Materials Flow Analysis and Modeling to Establish a Zero-Emission Network in Regional Areas

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Abstract

To reduce pollution load into environment, entire human activities in a regional scale, such as industrial production, social systems and our daily life should be evaluated based upon the material and energy flows. Approaches to minimize the emission are categorized into three groups. First is to minimize the materials consumption in industry not been converted into products by refining each unit process of the plant. Alternative process on different principles may be required to eliminate or change the characteristics of emissions. Second is to recycle or reuse the unused materials of a process among factories and industries by cascade-connection of the process and by the industrial clustering. Third is to establish appropriate materials flow systems in a regional scale. First step to actualize the emission minimization is to analyze the material and energy flows in the production process and in the regional area. In this paper we propose a methodology to clarify the materials flow in a regional area by using statistic data such as I/O table and that to construct a material flow networking in the area including industries. Discharge of waste materials from industries in a regional area has been estimated using the methodology.

Concept and Methodology to Minimize Emissions from Industry and in Regional Area

Figure 1 shows the step by step procedures to actualize industrial and regional zero emission. Well, it should be noted that it is impossible to actualize a real zero-emission. The term "zero-emission" reveals the transaction and countermeasures toward emission minimization in a focused production process or in a regional area.

What we have to do first is to analyze the materials and energy flows in industrial process and in a regional area. The information obtained by those investigations should be transferred to whom it may concern in zero-emission by constructing database. Appropriate scenario toward zero emission should be prepared and presented to the concerned people together with the expected effect of the countermeasure proposed in the scenario. This will be followed by a relating legislation or provision of economical incentives, which will promote the actualization of countermeasures in the scenario. Database

on emissions from industries and our daily life based on the materials flow will be of use to understand the present conditions and thus the problems in emissions into environment, and the consumptions of resources and energy. Based upon the information on emissions and the associated problems and that on technologies those will be applied for reduction, treatment and disposal of emissions. Prediction of emission from the industries and the daily life after the countermeasure is taken by introducing new and alternative concept and technologies. New life style, production process, social system and so on should be clearly shown to the people concerned. Additional legislation may be required to establish new social system. Economical incentives may also be required to accelerate the incorporation of new technologies and process into the industries. Energy and material synergetic process, cascade use of materials, process networking and thus industrial clustering are required in industries for complete use of resources and thus for emission minimization.

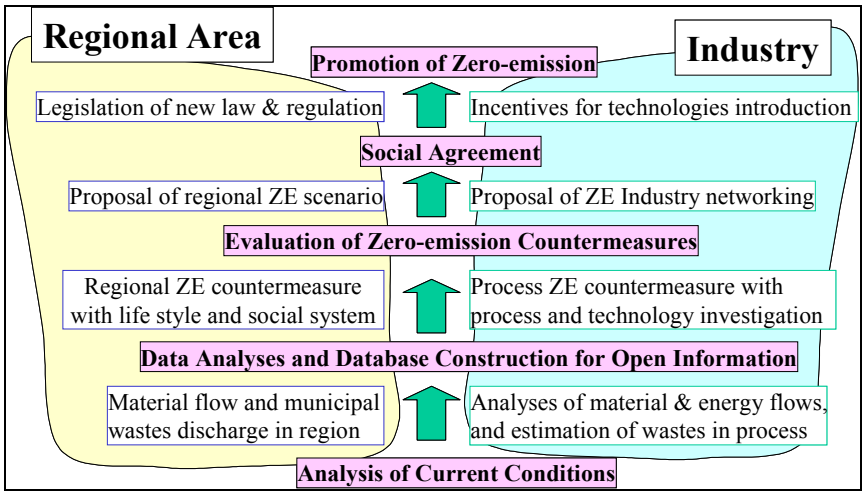

Fig.1 Method to establish zero-emission in industry and regional scale

Analysis of Material Flow in Regional Area toward Zero-Emission

Regional zero-emission requires not only emission reduction in industrial process but also minimization of the emission from the regional area. Material flows, such as products and raw materials, and those in processing, consumption, disposal and recycle are required to investigate to give appropriate information to establish countermeasures for emission minimization. More over materials exchange across the border of the focused regional area are required as well. Materials flow is categorized into three such as valuable (products and raw materials), wasted and renewed. There are no explicit statistics data can be used for the analysis of material flow in a regional area. Therefore the materials flow in regional area must be analyzed using input-output table (I-O table), which shows the cash flow among industries, and the Investigation Report of Industrial Wastes by local government published every five years (Industrial Wastes Report, hereafter). The Industrial Wastes Report includes the discharge, treatment and disposal of wastes from industries in each prefecture.

We proposed a method to analyze regional material flow derived from the statistics as shown in Figure 2. The I-O table shows inter-relation among all industries in cash flow and makes the all industries classify into several sectors (coarse classification is 38 groups, the medium is 93 and that of detailed is 186). Problems in using I-O table is that every five years investigated results in the table may not reflect the on-going industrial activities.

Onset of the conversion of I-O table into materials flow is to pick-up the relating industries to that fo-

cused, and the second is to determine the price of materials and products being traded in the market among those industries. The weighed-average price of the products and materials can be determined from the observation of relating market. Repeating this step clarifies the material flow around the focused sector/industry. It can be supposed that the amount of difference between input and output after subtracting the energy consumption, which is discharged as carbon dioxide into environment, is due to the wasted materials not being converted to products.

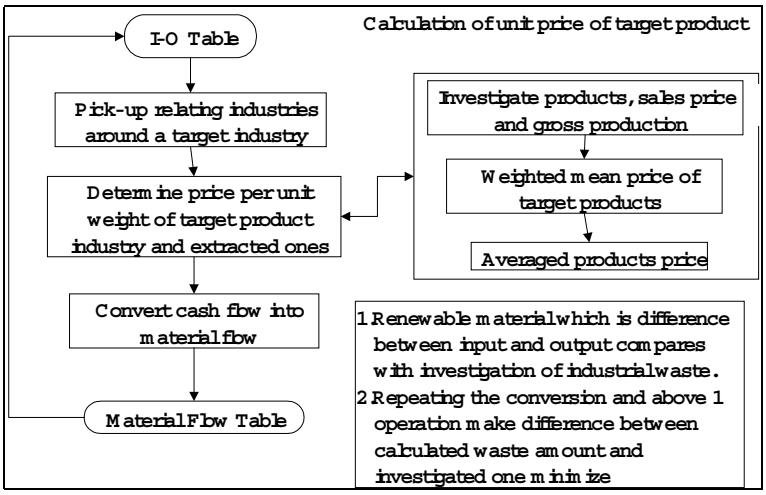

Fig.2 Procedure to convert I-O table to material flow table

Material flow around steel industries in Aichi prefecture was illustratively calculated and shown in Fig.2 using I-O table of Aichi prefecture. Import from other prefectures is 37 % of total input to the steel industries, while the output is about 52% of the total production. Main input is iron ore, scrap iron, limestone and so on.

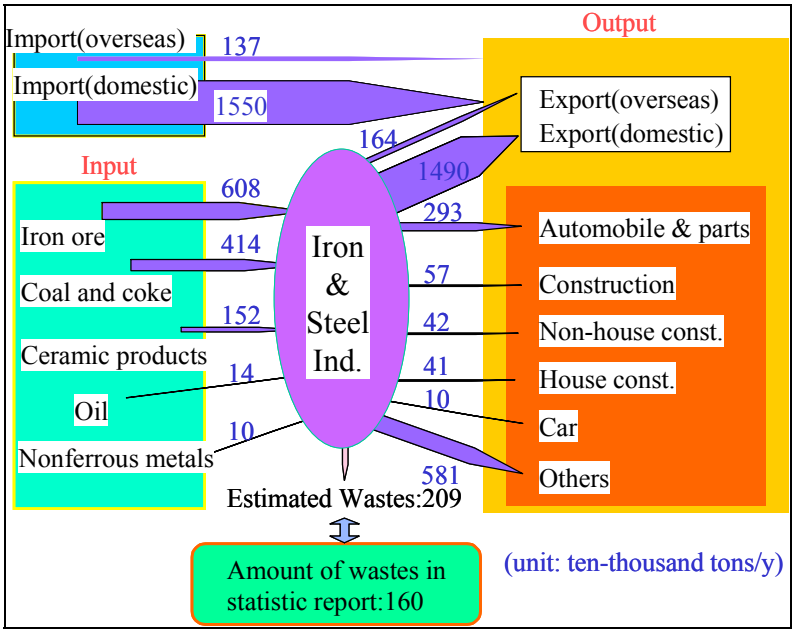

Fig.3 Material balance of steel industries in Aichi prefecture

Profile of Materials Flow in Regional Area

Table 1 shows the discharge of waste materials, their disposal, intermediate treatment for volume reduction and/or reclamation. Five million tons of waste materials is discharged form industries in Aichi prefecture, and as much as 4.5 million tons of discharged materials are recycled with or without intermediate treatment. This high recycle rate in this prefecture is due to the complete reuse of blast furnace slag as aggregate for constructions of road and fabrics. Final disposal is as little as about 0.6 million tons. Note that the amount of industrial wastes discharge reported by the Industrial Wastes Report was 5.1 million tones, while that estimated by the proposed method in the above was 4.25 million tons. The amount of industrial wastes discharge can be estimated by the proposed method.

Table 1 Waste materials flow of steel industry in Aichi prefecture.
□Unit□10,000 t/y□

<table>
<tr><td rowspan="5">Total discharge in industry 510.8</td><td rowspan="4">Wastes 160.3</td><td colspan="2">Final disposal 48.5</td></tr>
<tr><td colspan="2">Volume reduction 11.8</td></tr>
<tr><td colspan="2">Others 0.2</td></tr>
<tr><td>Reclamation 99.8</td><td rowspan="2">Recycle 450.3</td></tr>
<tr><td colspan="2">Valuable materials to be recycled 350.5</td></tr>
</table>

Figure 4 shows profile of material flow in Aichi prefecture estimated from the investigation report on industrial waste. Total amount of industrial wastes discharged in Aichi prefecture is as much as 17million tons per year. Where 57 % of the wastes are discharged from manufacturing and construction industries and livestock farm. Industrial wastes from manufacturing industries and the livestock farm takes large part of the total amount compared to other prefectures. Final disposal of the wastes, which is 3 million tones per year, is 9% of the total wastes discharge. The livestock wastes may be converted to compost for agricultural use. However excess application of N and P into farmyard often brings about the serious pollution of groundwater and river.

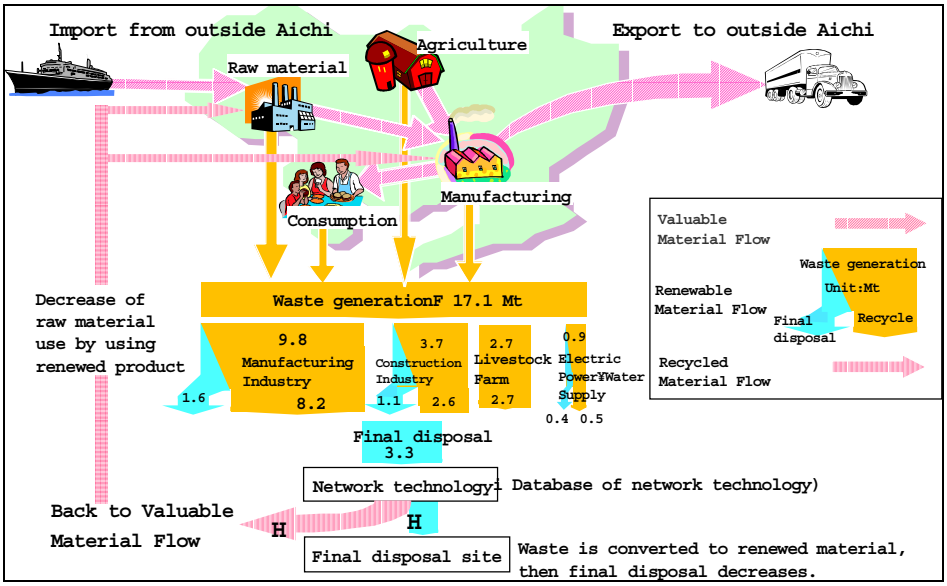

Fig.4 Profile of material flow in Aichi prefecture together with raw and wastes materials and products.

Database of Materials and Technologies for Industrial Clustering in Regional Area

In this paper, as a first step to construct material cycle network among industries for regional zero emission, we proposed a method to estimate the materials flow in the regional area using I/O table and Industrial Wastes Report. Here we also propose a network simulator together with database of wastes materials and reclamation technologies. This method will be applied for the networking of industries and production processes and cascade connect of production process in series for complete utilization of resources and for saving energy by establishing a synergetic process. Figure 5 shows a concept of industrial and process networking together with database of recycling technologies and discharged materials in a regional area. Industrial clustering and networking of processes requires database of discharged materials, which is available for raw material of other process, and that of applicable technologies for reclamation of wastes. Database of raw materials used in each industrial company is required to interlink the industries in the focused regional area. Finally, the effect of materials flow networking proposed for the focused regional area should be quantitatively evaluated to clarify how the networking is effective to minimize the emissions.

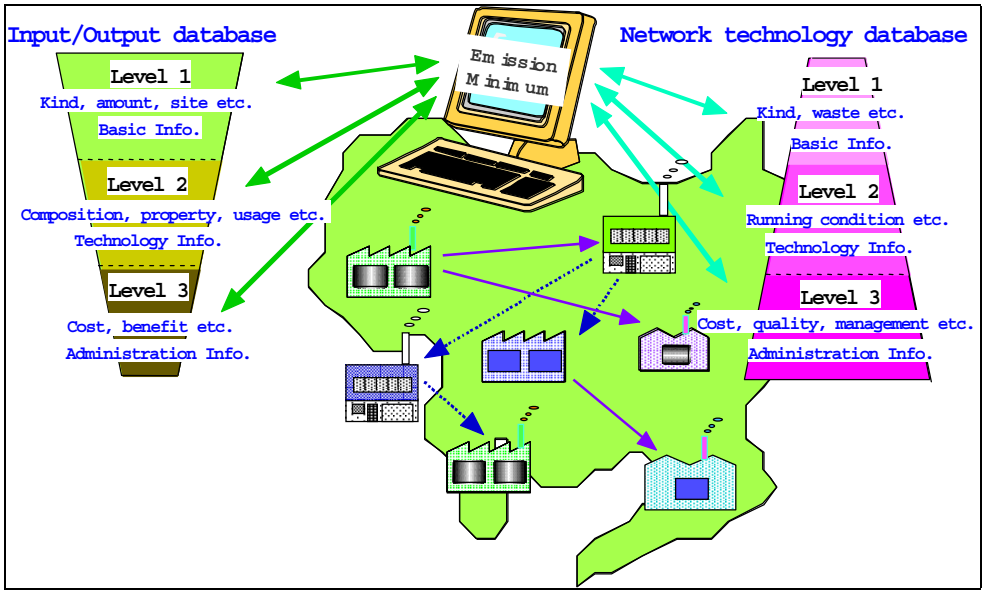

Fig.5 Database for industrial clustering and process networking

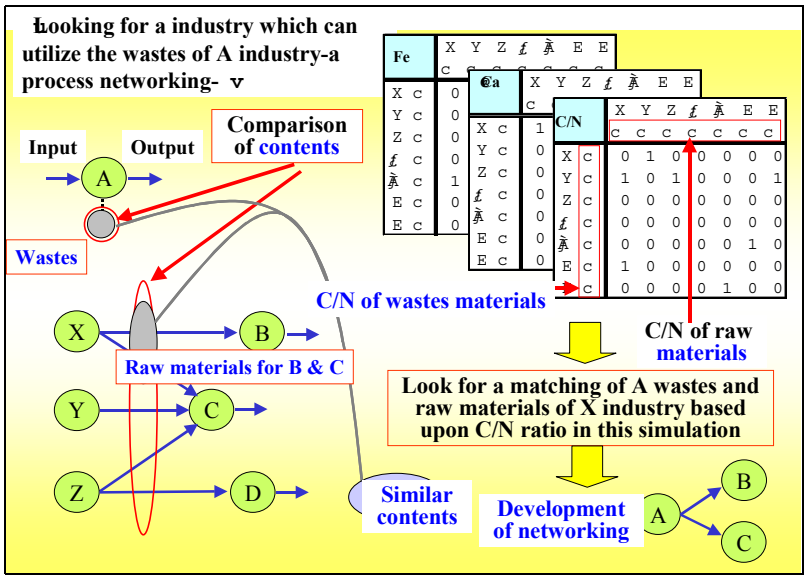

Fig.6 Procedure to Connect Process and Process based on Contents of Materials

To develop a materials flow network by connecting the industrial processes, database as shown in Fig.5 is required to look for candidates, which can accept unused wastes materials as one of the raw materials of the industry. Information on contents in unused wastes materials is essential to investigate the possibility of materials networking. Procedure illustratively shown in Fig.6 represents a example in which information on C/N ratio, other contents such as Ca, Fe, etc. are used to seek an acceptor of the wastes materials. Appropriate database of unused materials is very much helpful to establish process - process or industry - industry networking. It should be noted that the database on available technologies for resources reclamation or wastes regeneration, which is used to convert wastes materials to value added raw materials to be utilized in the other production industry.

Zero-Emission Scenarios and Implementation - as a Conclusive Summary

Observed and collected data can be utilized to establish a process to process networking based upon information of contents of wastes materials, while statistic data of materials flow determined from I/O table can be used to clarify the potential of trans-industry networking. By merging these results, a hypothetical material flow network can be designed. It is needless to say that individual activity for emission minimization in each production industry is essential as shown in the top of Fig.6. Effect of transactions including material flow networking, individual efforts and so on should be quantitatively evaluated to clarify how effectively emissions in the focused area will be reduced. Total quality management, scheduling of materials supply, construction of database, etc. are required to operate such material flow network. Economical incentives and juristic system are necessary after the public consensus for the implementation of zero-emission scenario.

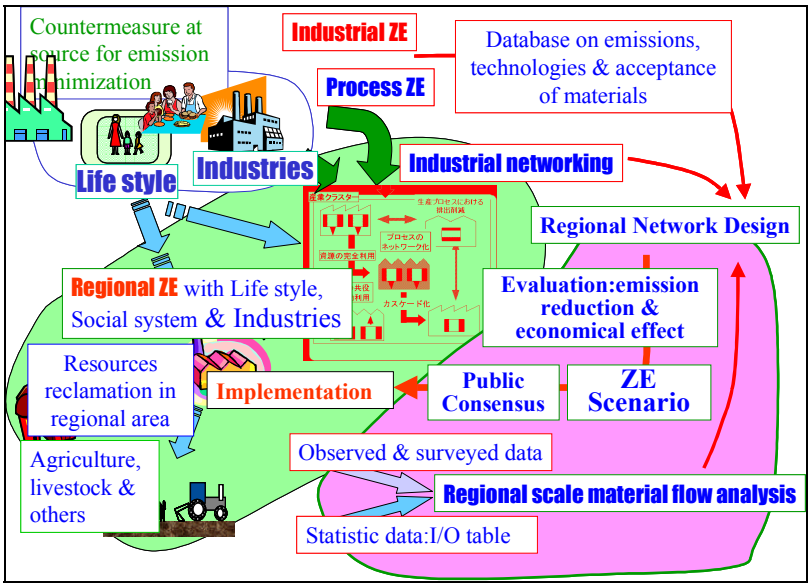

Fig.6 Procedure to develop zero-emission scenario and implementation.

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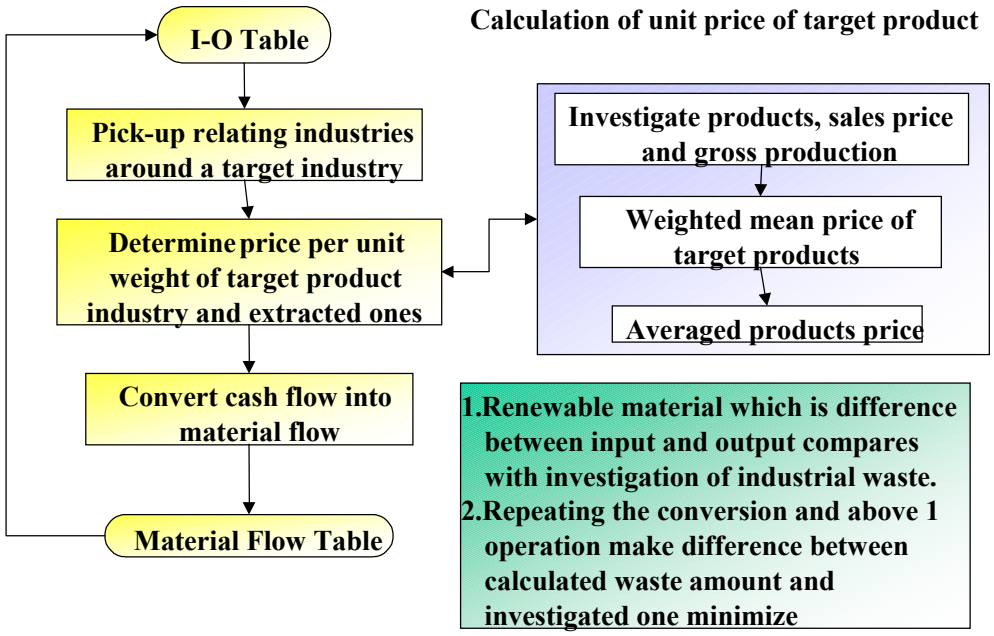
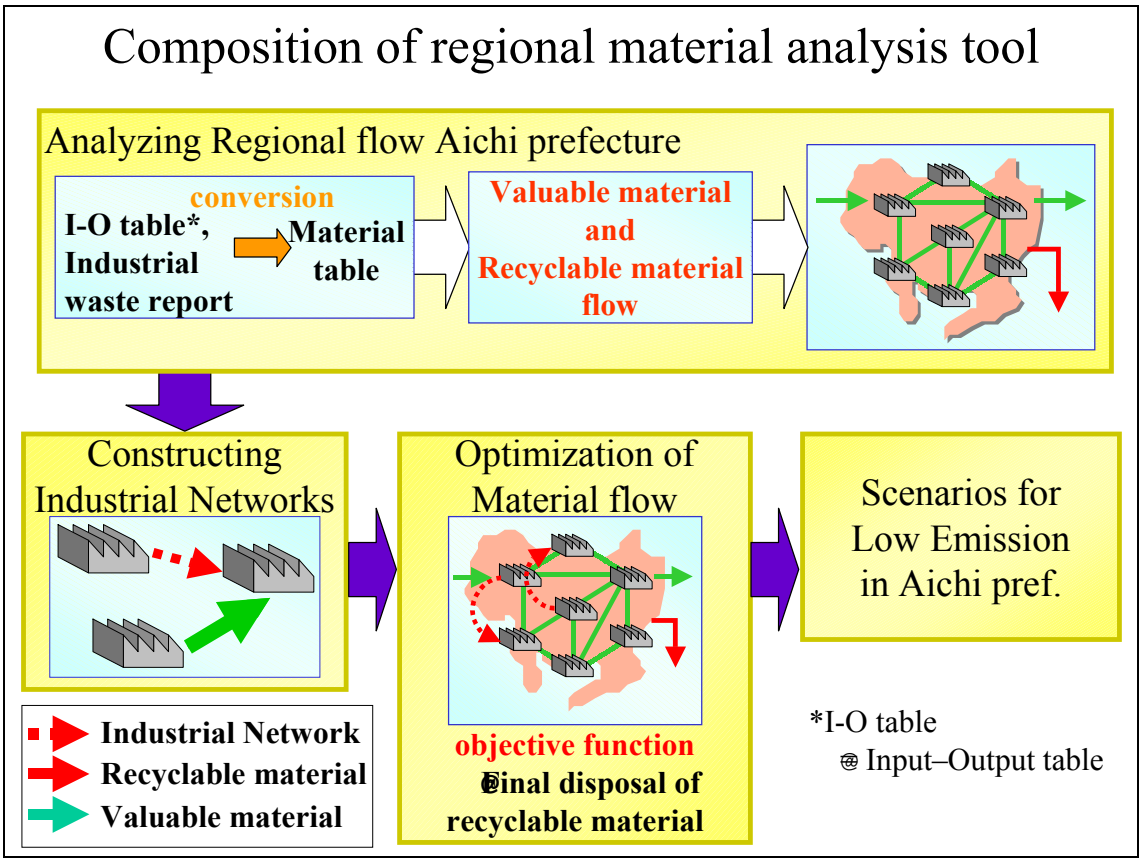
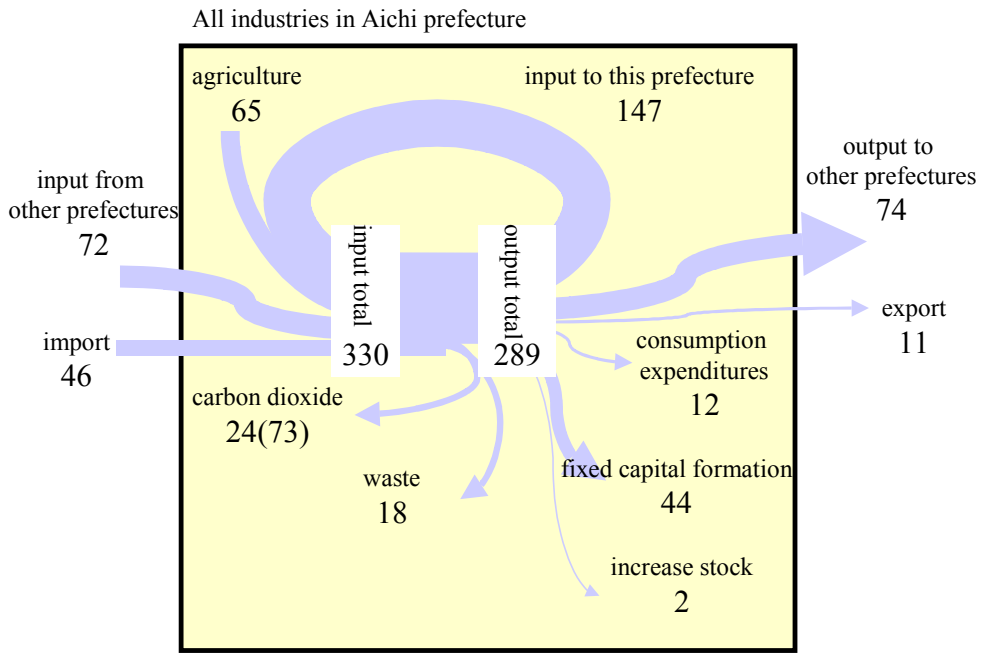
- Aichi prefecture, Input-Output Table of Aichi Pref., 1995
- Aichi prefecture, Survey report on Industrial Waste of Aichi Pref., 1996

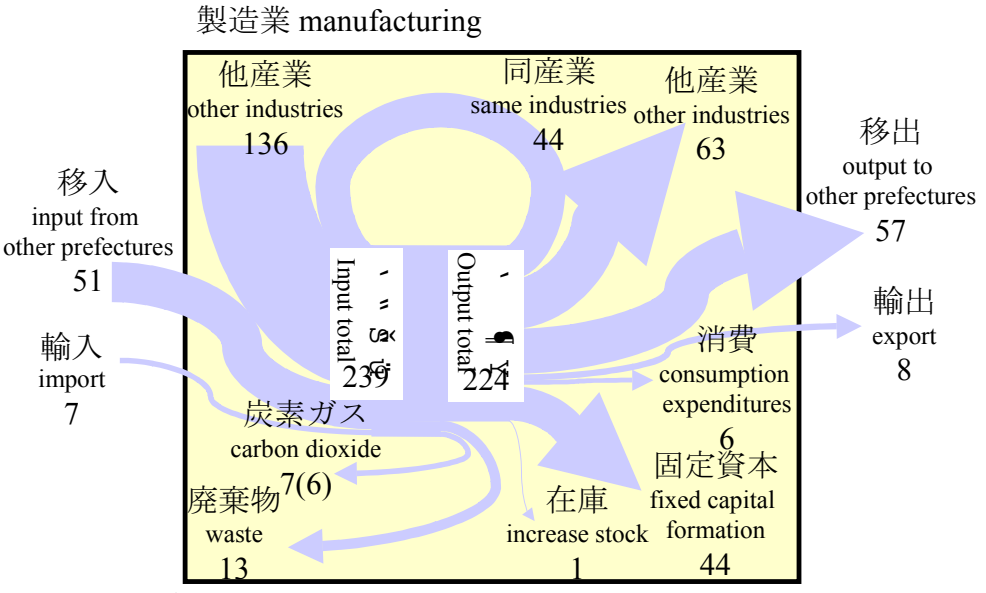


Procedure to convert I-O table to material flow table





Material flow of all industries
in Aichi Prefecture



単位：10^6t　※一部の食料品、飲料･飼料･たばこは除く。
＊炭素ガス量は使用された石油･石炭量で、
()内はその炭素含有量より炭酸ガス量に換算したもの

Material flow of all manufacture industries
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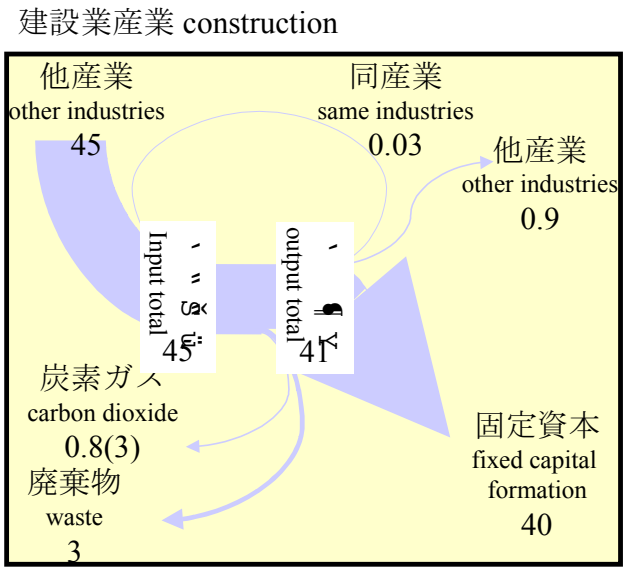

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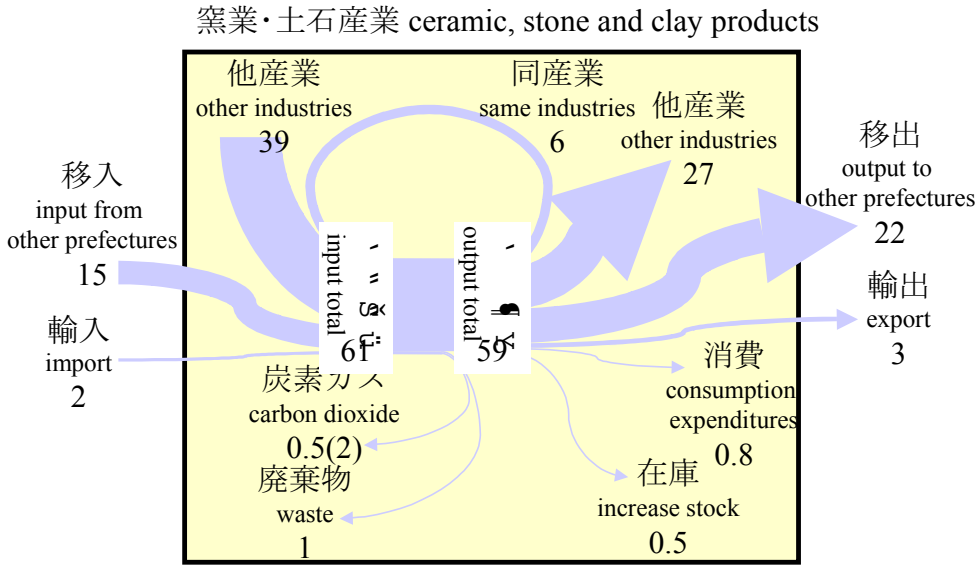
Material flow of construction industries in Aichi Prefecture



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Material flow of ceramic, stone and clay products industries in Aichi Prefecture