Sustainability Indicators related to Energy and Material Flow

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Backgrounds

Toward a sustainable society considering "trilemma" between energy/resource , environment and economy
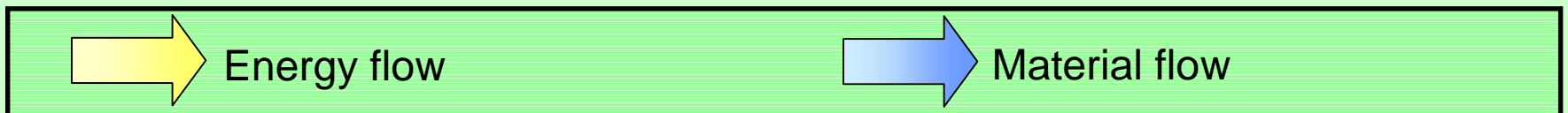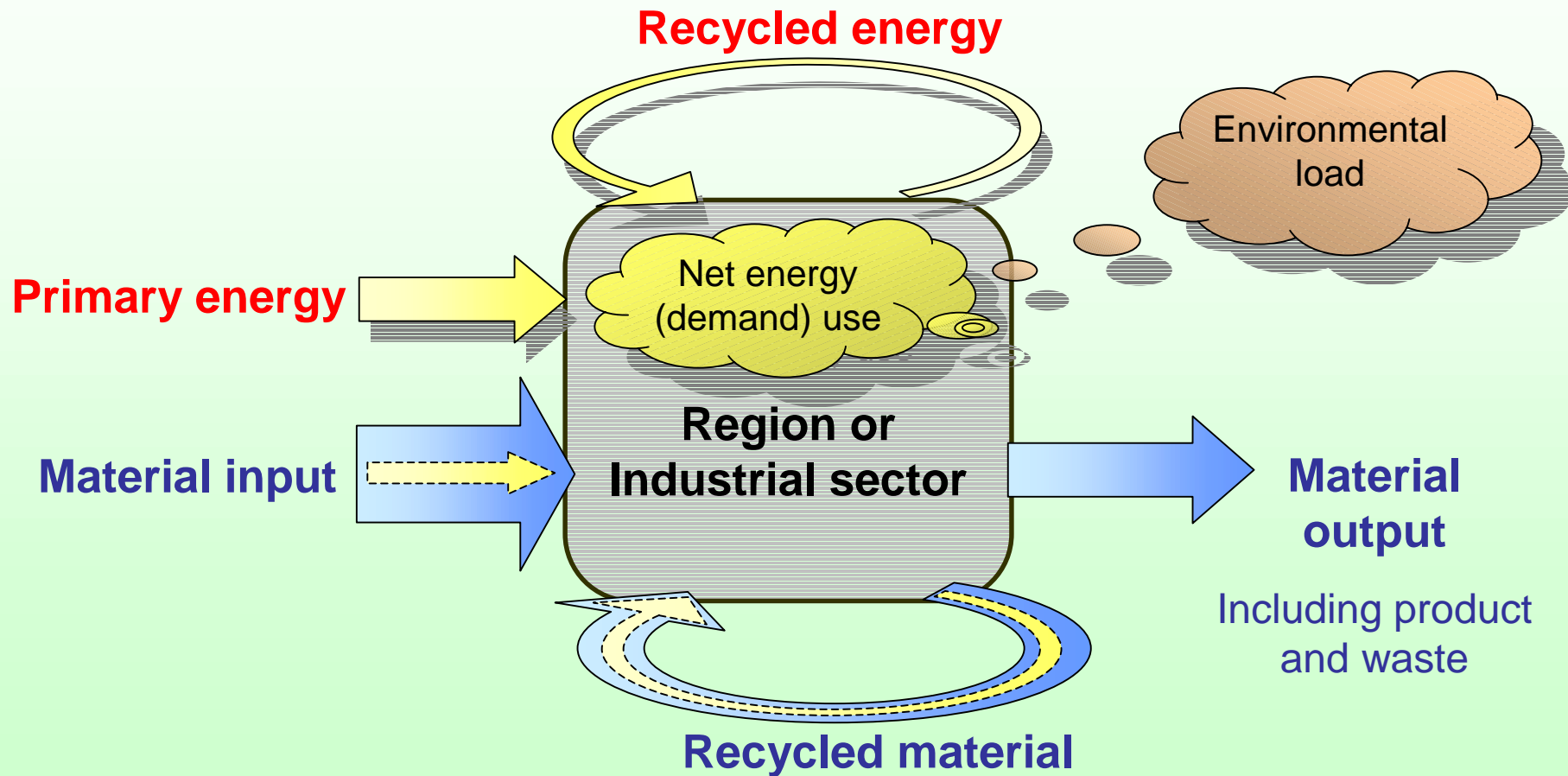
Objectives

Eco-efficiency evaluation as sustainability Indicator used for environmental management

#1 analyzing energy flow characteristics in detail

#2 combining energy flow and material flow

Estimating energy and material flows in each region and industrial sector to evaluate regional and industrial eco-efficiency

Recycled energy

Environmental load

Primary energy

Net energy (demand) use

Material input

Region or Industrial sector

Material output

Including product and waste

Recycled material

| Energy flow | Material flow |

HOKKAIDO

KYOTO

TOKYO

OSAKA   AICHI

OKINAWA

47 prefectures in Japan

Population:
0.6 - 12 (avg. 2.7) millions

Area:
1.9 - 83 (avg. 7.8) $10^3 km^2$

Distance from Tokyo: up to 2,200 km

Applied Data

Year	1995
Region	Japanese all 47 prefectures
Industrial 16 sectors	agriculture, mining, food, fiber, pulp, chemical, coal and petrol, cement, steel, nonferrous, metal, metal, other industry, construction, energy supply, transport, service and commercial
Source	*National physical distribution census **National and prefectural input-output tables *** Embodied Energy and Emission Intensity Data (CO_2, NO_x, SO_x, SPM) for Japan ****Comprehensive Energy Statistics

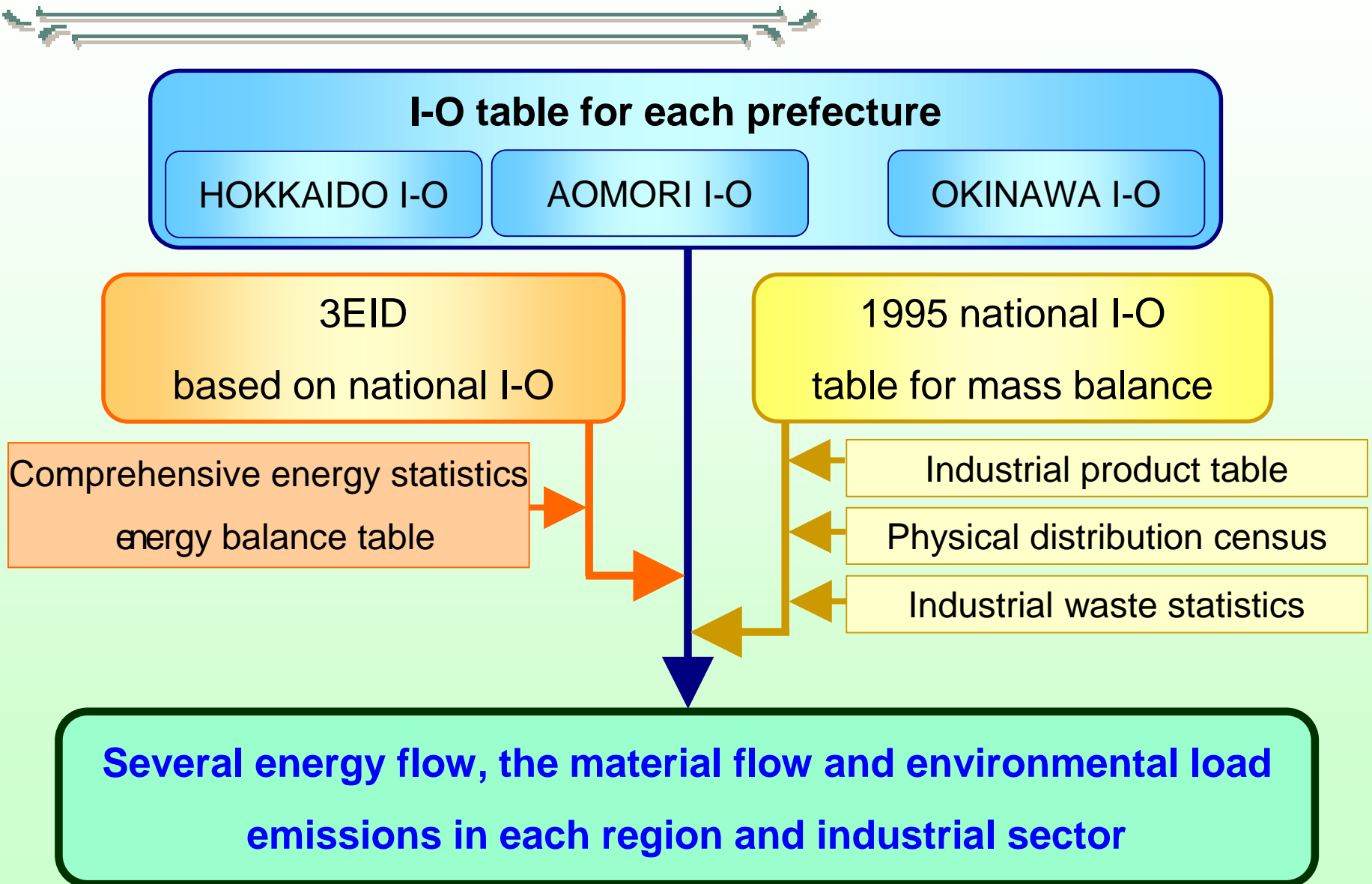*Ministry of Land, Infrastructure and Transport   **Ministry of Public Management

***National Institute for Environmental Studies   ****The Institute of Energy Economics

Calculation flow

I-O table for each prefecture

HOKKAIDO I-O | AOMORI I-O | OKINAWA I-O

3EID based on national I-O

1995 national I-O table for mass balance

Comprehensive energy statistics energy balance table

Industrial product table

Physical distribution census

Industrial waste statistics

Several energy flow, the material flow and environmental load emissions in each region and industrial sector

Analyzing energy flow characteristics in detail

Recycled energy:

Novel energy use by recycling waste including biomass and tire waste

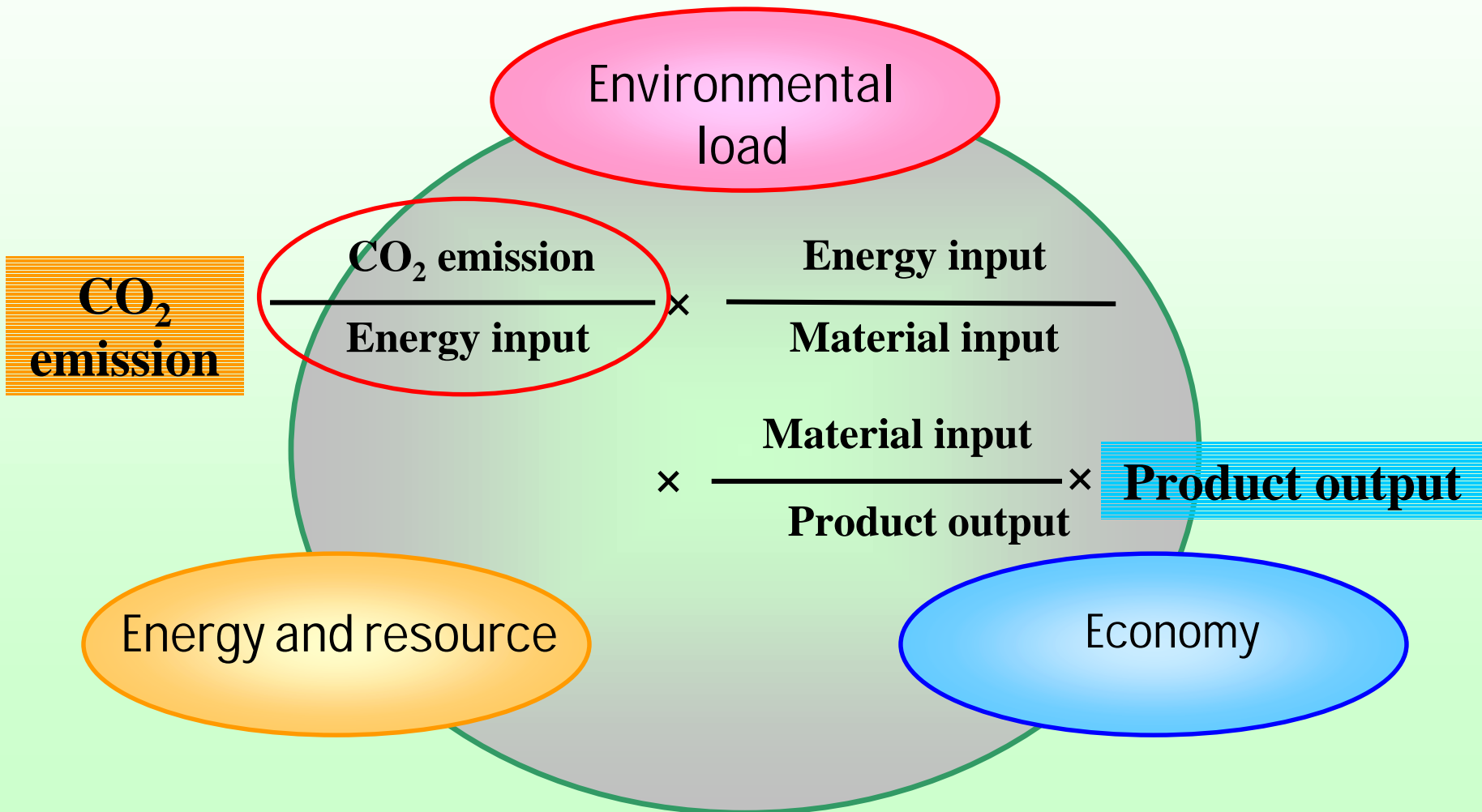energy demand   t   energy supply   t

net energy use	gross energy supply	primary energy	fossil fuel	petrol
				coal
				LNG
			nuclear power	uranium
			renewable energy	hydro and geothermal
				solar and wind
lost energy			recycled energy	waste

Sustainability in energy and material flow

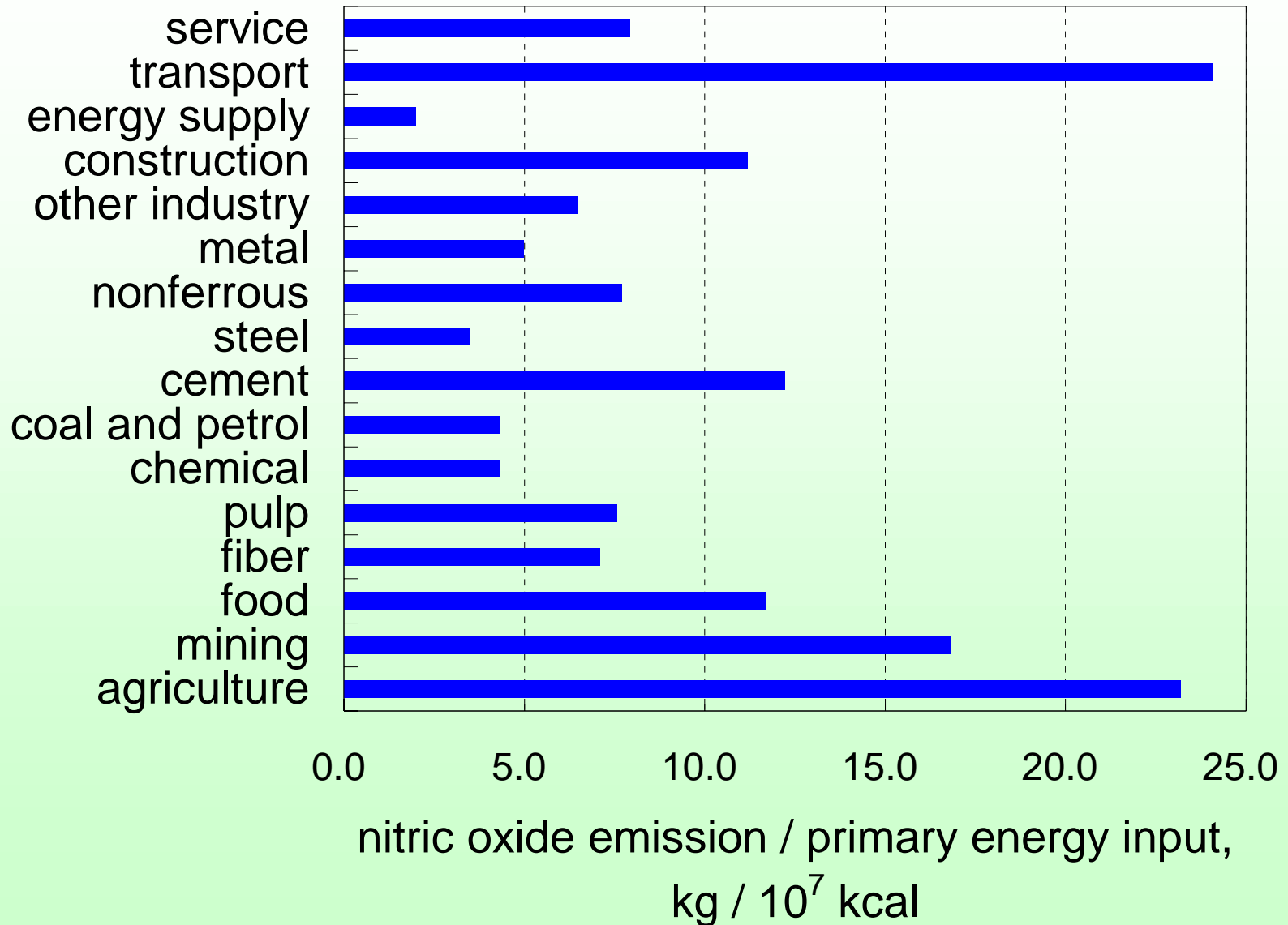… considering trilemma between environment, energy and economy

Environmental load

CO_2 emission

Energy and resource

Economy

$$\frac{CO_2 \text{ emission}}{\text{Energy input}} \times \frac{\text{Energy input}}{\text{Material input}} \times \frac{\text{Material input}}{\text{Product output}} \times \text{Product output}$$

Ratio of carbon dioxide emission to primary energy input

carbon dioxide emission / primary energy input, t-c / 10^7 kcal
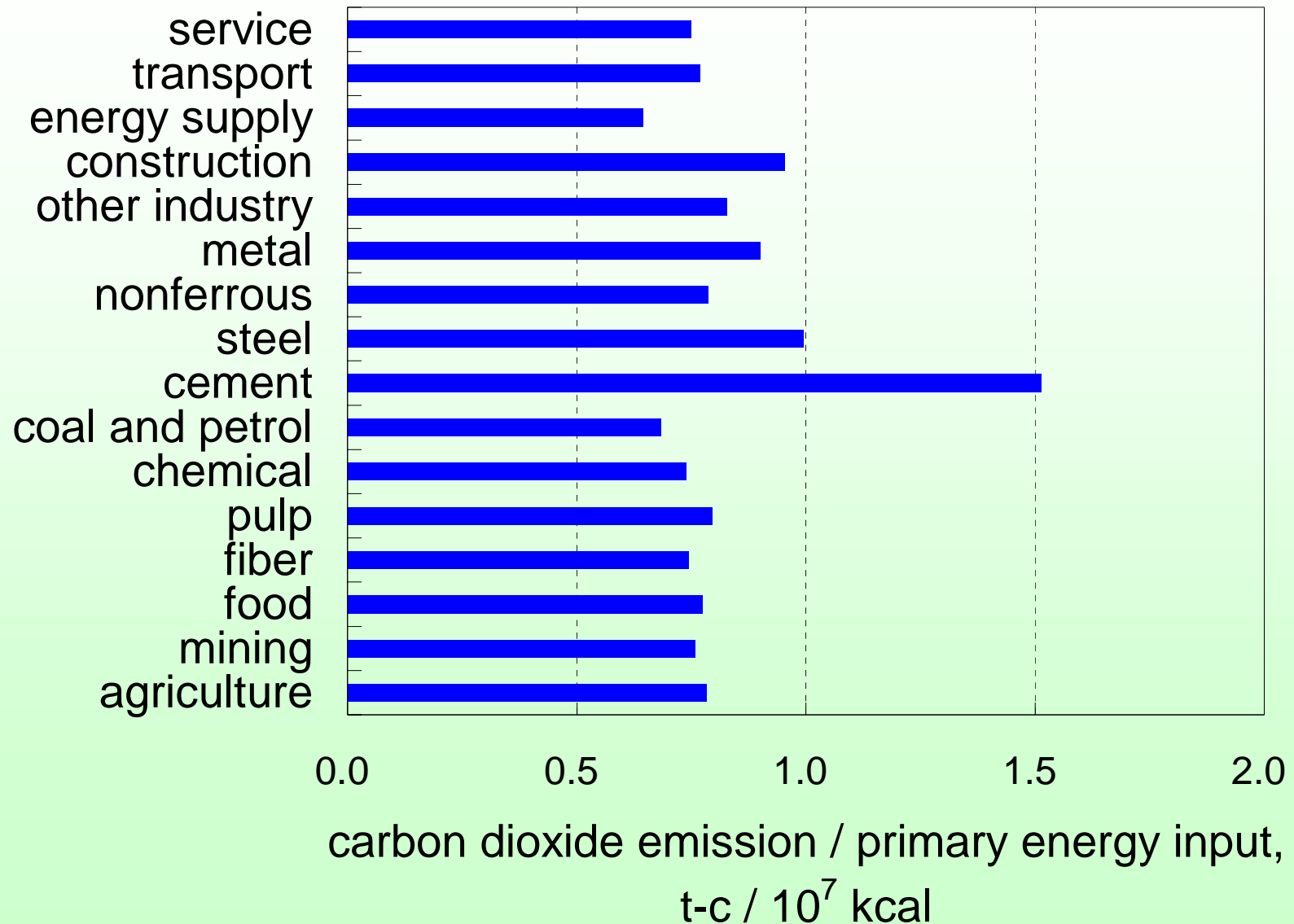
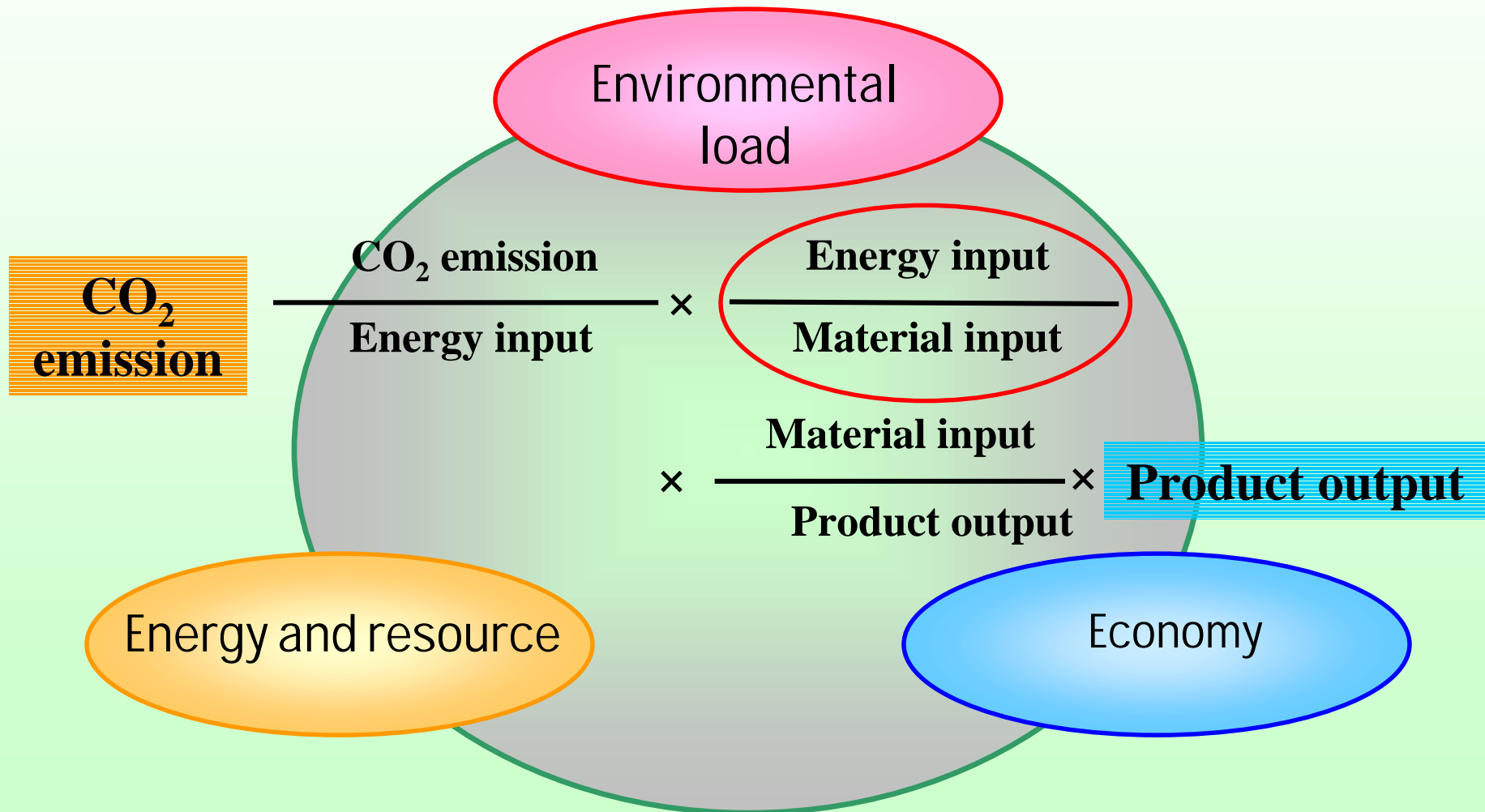Ratio of nitric oxide emission to primary energy input

nitric oxide emission / primary energy input, kg / 10^7 kcal

Sustainability in energy and material flow

… considering trilemma between environment, energy and economy

Eco-intensity based on energy and material flow

$$\frac{\text{thermal unit}}{\text{mass unit}}$$

#1 $$\frac{\text{Primary energy input}}{\text{Total material input}}$$

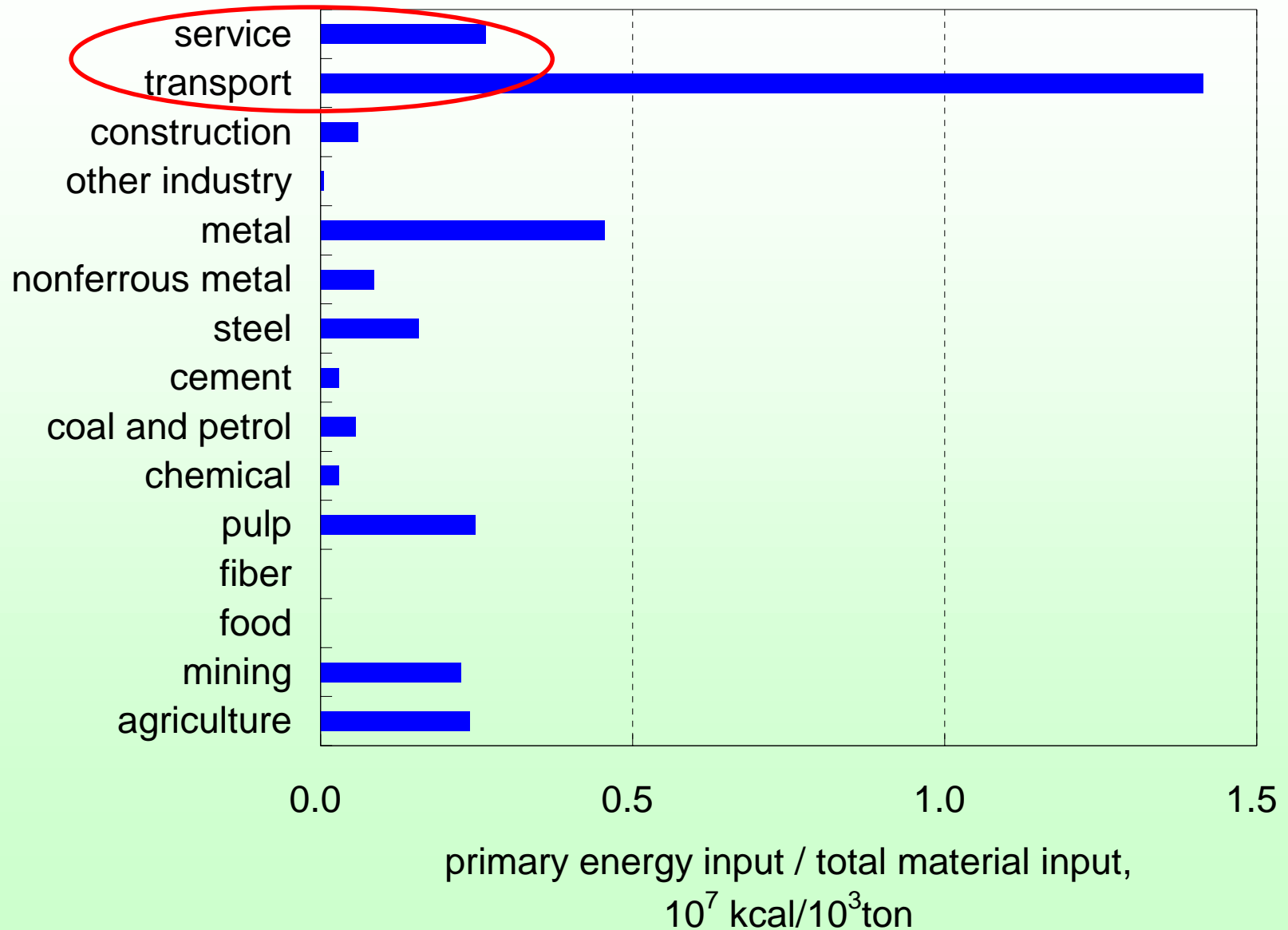#4 $$\frac{\text{Net energy use}}{\text{Total material input}}$$

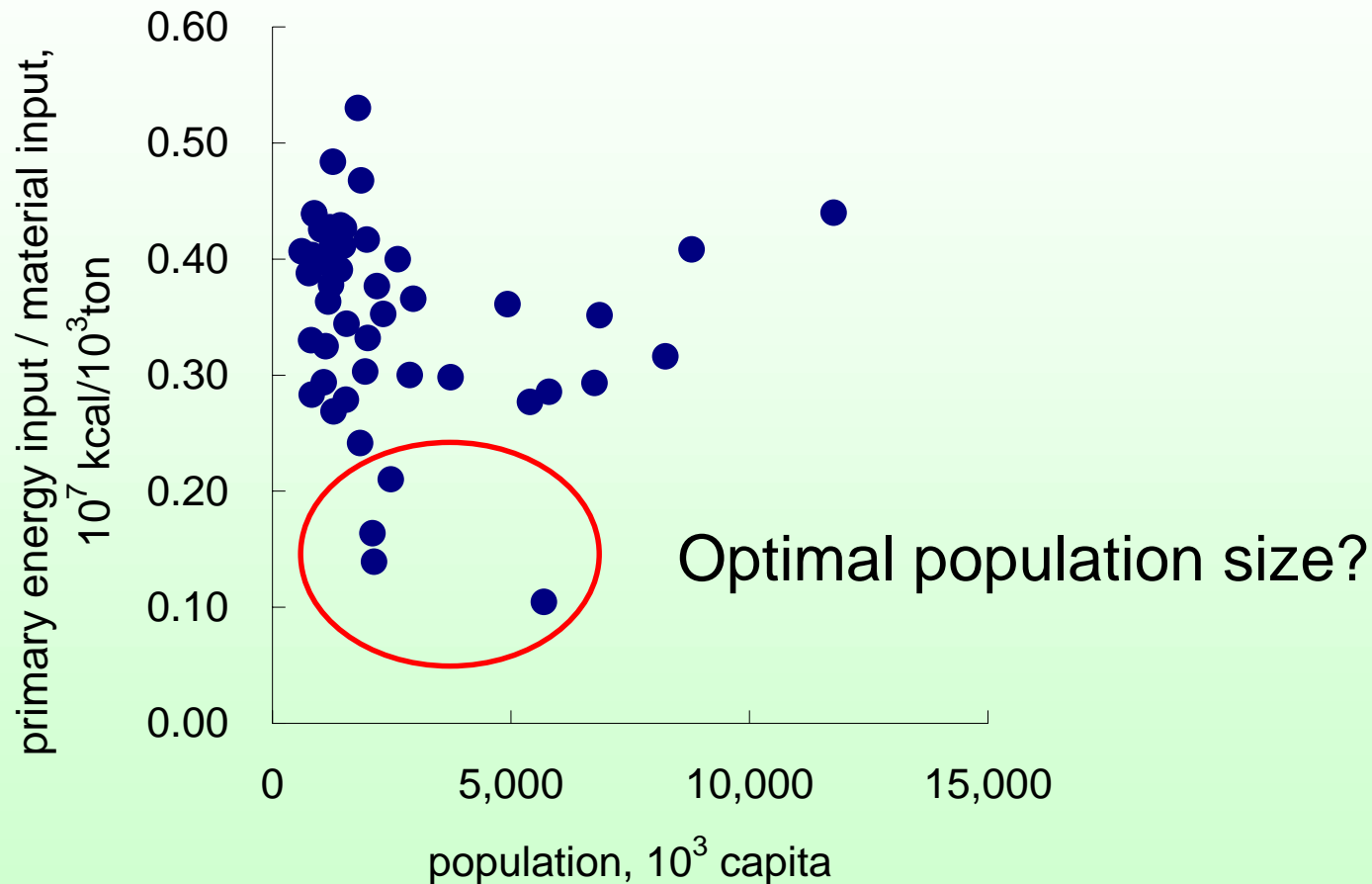#2 $$\frac{\text{Net energy use}}{\text{Product output}}$$

#5 $$\frac{\text{Primary energy input}}{\text{Product output}}$$

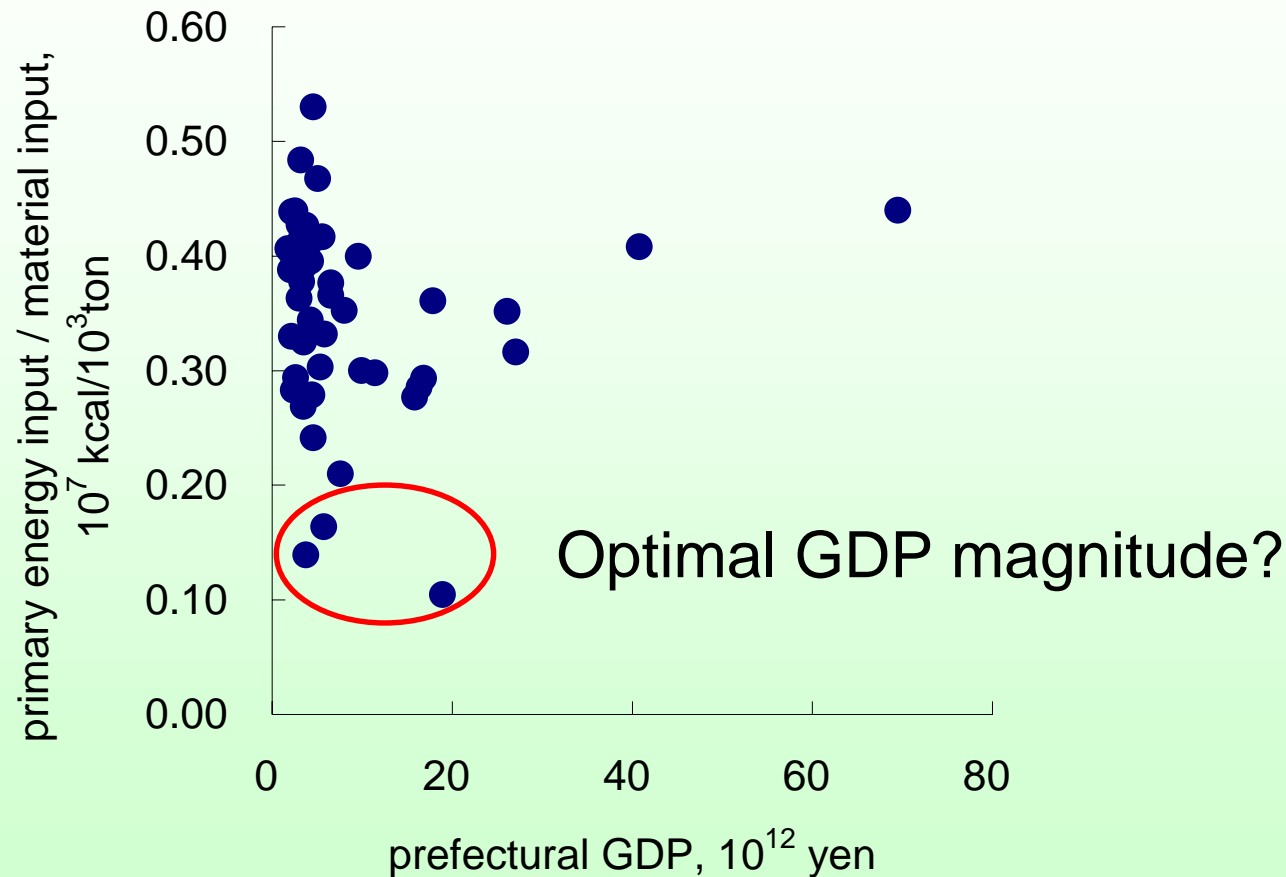#3 $$\frac{\text{Recycled energy input}}{\text{Recycled material input}}$$

Ratio of primary energy input to total material input (RPM)

primary energy input / total material input, 10^7 kcal/10^3ton

Relationship between RPM and population

Relationship between primary energy input / total material input of the service industry and population of each prefecture
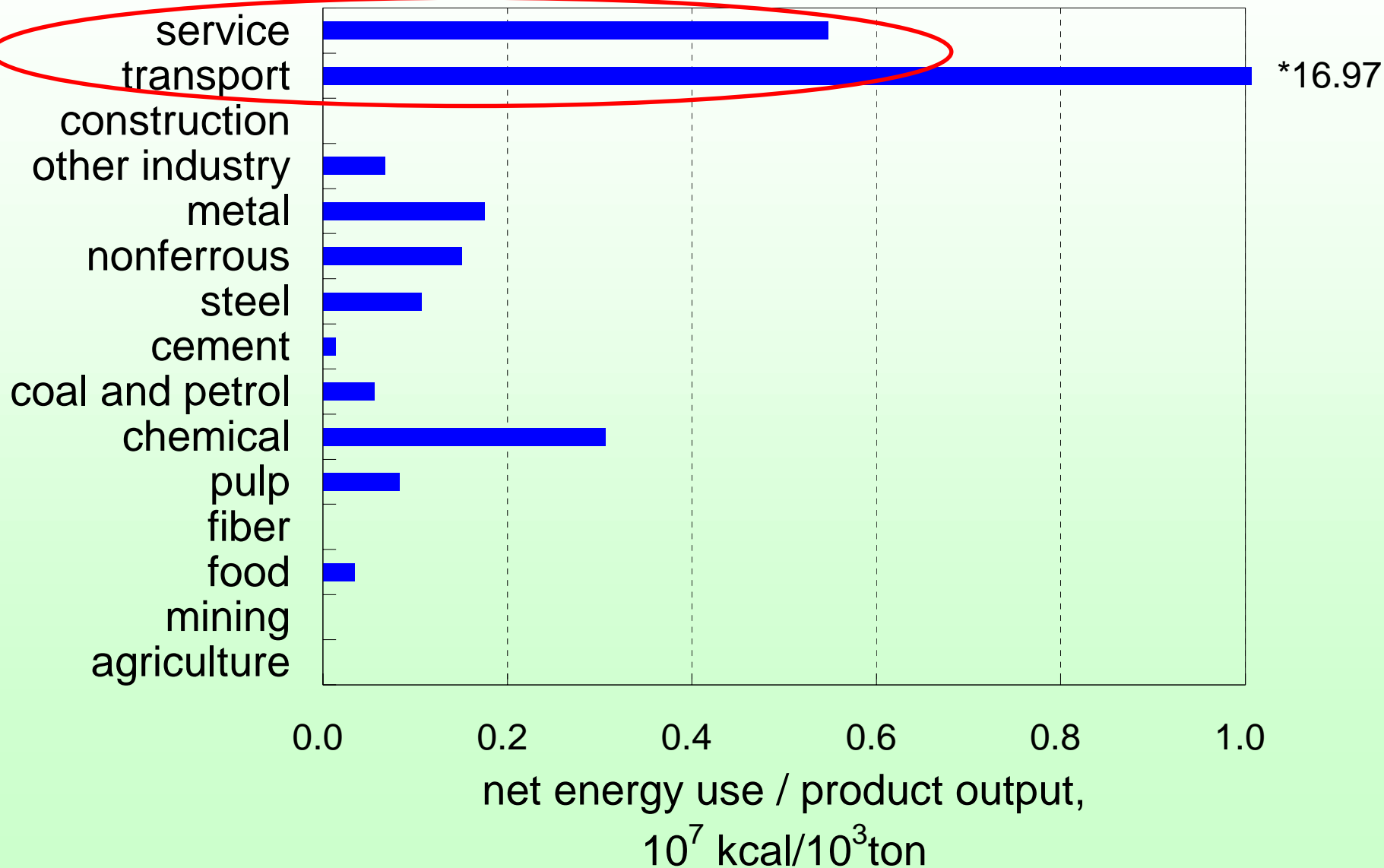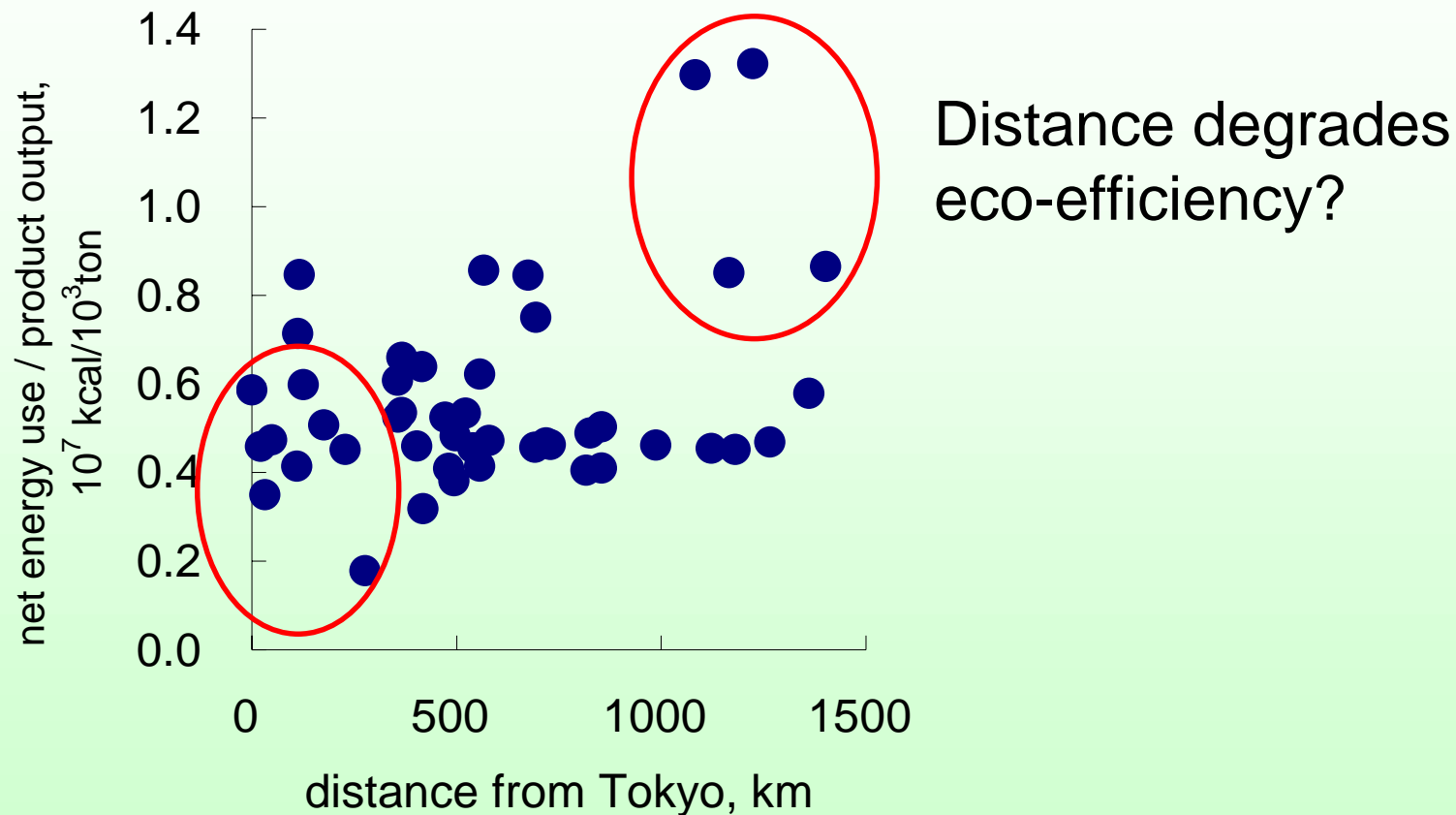
Relationship between RPM and GDP

Relationship between primary energy input / total material input of the service industry and GDP of each prefecture
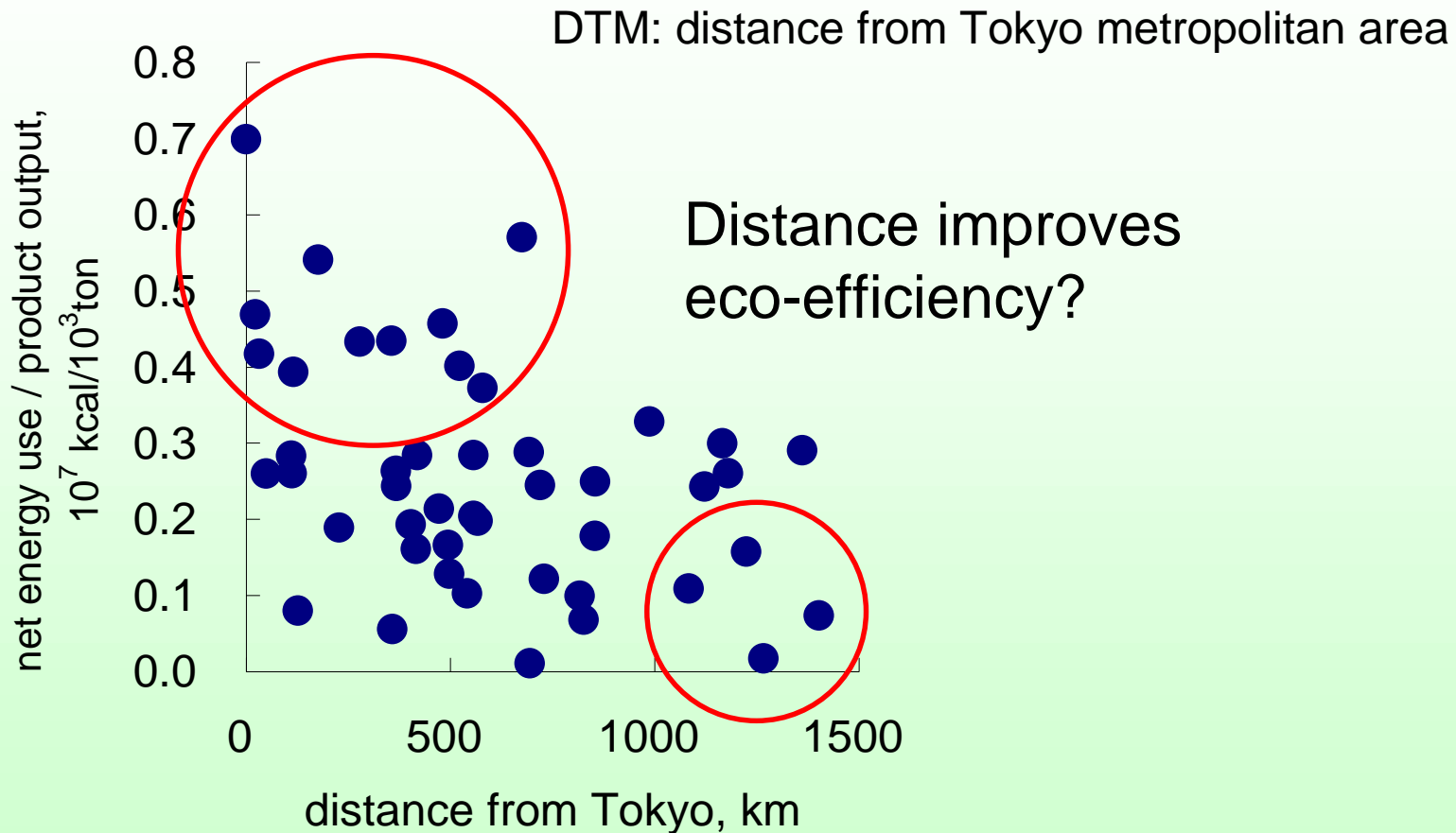
Ratio of net energy use to product output (RNP)

Category	Value
service	
transport	*16.97
construction	
other industry	
metal	
nonferrous	
steel	
cement	
coal and petrol	
chemical	
pulp	
fiber	
food	
mining	
agriculture	

net energy use / product output, 10^7 kcal/10^3ton

Relationship between RNP and Dist. from Tokyo

Distance degrades eco-efficiency?

Relationship between net energy use / product output of the service industry and Dist. from Tokyo of each prefecture

Relationship between RNP and Dist. from Tokyo

DTM: distance from Tokyo metropolitan area

Distance improves eco-efficiency?

y-axis: net energy use / product output, 10^7 kcal/10^3 ton

x-axis: distance from Tokyo, km

Relationship between net energy use / product output of the chemical industry and Distance from Tokyo of each prefecture

Summary

- Simple ratios ("CO_2 / *energy*", "*energy* / *flow*", and "*flow* / *GDP*") could be utilized as a kind of sustainability indicators to evaluate eco-efficiencies of local regions or industrial sectors.

- Those ratios could be compared in each region and industrial sector for comprehensive sustainability evaluation.

- Several relationships between the "primary energy input / total material input " ratio and regional or industrial characteristics were obtained, and some optimal population size or economic growth potential could be presented.

- Another relationship between the "net energy use / product output " ratio and regional or industrial characteristics were also obtained, such as distance from major markets.