

## Sustainability Indicators related to Energy and Material Flow

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This study analyzed energy and material flow in individual regions and industrial sectors to evaluate a regional and industrial sustainability. Several life cycle approaches to quantify environmental efficiency related to energy and material flow were investigated as the application of life cycle tools in emerging markets, including services and the public sector. The regions included all 47 Japanese prefectures and each prefectural data considered 16 industrial categories based on the national physical distribution census and national input-output tables in 1995.

In using the life cycle carbon dioxide emission as a typical environmental loading item, sustainability indicators related to energy and material flow are extracted from the following equation.

$$CO_2 = \frac{CO_2}{energy} \times \frac{energy}{flow} \times \frac{flow}{GDP} \times GDP$$

in which,

*CO<sub>2</sub>*: carbon dioxide emission (direct or life-cycle)  
*energy*: energy consumption or primary energy supply  
*flow*: total material input or total material flow  
*GDP*: gross domestic product or industrial product amount

This is a kind of identity of the energy and material flow in regional economic system. Energy flow consists of the primary energy supply and the recycled energy recovery as material flow consists of the primary resources and the recycled. CO<sub>2</sub> reduction with economic growth (increasing GDP) should need a remarkable reduction of “CO<sub>2</sub>/energy”, “energy/flow” and “flow/GDP” as an advanced sustainability indicator. Those ratios were compared in each region and industrial category.

The ratio of primary energy supply to total material input at service industry varied between 0.1 and 0.5 [TOE/10<sup>3</sup>ton] for 47 prefectures. Finally several relationships between “energy/flow” and some regional and/or industrial characteristics could be obtained such as regional population, distance from major markets and so on.