ash for food additives and industrial detergent (N-2) 0.2 Mt-CO2
  - Limestone origin Calcium carbonate powder for material (N-2) 0.2 Mt-CO2
  - Soda Ash for export (N-2) 0.0 Mt-CO2

In total, quantity of "Under estimate" that is not included in emission by the present methodology; present methodology is larger than quantity of "Over estimate" that is not excluded in emission by the present methodology.

These problems consist the reason for the discrepancy and estimation errors.

4-1-5. Summary for the evaluation and verification of present methodology

(1) Summation of the quantitative discrepancies and time series impact analysis

The author summed up the quantitative discrepancies of estimated emission level with present methodology and new methodology for 4-1-1 to 4-1-4 in time series and identified major reasons of discrepancy.

Most part of the "Over estimate" that estimated emission level of present methodology is greater than the new methodology is caused by duplication of Limestone and Dolomite and Quick Lime and Calcined Dolomite for Iron and Steel industry explained in 4-1-2 and the impact of the problem is around 4.0 to 5.0 Mt-CO2 per year.

On the contrary, there are many reasons for the "Under estimate" that estimated emission level of present methodology is less than the new methodology; for example, discrepancy of Limestone origin CO2 emissions in the Cement and Cement like earth solidifier material explained in 4-1-1 that corresponds around 2.0 Mt-CO2 per year, emission uses such as Limestone origin Calcium carbonate powder for SOx scrubber, Limestone for earthenware and chemical material or Dolomite for refractory and chemical material that had impact around 0.5 to 1.0 Mt-CO2 per year.

[Table 4-1-5-1. Summary of the quantitative discrepancies of Limestone and Dolomite origin CO_2 emission with present and new methodology and time series impact analysis]

kt-CO_2	1990CY	2000CY	2005CY	2006CY	2007CY
("Over estimate" of present methodology)	+5395	+5302	+5450	+5405	+5926
Iron and Steel indirect use duplication	+3867	+3941	+4481	+4456	+4881
Limestone for Glass material duplication	+ 343	+ 464	+ 274	+ 321	+ 432
Soda Ash for material duplication	+ 469	+ 276	+ 164	+ 148	+ 136
Soda Ash for missing non-emission use	+ 382	+ 321	+ 246	+ 206	+ 215
Dolomite for Glass duplication	+ 130	+ 100	+ 114	+ 111	+ 101
Limestone for missing non-emission use	+ 176	+ 197	+ 169	+ 161	+ 161
Soda Ash export	+ 28	+ 1	+ 1	+ 1	+ 1
("Under estimate" of present methodology)	-5510	-6142	-4203	-4535	-5369
Limestone for Cement material missing	-1199	-2964	-1796	-1968	-2494
Limestone for Earthenware missing	-2460	-1656	- 718	- 915	-1045
Limestone for SOx scrubber missing	- 858	- 902	-1065	- 979	-1097
Dolomite for refractory material missing	- 993	- 619	- 624	- 674	- 734
(Other error, Stockpile change etc.)	- 58	+ 147	+ 46	- 133	- 268
Total deviation (+ Over / - Under)	- 57	- 987	+1201	+1002	+ 825

+ 1009 (2005 to 2007 average)

(2) Comprehensive evaluation for the present methodology

As a result of above evaluation and verification, the author considers that present methodology has many a very serious problems and not suitable for continuous use as Limestone and Dolomite origin CO2 quantification and estimation methodology.

So the author considers that prompt switching of the methodology and recalculation are necessary.

- Present methodology for Limestone and Dolomite origin CO_2 emission has around 1.0 Mt-CO_2 "Over estimate" side error. The error scale corresponds to around 2 per cent to the base year emission of 2A Mineral resources, and around 0.1 per cent to the base year emission of Japan under the Kyoto Protocol first commitment period.
- The error is not caused by single factor but a result of complexed interference and cancellation by single "Over estimate" factor and multiple "Under estimate" factors, so the error is supposed to be very unstable by its nature.
- The Limestone and Dolomite origin CO_2 emission for the base year; calendar year 1990 was almost same with present methodology and new methodology and the error was very small. But such a small error in the base year is supposed to be nothing but an accidental phenomena.
- Similarly, it is nothing but an accidental phenomena that calendar year of 2005 to 2007 emission under present methodology had been 1.0 Mt-CO_2 "Over estimate" error.
  Hence, the error may drastically change and get suddenly unstable depending on the condition and balance of the single "Over estimate" factor and multiple "Under estimate" factors, so the author consider that present methodology lacks adequacy for continuous use any more.

(3) Root cause analysis for the error of present methodology

The root cause for the error in the present methodology is deemed that present methodology did not try to watch the full scope of demand and supply of Limestone, Dolomite and their derivatives but continued partial estimation with a "patch-work" approach; mixing up industrial and technological classifications for estimation and using both supply side statistics and demand side statistics case by case, and continued such approach ignoring misunderstandings of the relationship of different statistics and overlooking some leakage.

And most part of the error might be avoided if they cross checked sales statistics of Mineral Resources Production Statistics and material consumption statistics of Iron and Steel Statistics abolished in calendar year 2000 at the point of calculating the base year emission in calendar year 1990.

Moreover, Limestone and Soda Ash is clearly classified in I/O table issued in 5 year regular interval and the consumption amount could be easily estimated from the analogy of "3E-ID" by National Institute of Environment or General Energy Statistics. At least someone would have found some leakage emission from some sector that is not estimated under present methodology, immediataly after they checked the I/O table.

4-2. Recommendations

4-2-1. Recalculaion of the Limestone and Dolomite origin CO2 emission

In this paper, the author tried to develop new methodology making non-equivalent price input table from I/O table and various industrial statistics with emission or non-emission use estmation in order to evaluate and verify Japanese Limestone and Dolomite origin CO2 emission with present methodology.

And the author found that the estimated CO2 emission with present methodology is "Over estimate" around 1.0 Mt-CO2 due to the influence of various error factors such as double counting and/or overlooking some leakage and need correction.

By the way, in this paper the author uses many estimated data by regression analysis in order to cover the abolished statistics data on Limestone, Dolomite and related derivatives after century year 2000 because there are no alternative way to get data.

It is obvious that even though such estimation by regression does not have significant and substantial effect on the result of the evaluation and analysis for the present methodology, but there remains some other type concern that data consistency is not maintaied when we are going to apply the new methodology as a methodology for Japanese Greenhouse Gas Inventory.

Hence, the author recommends to apply new methodology and achieve recalculation for the Limestone, Dolomite and related derivatives origin CO2 emission immediately, covering the abolished industrial statistics data and ensuring the estimation accuracy asking data cooperation of related industrial association for Limestone, Dolomite and related derivatives production and consumption.

4-2-2. New methodology for Limestone, Dolomite and related derivatives origin CO2 emission

Present national greenhouse gas inventory guideline issued by IPCC-NGGIP in 1996 recommends to estimate CO2 emission separately for 4 categories; 2A1 - Cement, 2A2 - Quick Lime, 2A3 - Other Limestone and Dolomite use and 2A4 - Soda Ash.

That methodology is useful as an estimate under the limited data and information condition such as developing countries or economy in transition countries.

But we need to remind that most of the industrialised countries and some well developed developing countries have detailed and accurate I/O table, and we can expect consistent estimation from the end use side if we apply the new methodology in this paper, instead of the present 1996 national greenhouse gas incentory guideline which may cause to latent duplication or leakage by separate estimation for the 4 categories.

Thus, we can expect better estimate for Limestone, Dolomite and related derivative origin CO2 emissions applying new methodology in this paper or more advanced methodology in accordance with the circumstances than just following the present 1996 national greenhouse gas incentory guideline in case of industrialised countries or well developed developing countries.

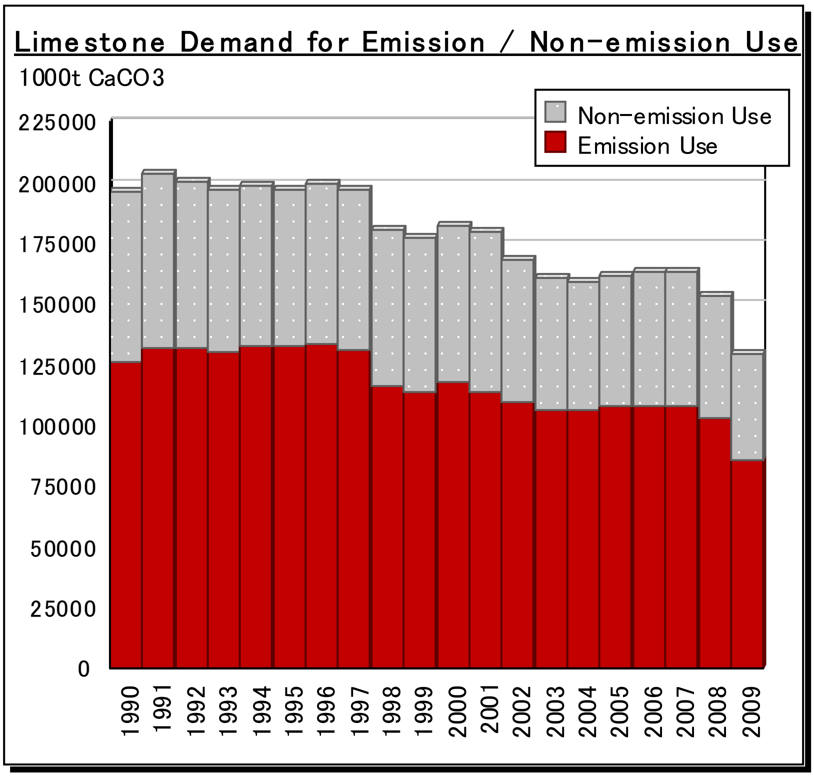
The estimation procedure for the new methodology is as follows; first we prepare comprehensive sectoral demand quantiry table of Limestone, Dolomite and related derivative at the final consumption and end use side using I/O table and Industrial statistics, and then fill in the necessary values in the required greenhouse gas inventory format from the comprehensive sectoral demand quantity table.

Annexed Figures and Tables

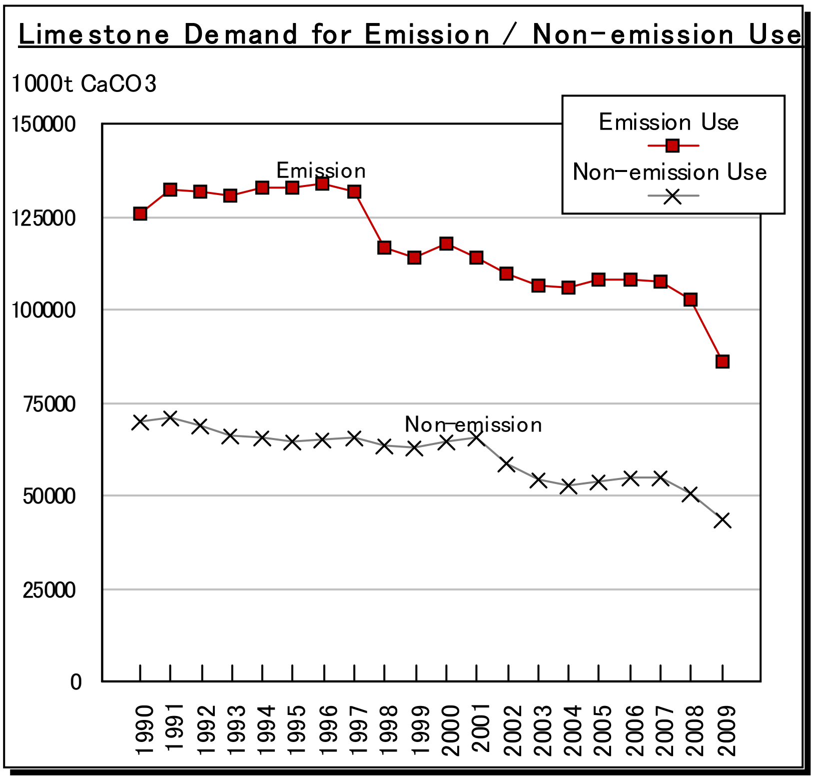
[Table 3-1-1-1. Limestone demand and supply by emission and non-emission use classification and Limestone origin CO_2 emission]

1000t$CaCO_3$	1990CY	2000CY	2005CY	2006CY	2007CY	90-07	07/90 ratio
(Limestone Primary Supply)							
Indigenous	198224	185569	165240	166621	165982	-32243	-0.163
Inport	1	283	294	324	439	+ 438	+486.4
Export	- 1945	- 3118	- 3317	- 3518	- 3221	- 1275	+0.656
Domestic Supply	196280	182734	162217	163428	163200	-33080	-0.169
(Final Consumption / Emission)							
	126206	117996	108112	108471	108047	-18159	-0.144
Mining	1951	2052	2423	2227	2494	+ 542	+0.278
Food and drink	0	0	0	0	0	0	---
Pulp and paper	0	0	0	0	0	0	---
Chemical	4074	1723	703	885	998	- 3076	-0.755
Cement etc.	105201	100198	92044	92192	91130	-14070	-0.134
Glass	69	25	33	31	28	- 42	-0.602
Cement	89070	85051	76073	75832	74071	-14999	-0.168
Earthenware	315	1009	439	559	639	+ 324	+1.028
Others	15417	14113	15500	15770	16392	+ 645	+0.041
Iron and steel	13387	13082	12489	12578	12740	- 1148	-0.083
Non ferrous metal	1092	941	453	589	686	- 405	-0.371
Other manuf.	0	0	0	0	0	0	---
Other	0	0	0	0	0	0	-1.000
(Final Consumption / Non-emission)							
	70074	64738	54105	54957	55153	-14922	-0.213
Mining	0	0	0	0	0	0	---
Food and drink	0	0	0	0	0	0	---
Pulp and paper	8026	7323	3001	3779	4264	- 3761	-0.469
Chemical	2573	1074	570	588	599	- 1973	-0.767
Cement etc.	459	499	410	398	404	- 56	-0.121
Iron and steel	0	0	0	0	0	0	---
Non ferrous metal	0	0	0	0	0	0	---
Other manuf.	202	105	40	50	55	- 147	-0.726
Other	58814	55738	50084	50141	49830	- 8984	-0.153
(CO_2 emission ktCO_2)							
	55494	51884	47538	47696	47510	- 7985	-0.144

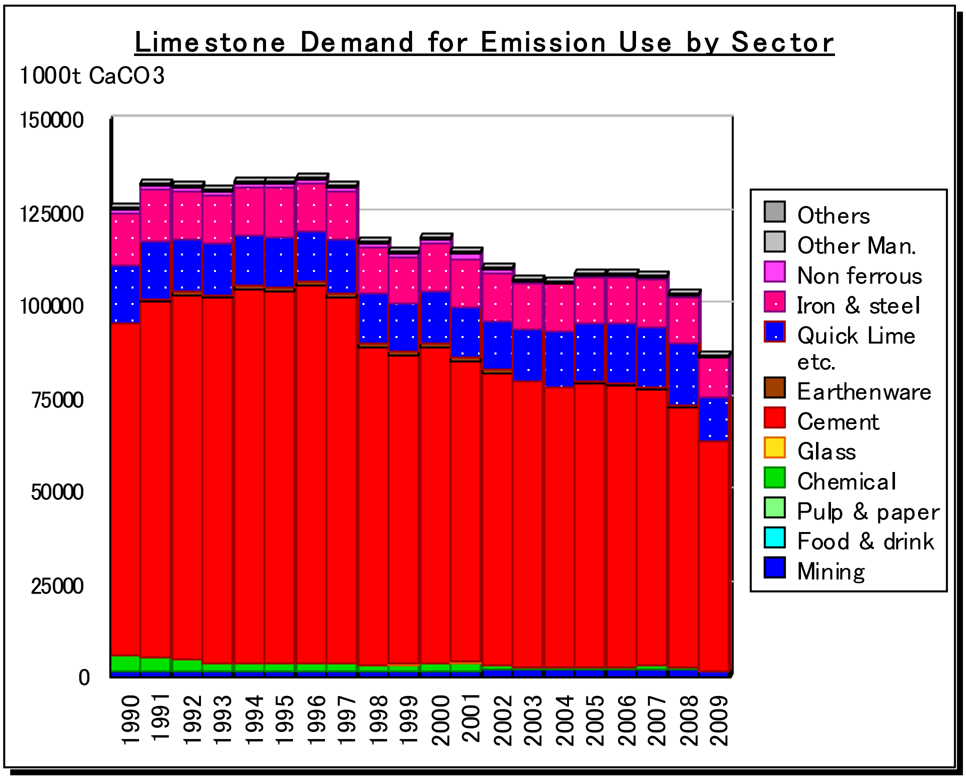
[Figure 3-1-1-1. Limestone Demand for Emission/ Non-emission use]



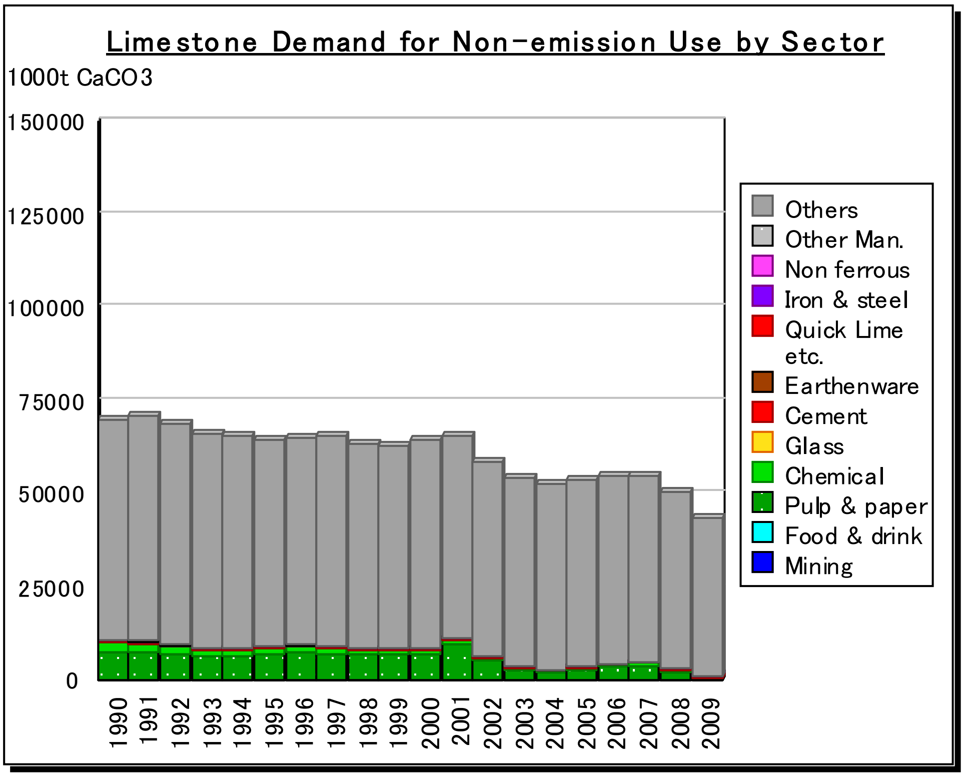
[Figure 3-1-1-2. Limestone Demand for Emission/ Non-emission use]



[Figure 3-1-1-3. Limestone Demand for Emission Use by Sector]



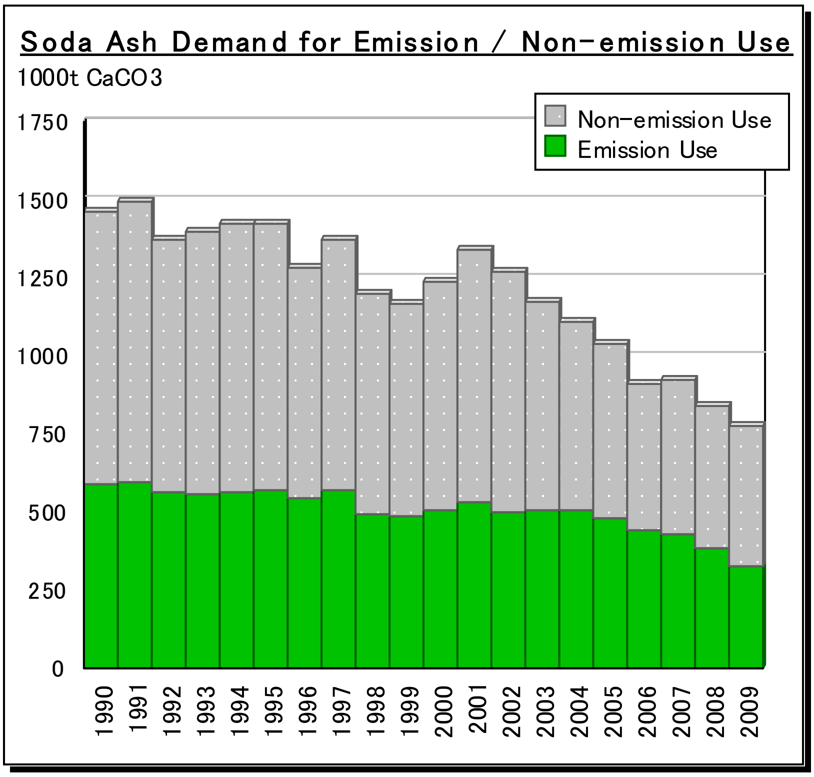
[Figure 3-1-1-4. Limestone Demand for Non-emission Use by Sector]



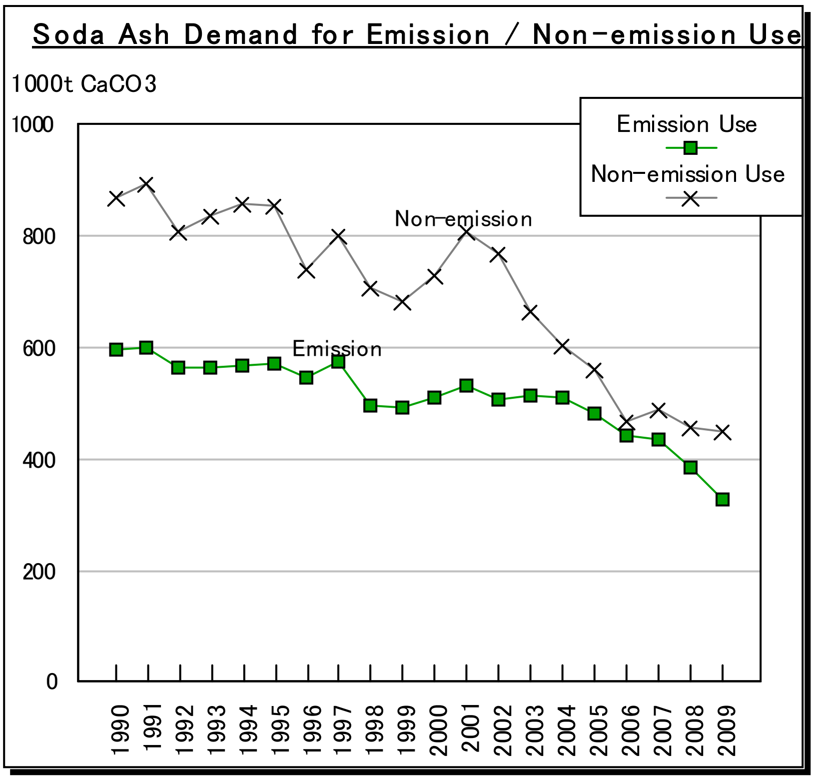
[Table 3-1-1-2. Soda Ash demand and supply by emission and non-emission use classification and Soda Ash origin CO_2 emission]

$1000tCaCO_3$	1990CY	2000CY	2005CY	2006CY	2007CY	90-07	07/90 ratio
(Soda Ash Primary Supply)							
Indigenous	1066	629	373	336	309	－ 757	-0.710
Inport	460	616	671	579	616	＋ 156	+0.338
Export	－ 63	－ 5	－ 1	－ 2	－ 2	＋ 61	-0.963
Domestic Supply	1464	1240	1043	913	923	－ 541	-0.369
(Final Consumption / Emission)							
	596	511	483	443	435	－ 161	-0.270
Mining	0	0	0	0	0	0	---
Food and drink	0	0	0	0	0	0	---
Pulp and paper	0	0	0	0	0	0	---
Chemical	198	207	159	135	137	－ 62	-0.310
Cement etc.	329	239	259	252	236	－ 93	-0.282
Glass	313	225	252	247	232	－ 82	-0.260
Cement	0	0	0	0	0	---	---
Earthenware	0	0	0	0	0	－ 0	-0.188
Others	16	13	7	5	4	－ 11	-0.712
Iron and steel	18	11	6	5	5	－ 13	-0.726
Non ferrous metal	10	9	5	4	4	－ 6	-0.634
Other manuf.	20	19	23	20	22	＋ 2	+0.093
Other	21	25	32	28	31	＋ 10	+0.496
(Final Consumption / Non-emission)							
	868	730	560	469	488	－ 380	-0.437
Mining	0	0	0	0	0	0	---
Food and drink	151	159	88	67	65	－ 87	-0.573
Pulp and paper	9	14	8	6	6	－ 3	-0.353
Chemical	269	244	187	165	167	－ 102	-0.378
Cement etc.	0	0	0	0	0	0	---
Iron and steel	205	190	197	169	187	－ 18	-0.087
Non ferrous metal	0	0	0	0	0	0	---
Other manuf.	145	100	34	21	15	－ 130	-0.895
Other	87	24	45	41	48	－ 40	-0.453
(CO_2 emission $ktCO_2$)							
	262	225	212	195	191	－ 71	-0.270

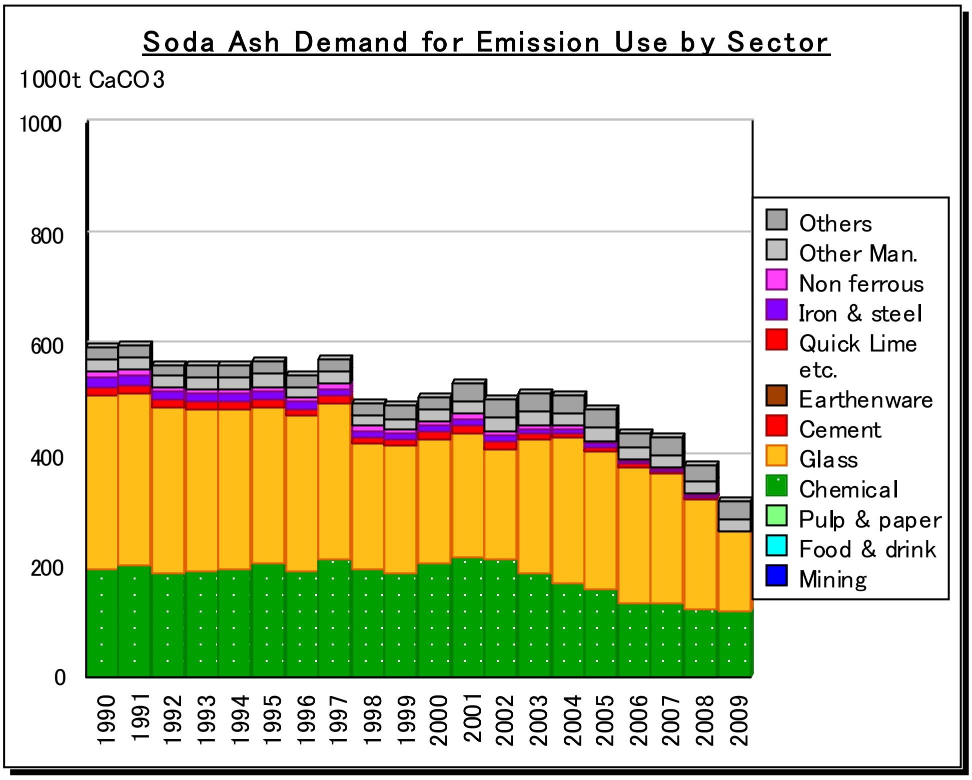
[Figure 3-1-2-1. Soda Ash Demand by Emission/ Non-emission Use]



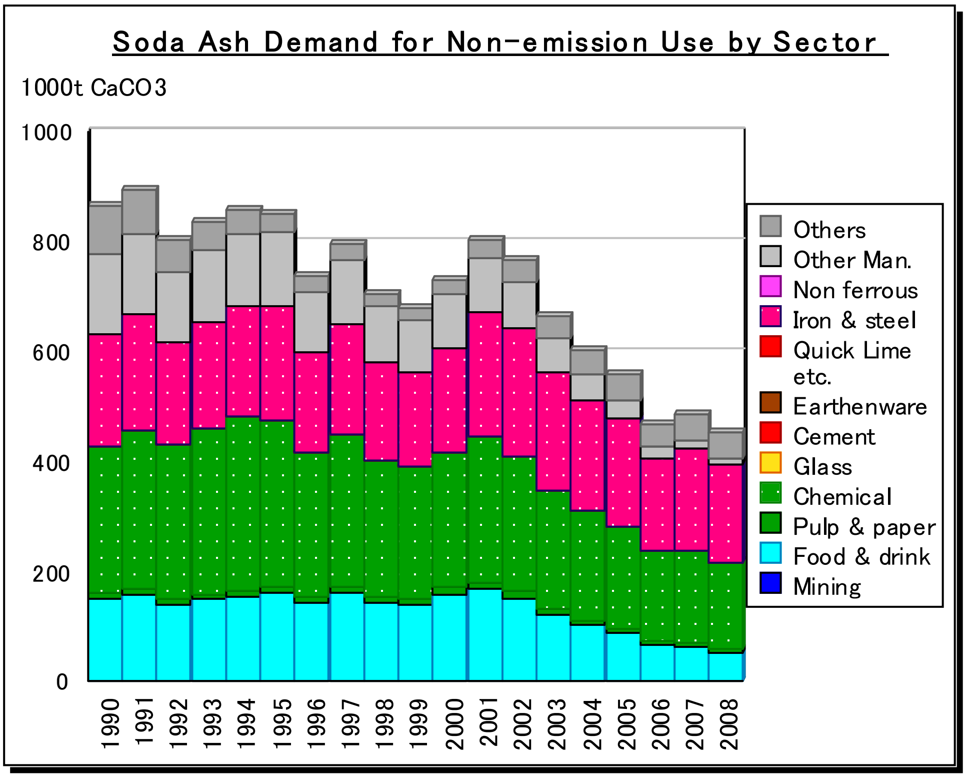
[Figure 3-1-2-2. Soda Ash Demand by Emission/ Non-emission Use]



[Figure 3-1-2-3. Soda Ash Demand for Emission Use by Sector]



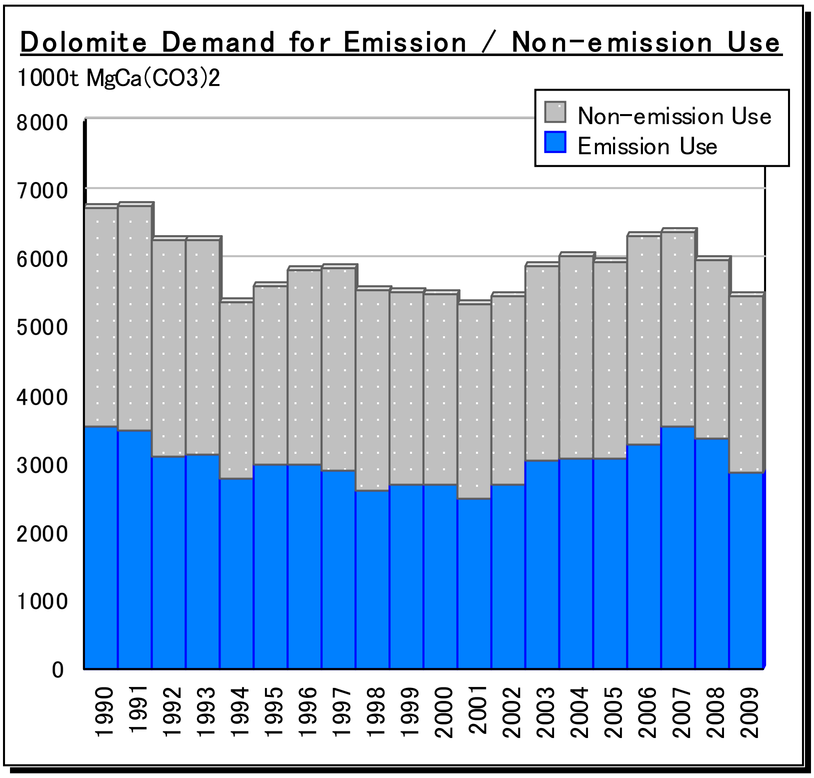
[Figure 3-1-2-4. Soda Ash Demand for Non-emission Use by Sector]



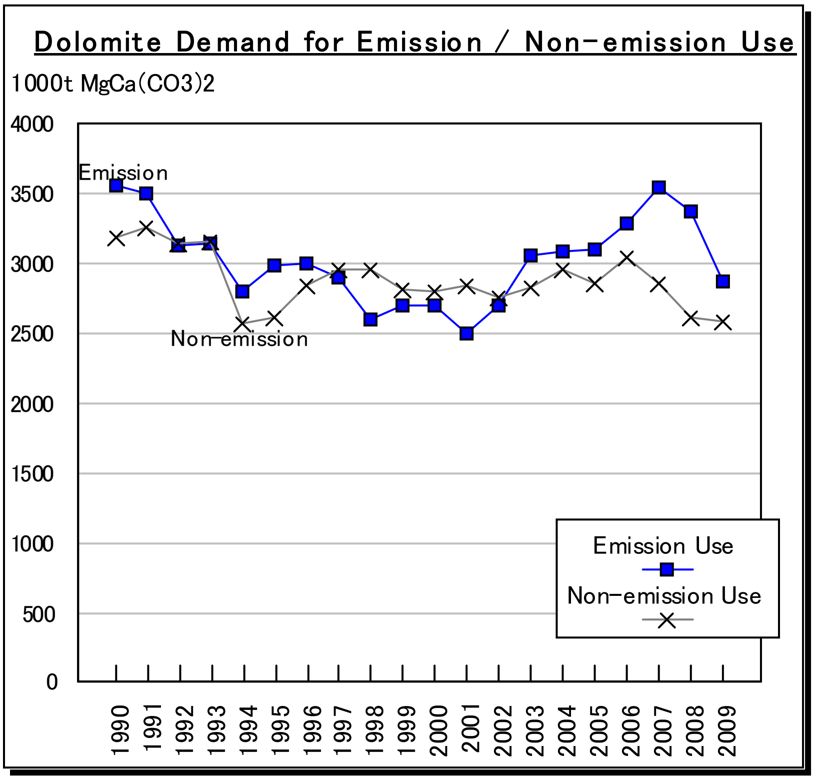
[Table 3-1-1-3. Dolomite demand and supply by emission and non-emission use classificaion and Dolomite origin CO_2 emission]

$1000tCaCO_3$	1990CY	2000CY	2005CY	2006CY	2007CY	90-07	07/90 ratio
(Dolomite Primary Supply)							
Indigenous	5371	3539	3534	3695	3655	− 1715	−0.319
Inport	1383	1964	2426	2638	2757	+ 1374	+0.993
Export	− 0	− 0	− 0	− 0	− 3	− 2	−39.05
Domestic Supply	6754	5504	5960	6333	6409	− 344	−0.051
(Final Consumption / Emission)							
	3561	2703	3101	3290	3546	− 15	−0.004
Mining	82	47	61	69	79	− 3	−0.041
Food and drink	0	0	0	0	0	---	---
Pulp and paper	0	0	0	0	0	---	---
Chemical	152	92	55	52	48	− 105	−0.688
Cement etc.	2075	1337	1409	1504	1604	− 471	−0.227
Glass	273	210	239	233	212	− 61	−0.224
Cement	321	111	111	120	131	− 191	−0.594
Earthenware	857	665	768	850	948	+ 92	+0.107
Others	624	351	291	301	313	− 311	−0.498
Iron and steel	1208	1195	1554	1645	1797	+ 589	+0.488
Non ferrous metal	1	1	0	0	0	− 1	−0.761
Other manuf.	38	24	12	10	8	− 30	−0.791
Other	4	8	9	10	11	+ 6	+1.421
(Final Consumption / Non-emission)							
	3193	2801	2859	3043	2863	− 330	−0.103
Mining	0	0	0	0	0	---	---
Food and drink	0	0	0	0	0	---	---
Pulp and paper	358	260	205	209	214	− 143	−0.401
Chemical	8	6	4	3	3	− 5	−0.603
Cement etc.	30	19	27	31	35	+ 5	+0.172
Iron and steel	0	0	0	0	0	---	---
Non ferrous metal	0	0	0	0	0	---	---
Other manuf.	80	61	52	54	57	− 23	−0.291
Other	2717	2455	2572	2746	2553	− 163	−0.060
(CO_2 emission $ktCO_2$)							
	1700	1290	1480	1570	1693	− 7	−0.004

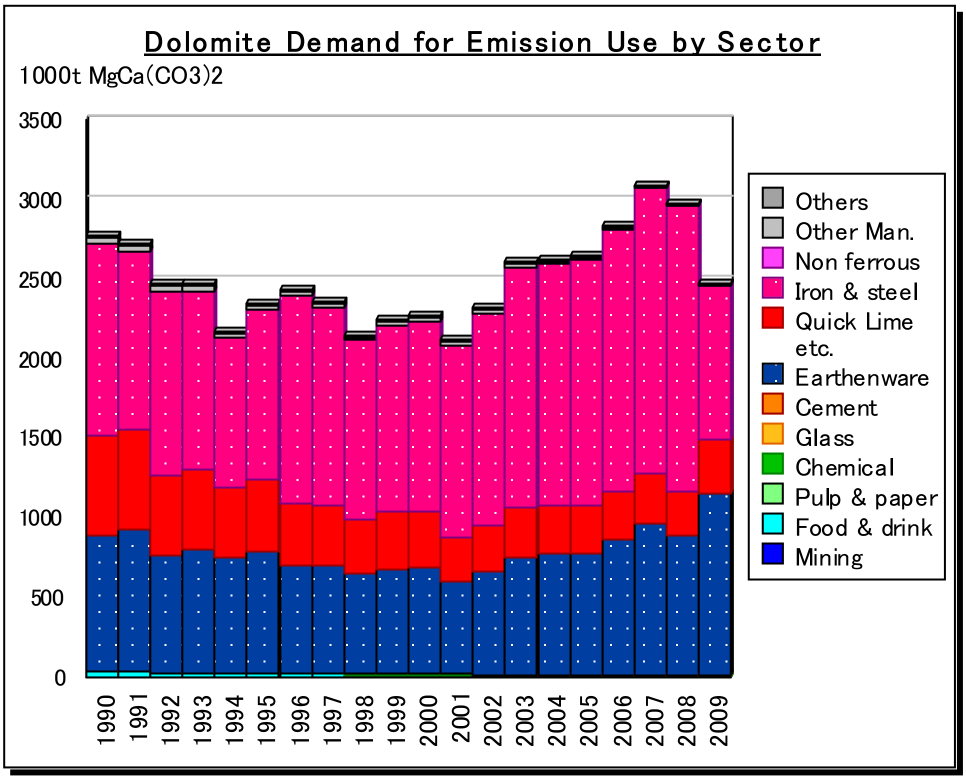
[Figure 3-1-3-1. Dolomite Demand for Emission / Non-emission Use]



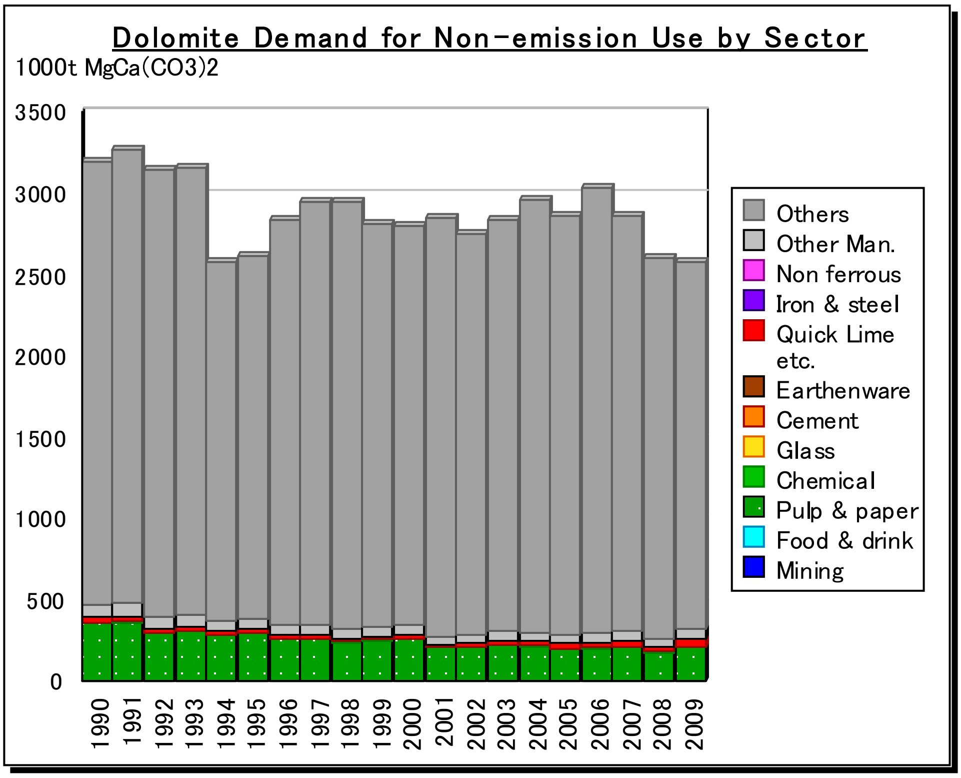
[Figure 3-1-3-2. Dolomite Demand for Emission / Non-emission Use]



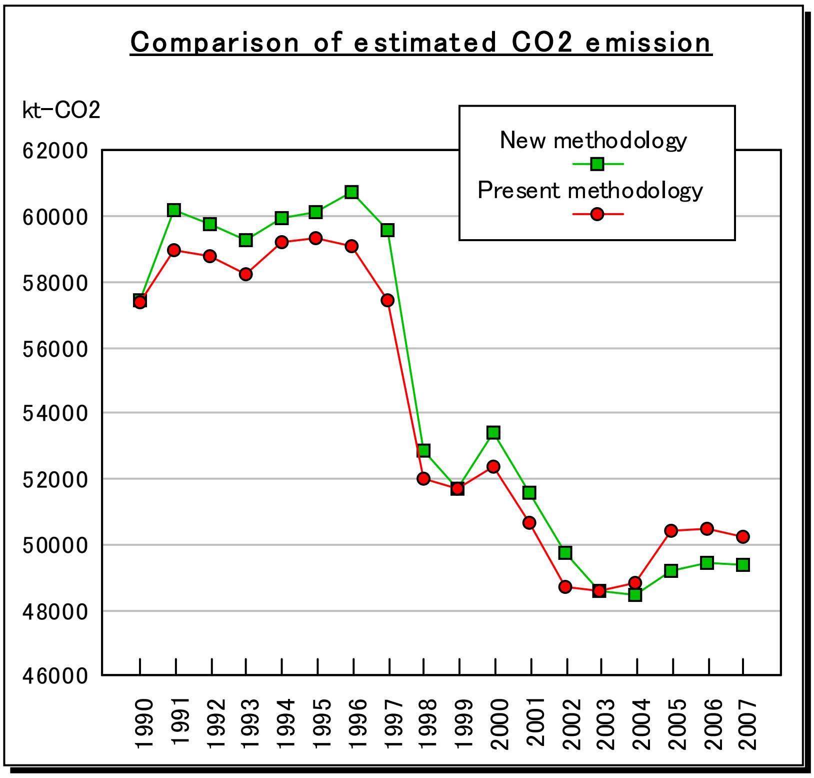
[Figure 3-1-3-3.　Dolomite Demand for Emission Use by Sector]



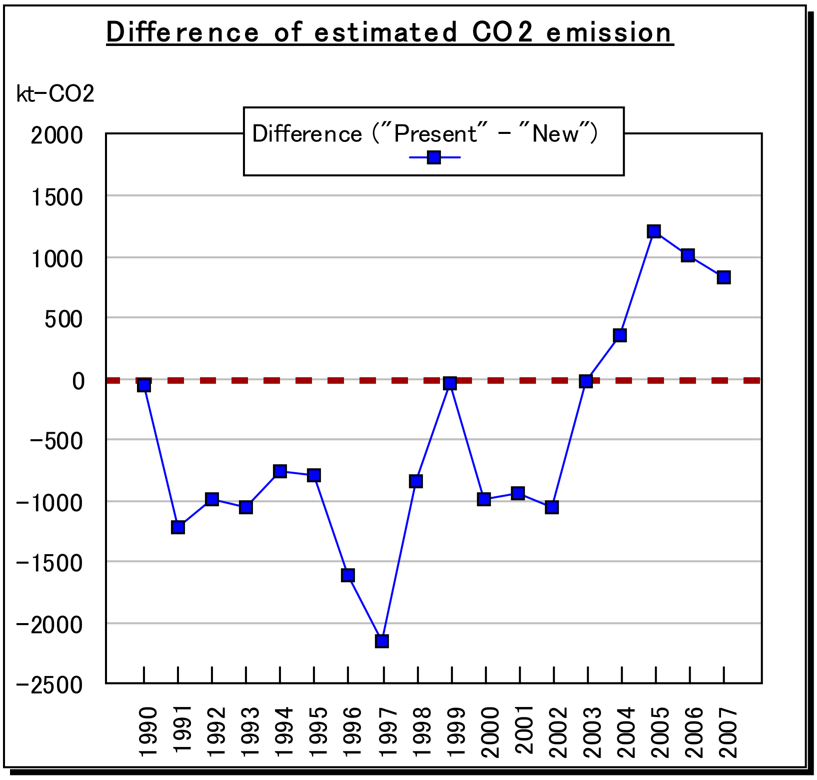
[Figure 3-1-3-4.　Dolomite Demand for Non-emission Use by Sector]



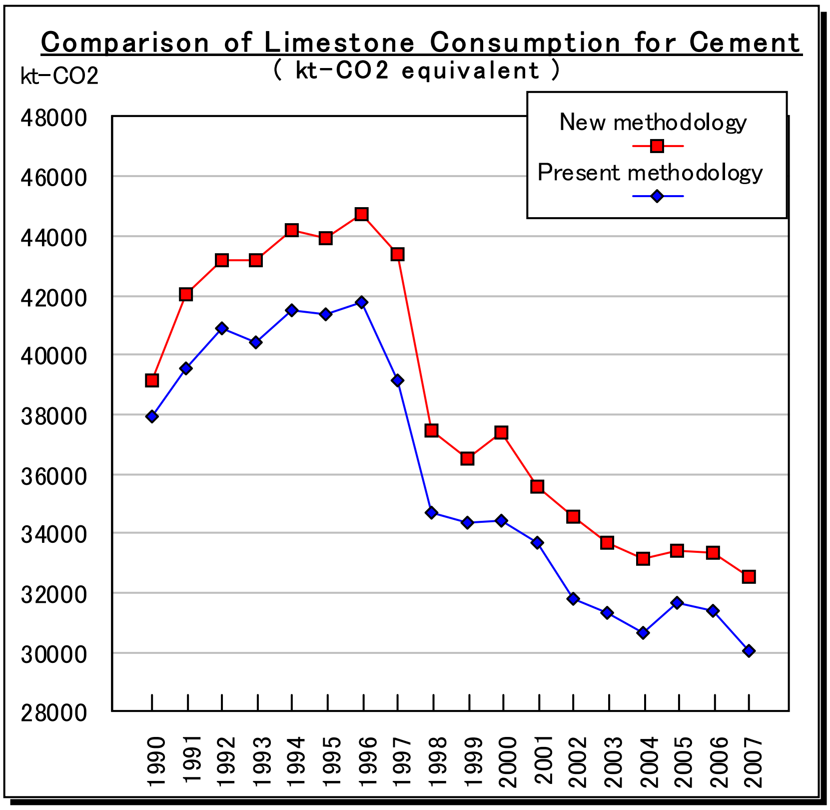
[Figure 3-2-2-1. Comparison of estimated CO_2 emission quantity with new and present methodology]



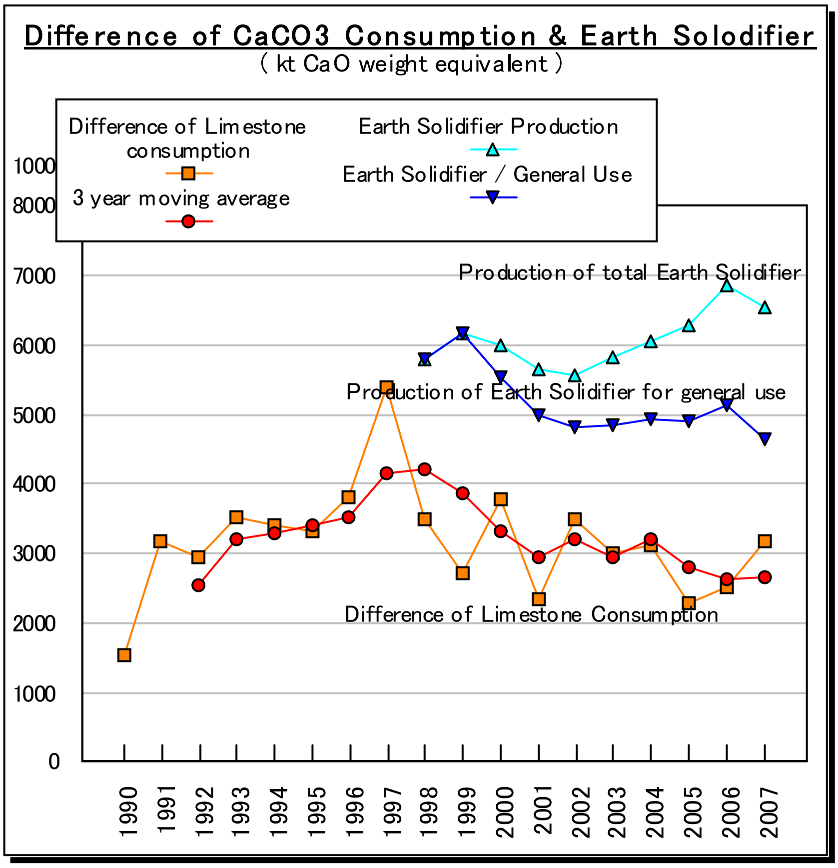
[Figure 3-2-2-1. Difference of estimated CO_2 emission quantity with new and present methodology]



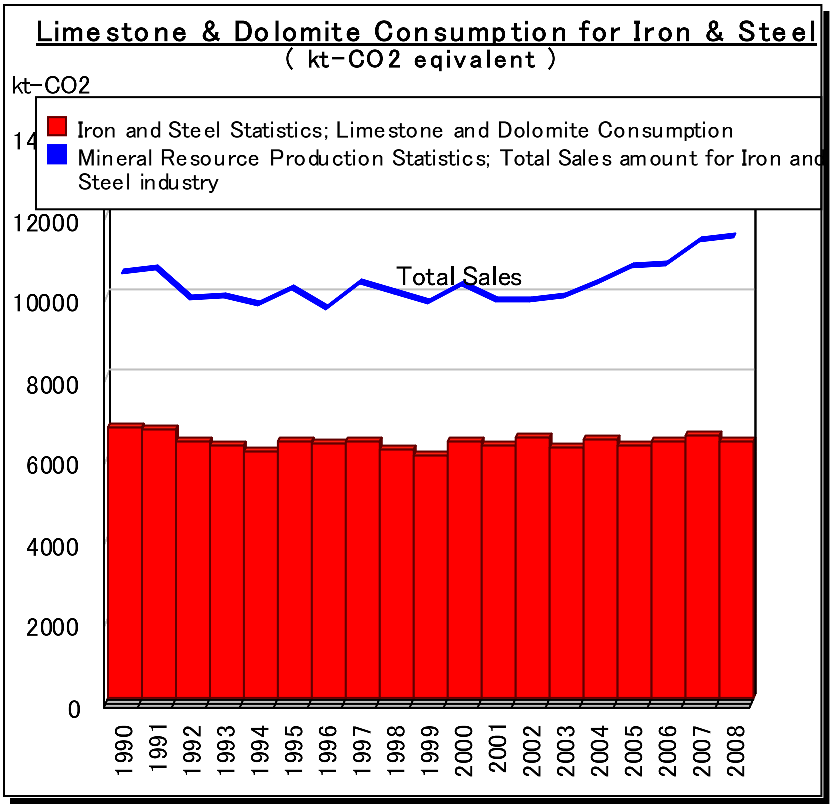
[Figure 4-1-1-1. Comparison of Limestone consumption for Cement (CO_2 equivalent) by CO_2 emission equivalent with new and present methodology]



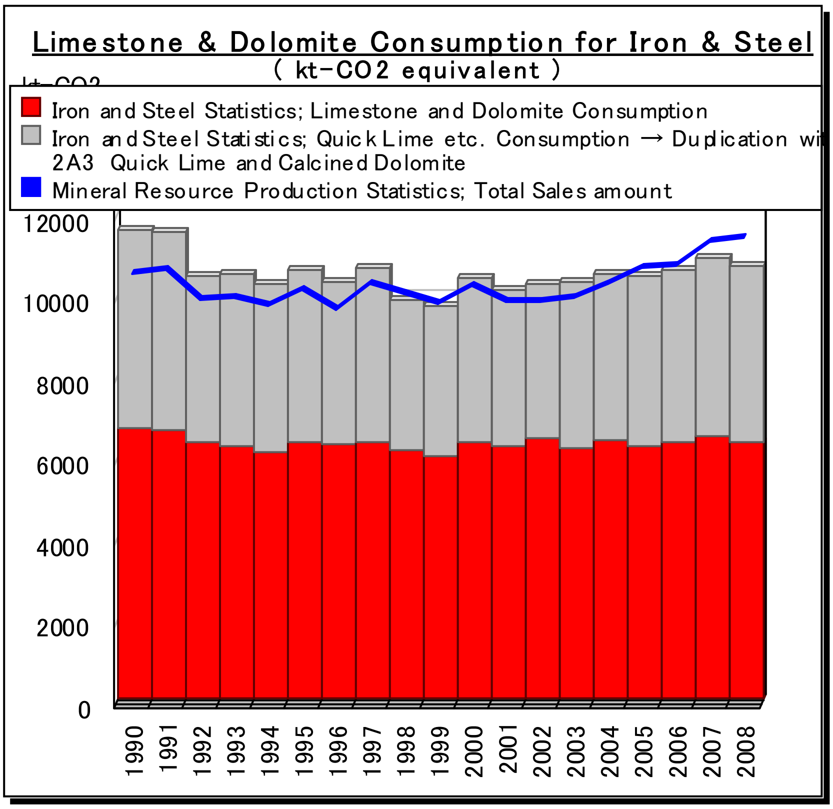
[Figure 4-1-1-2. Comparison of difference of Limestone Consumption for Cement and production of cement like Earth Solidifier]



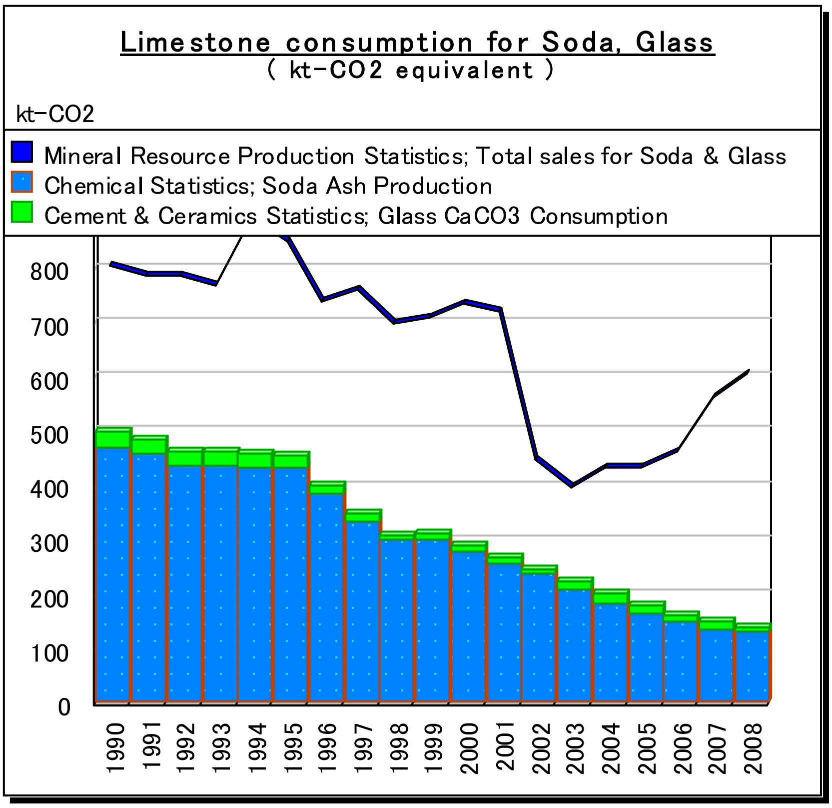
[Figure 4-1-2-1. Comparison of Limestone and Dolomite consumption in Iron and Steel industry and sales amounts by Mineral Resource Production Statistics; (1)]



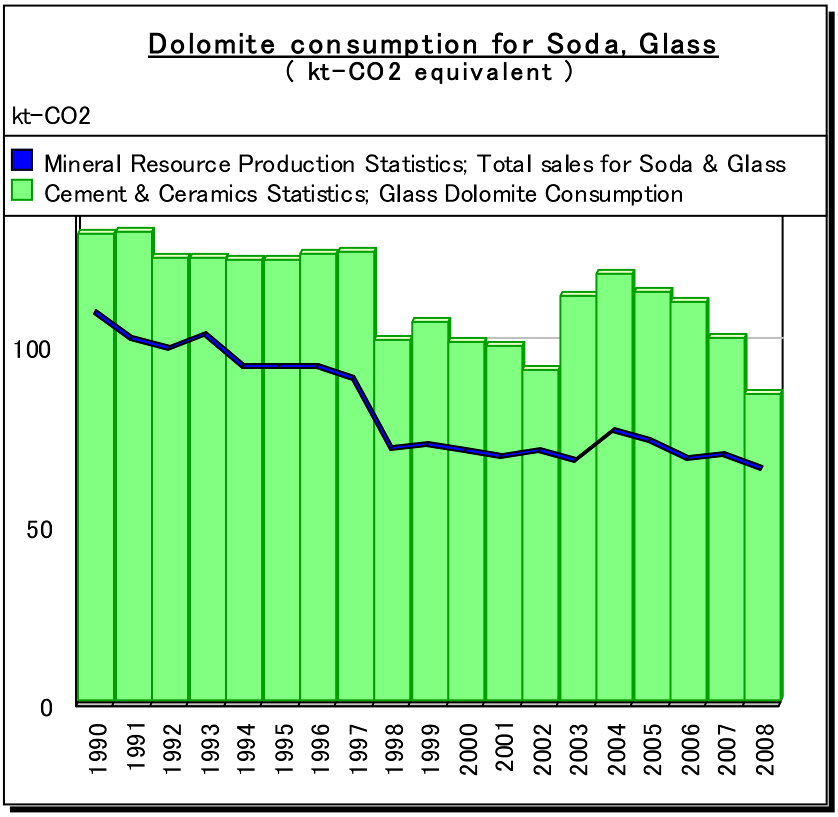
[Figure 4-1-2-2. Comparison of Limestone and Dolomite consumption in Iron and Steel industry and sales amounts by Mineral Resource Production Statistics; (2)]



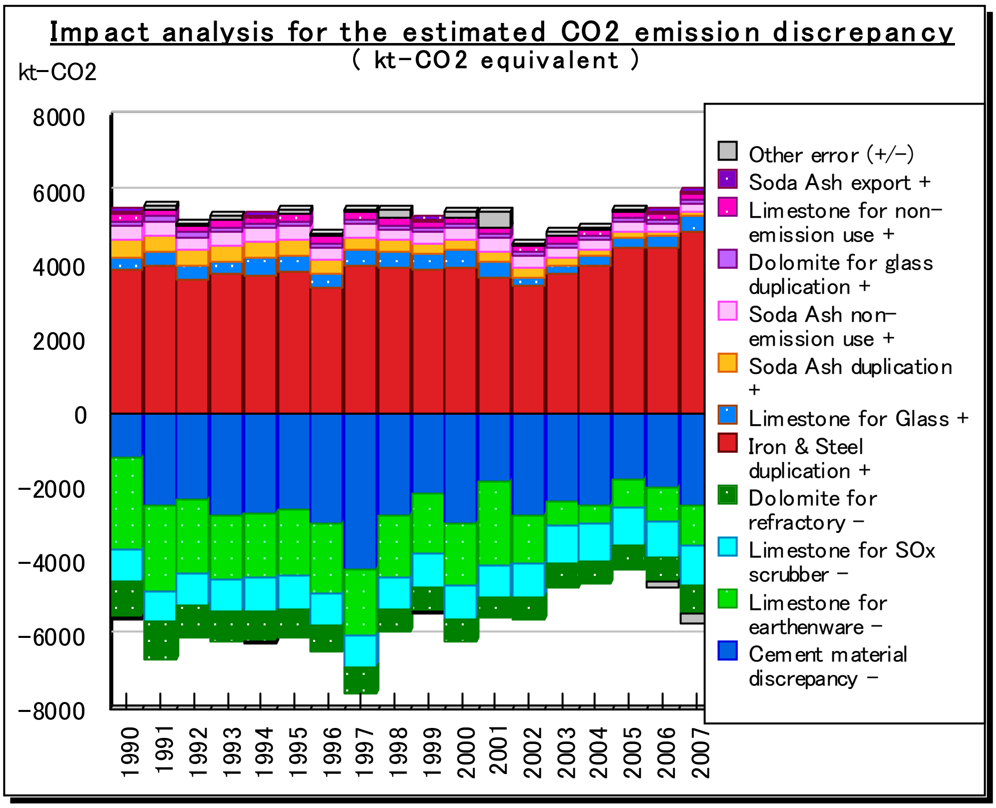
[Figure 4-1-3-1. Comparison of Limestone consumption by Industrial statistics for Soda Glass and sales amounts by Mineral Resources Production Statistics]



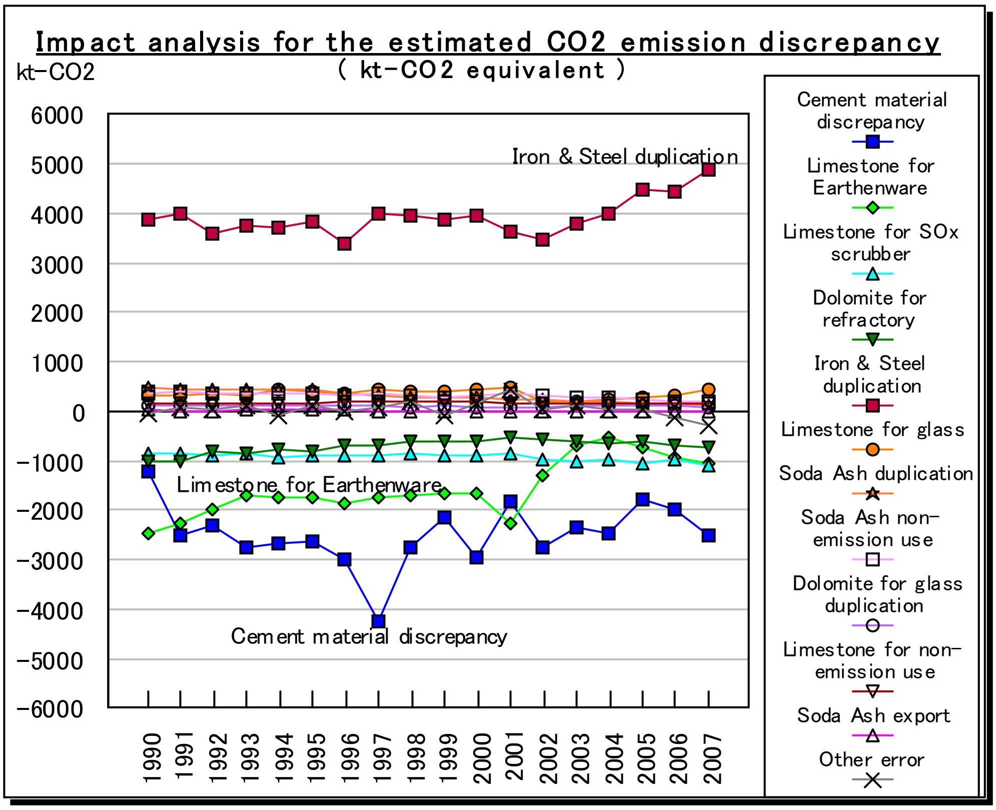
[Figure 4-1-3-2. Comparison of Dolomite consumption by Industrial statistics for Glass and sales amounts by Mineral Resources Production Statistics]



[Figure 4-1-5-1. Time series impact analysis for the quantitative discrepancies of Limestone and Dolomite origin CO_2 emission with present and new methodology



[Figure 4-1-5-2. Time series impact analysis for the quantitative discrepancies of Limestone and Dolomite origin CO_2 emission with present and new methodology



Appendixes

Appendix A. Estimation of Limestone and Dolomite consumption for material uses by time-series regression analysis

Here the author show the result of regression analysis and extrapoltion estimation for material consumpion data and so on that official Industrial statistics had been abolished and no data available now, using time series production data, past trends of consumption data or other available data.

The author recommends those data should be revised by accurate data as far as possible requesting cooperation of related industrial associations when quantifying the national greenhouse gas inventory.

Following tables show coefficients a0 to ai for the equations as follows, including trans logarithm equations;

$Y(t)$ (Target valiable) = Σ_i ($a_i * X_i(t)$ (explanatory variable)) + a_0(Constant) + $e(t)$ (Error term)

Timeseries variable as an explanatory variable is an arithmetic series from calendar year 1990.

Values in the pharensis ( ) shows p-value, characters in "Sgn." line means as follows; "***" for 99.0 per cent level significant, "**" for 95.0 per cent level significant, "*" for 90.0 per cent level significant and "-" for not siginificant.

1. Mineral Resource Production Statistics / Limestone, Dolomite for construction material use / Other construction material use sales

1-1. Limestone / Other consutruction material use sales / after calendar year 2000

	Road construction	Concrete material	Constant	R^2
ai,a0	-0.108	-0.367	+20286302	0.526
p-value	(0.185)	(0.043)	(0.000)	
Sgn.	--	**	***	

1-2. Dolomite / Other consutruction material use sales / after calendar year 2000

	Road construction	Concrete material	Constant	R^2
ai,a0	-0.243	+0.178	+19212	0.941
p-value	(0.003)	(0.064)	(0.649)	
Sgn.	***	*	--	

2. Chemical Industry Statistics / Soda Ash production and Soda Ash consumption for chemical material use

2-1. Soda Ash production / after 2001CY / Trans logalismic equation

LN	Glass production	Soda Ash production(-1)	Time series	Constant	R^2
ai,a0	-0.362	+0.754	-0.028	+8.776	0.949
p-value	(0.520)	(0.049)	(0.126)	(0.000)	
Sgn.	--	**	--	***	

2-2. Soda Ash consumption for chemical material use / after 2002CY / Trans logalismic equation

Soda material LN

LN	Time series	Constant	R^2
ai,a0	-0.703	+9.946	0.642
p-value	(0.002)	(0.000)	
Sgn.	***	***	

Cyclic compound LN

LN	Time series	Constant	R^2
ai,a0	-0.422	+9.003	0.866
p-value	(0.000)	(0.000)	
Sgn.	***	***	

Non organic chemicals

	Time series	Constant	R^2
ai,a0	-2146.	+84592.	0.638
p-value	(0.002)	(0.000)	
Sgn.	***	***	

Oil and fat products

	Time series	Constant	R^2
ai,a0	+1246.	+82626.	0.124
p-value	(0.259)	(0.000)	
Sgn.	--	***	

3. Cement and ceramics statistics / Glass material consumption / Limestone, Dolomite and Soda Ash

3-1. Soda Ash / Glass material consumption / after 2005CY / Trans logalismic equation

LN	Float Glass	Glass Fiber	Scrap Glass	Consumpion(-1)	Time series	Constant	R^2
ai,a0	+1.057	+0.176	+0.106	+0.233	+0.003	-10.58	0.973
p-value	(0.000)	(0.449)	(0.386)	(0.128)	(0.554)	(0.000)	
Sgn.	***	--	--	--	--	***	

3-2. Dolomite / Glass material consumption / after 2005CY / Trans logalismic equation

LN	Float Glass	Glass Fiber	Scrap Glass	Consumpion(-1)	Time series	Constant	R^2
ai,a0	+0.992	+0.433	+0.058	+0.174	+0.005	-10.40	0.955
p-value	(0.000)	(0.104)	(0.808)	(0.237)	(0.369)	(0.000)	
Sgn.	***	--	--	--	--	***	

3-3. Limestone / Glass material consumption / after 2005CY / Trans logalismic equation

LN	Float Glass	Glass Fiber	Scrap Glass	Consumpion(-1)	Time series	Constant	R^2
ai,a0	+2.905	--	--	--	--	-30.48	0.906
p-value	(0.000)					(0.000)	
Sgn.	***					***	

4. Iton and Steel, Non-ferrous Metal, Metal Product Statistics / Limestone for Iron and Steel material use consumption

4-1. Limestone / Sintering material / after 2004CY / Trans logalistic equation

LN	Pig iron	Consumption(-1)	Time series	Constant	R^2
ai,a0	+0.537	-0.184	-0.012	+9.675	0.866
p-value	(0.002)	(0.361)	(0.000)	(0.000)	
Sgn.	***	--	***	***	

4-2. Limestone / Pig iron material / after 2004CY / Trans logalistic equation

LN	Pig iron	Consumption(-1)	Time series	Dummy(1 after 2001CY)	Constant	R^2
ai,a0	+2.420	-0.100	-0.043	+0.666	-30.65	0.832
p-value	(0.090)	(0.649)	(0.037)	(0.008)	(0.000)	
Sgn.	*	--	**	***	***	

4-3. Limestone / Fello-alloy (FA) / after 2004CY / Trans logalistic equation

LN	FA production	Consumption(-1)	Time series	Dummy(1 for 2001,2CY)	Constant	R^2
ai,a0	+1.491	-0.355	-0.035	+0.579	-5.140	0.877
p-value	(0.018)	(0.154)	(0.026)	(0.000)	(0.000)	
Sgn.	**	--	**	***	***	

4-4. Limestone / Crude steel (CS) / after 2004CY / Trans logalistic equation / N - normal, S - special

LN	OCF NCS	OCF SCS	GVF NCS	GVF SCS	Time series	Constant	R^2
ai,a0	+1.156	-0.237	+4.529	-3.006	+0.081	-34.10	0.844
p-value	(0.424)	(0.814)	(0.067)	(0.056)	(0.012)	(0.000)	
Sgn.	--	--	*	*	**	***	

4-5. Limestone / Other use / after 2004CY

	Sintering	FA	Pig iron	Crude steel material	Crude steel	Constant	R^2
ai,a0	-0.005	-0.038	-0.019	+0.023	+0.001	-29882.	0.983
p-value	(0.302)	(0.401)	(0.833)	(0.144)	(0.006)	(0.000)	
Sgn.	--	--	--	--	**	***	

4-6. Quick Lime / Sintering / after 2004CY / Trans logalistic equation (Reference)

LN	Pig iron	Consumption(-1)	Time series	Constant	R^2
ai,a0	+2.837	-0.047	-0.018	-37.87	0.859
p-value	(0.000)	(0.761)	(0.005)	(0.000)	
Sgn.	***	--	***	***	

4-7. Quick Lime / Pig iron material / after 2004CY / Trans logalistic equation (Reference)

LN	Pig iron	Consumption(-1)	Time series	Dummy(1 for 2001,2CY)	Constant	R^2
ai,a0	-2.039	+0.030	+0.019	-0.410	+47.37	0.817
p-value	(0.059)	(0.864)	(0.121)	(0.001)	(0.000)	
Sgn.	*	--	--	***	***	

4-8. Quick Lime / Fello-alloy (FA) / after 2004CY (Reference)

	FA production	Consumption(-1)	Constant	R^2
ai,a0	+0.002	+0.866	-1740.	0.961
p-value	(0.914)	(0.000)	(0.000)	
判定	--	***	--	

4-9. Quick Lime / Crude steel (CS) / after 2004CY / N - normal, S - special (Reference)

	OCF NCS	OCF SCS	GVF NCS	GVF SCS	Consumption(-1)	Time series	Constant	R^2
ai,a0	+0.024	+0.011	-0.033	+0.197	+0.080	-33044.	+852299.	0.946
p-value	(0.041)	(0.744)	(0.385)	(0.026)	(0.685)	(0.058)	(0.000)	
判定	**	--	--	**	--	*	***	

4-10. Quick Lime / Other use / after 2004CY / Trans logalistic equation (Reference)

LN	Sintering	FA	Pig iron	Crude steel material	Crude steel	Constatnt	R^2
ai,a0	-3.400	-0.768	+1.225	-13.34	+20.64	-127.26	0.782
p-value	(0.066)	(0.220)	(0.012)	(0.026)	(0.002)	(0.000)	
判定	*	--	**	**	***	***	

5. Iton and Steel, Non-ferrous Metal, Metal Product Statistics / Dolomite and Calcined Dolomite for Iron and Steel material use consumption

5-1. Dolomite / Sintering material / after 2004CY

	Pig iron	Consumption(-1)	Time series	Dummy(1 for 1992.3,9CY)	Constant	R^2
ai,a0	+0.030	+0.030	+12940.	+179897.	+9.675	0.866
p-value	(0.021)	(0.915)	(0.092)	(0.005)	(0.000)	
Sgn.	**	--	*	***	***	

5-2. Dolomite / Galvanic Furnace (GVF) material / after 2004CY Trans logalistic equation

LN	GVF NCS	Consumption(-1)	Time series	Constant	R^2
ai,a0	+2.011	+0.410	-0.011	-28.75	0.823
p-value	(0.068)	(0.123)	(0.512)	(0.000)	
Sgn.	*	--	--	***	

5-3. Dolomite / Other use / after 2004CY

	Crude Steel	OCF SCS	Time series	Constant	R^2
ai,a0	+0.000	+0.023	+6861.	-218298.	0.930
p-value	(0.959)	(0.030)	(0.055)	(0.000)	
Sgn.	--	**	*	***	

5-4. Calcined Dolomite / Oxygen Converter Furnace (OCF) / after 2004CY (Reference)

	OCF NCS	OCF SCS	Consumption(-1)	Constant	R^2
ai,a0	+0.006	-0.001	+0.922	-328331.	0.855
p-value	(0.148)	(0.923)	(0.000)	(0.000)	
Sgn.	--	--	***	***	

5-5. Calcined Dolomite / Galvanic Furnace (GVF) / after 2004CY (Reference)

LN	GVF NCS	GVF SCS	Consumption(-1)	Time series	Dummy(1 for 1996-2000)	Constant	R^2
ai,a0	+0.231	+0.365	+0.488	+0.012	+0.433	-4.631	0.964
p-value	(0.811)	(0.578)	(0.003)	(0.264)	(0.000)	(0.000)	
Sgn.	--	--	***	--	***	***	

Appendix B. Carbon dioxide equivalent weight conversion table for Limestone, Dolomite and their derivatives

1. Atomic weight (IUPAC (2009))(g)

Ca	Calsium	40.078
Mg	Magnesium	24.305
Na	Sodium	22.990
H	Hydrogen	1.008
C	Carbon	12.011
O	Oxygen	15.999

2. Molecular weight Limestone, Dolomite and related derivatives (g/mol)

$CaCO_3$	Limestone	100.087
CaO	Quick Lime	56.077
$Ca(OH)_2$	Slaked Lime	74.093
Na_2CO_3	Soda Ash	105.988
$CaMg(CO_3)_2$	Dolomite	184.401
$CaO \cdot MgO$	Calcined Dolomite	96.382
(CO_2	Carbon Dioxide	44.010)

3. Conversion factor from molecular weight to CO_2 weight equivalent (gCO_2/g)

$CaCO_3$	Limestone	0.4397
CaO	Quick Lime	0.7848
$Ca(OH)_2$	Slaked Lime	0.5938
Na_2CO_3	Soda Ash	0.4152
$CaMg(CO_3)_2$	Dolomite	0.4773
$CaO \cdot MgO$	Calcined Dolomite	0.8413

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