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A proposal to develop a model for the future strategy of materials industries

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Material flow analysis; simulation model; GHG; CO_2; LCA

Abstract – In this presentation, the development of a simulation model that can examine the long-term strategy of materials industries, called a material strategy model, is proposed. This model has the following structure: first, the world is divided into a number of areas and a scenario for the demand for end products in the future in each area is provided. Then, the system required to realize the scenario and to minimize CO_2 emission or the total cost is calculated using this model. In other words, the optimization to select processes in society to minimize total CO_2 emission or total cost is carried out. As a result, the possibility of the long-term scenario; for example, the amount of car production based on population increase and GDP growth, can be discussed by considering CO_2 emission and consumption of resources. A few simulation models to discuss long-term strategy have been developed in the field of energy system studies. In the energy system model, only a few resources such as coal, oil, natural gas and uranium are considered, but, in the material strategy model, it is necessary to examine many materials and resources. In addition, the material strategy model should have an energy model as one part of the model. As a first step, a prototype model mainly focusing on iron and steel with their alloys should be developed to show the capability to develop the whole model.

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For several years, consumption of materials has been increasing greatly due to economic growth. On the other hand, resource depletion and environmental problems such as global warming have been paid significant attention. Therefore, many studies about material flow in society and environmental impacts caused by the consumption of materials have been conducted [1]. However, the studies of material flow are often investigated material by material, and as a result it is difficult to see the whole structure of material consumption in society. In this presentation, I suggest developing a simulation model that can calculate material consumption due to the increase in demand for end products such as a car, and of environmental loads due to material consumption.

Using the model proposed in this presentation (a material strategy model), the long-term CO_2 emission, the required amount of resources and the total cost to realize a future concrete image of society (for example, the volume of production of cars) can be calculated based on the scenario estimating the volume of production of the end products, material-related technology, and so on.

The material strategy model can calculate, for example:

- Resource consumption, CO_2 emissions and conversion cost when the volume of production of a car increases as it is (business as usual).
- Resource consumption, CO_2 emissions and conversion cost when fuel cell-powered cars become available.
- Reduction of CO_2 emissions by introduction of a car with a plastic body.

1 Difference between a material strategy model and an energy model

The IPCC, in particular, has discussed the long-term energy system using an energy (economy) model, and the long-term CO_2

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Table 1. Difference between general energy model and material strategy model.

	Energy Model	Material Strategy Model
Resources	Coal, Oil, Natural Gas, Uranium	Many (iron and non-iron)
Small amount ingredient	None	Many
Flow and stock	Only flow	Both should be considered
Waste and recycle	Not considered	Should be considered
Substitute characteristics	Can be evaluated by heat equivalence	Must be evaluated according to each material's value

emission in the world has already been calculated [2]. Among energy (economy) models, there are some based on process linkage written with energy and material flows and others based on input/output analysis.

Models based on process linkage calculate the CO_2 emission by estimating the production volume of each industrial sector and technological innovation. However, because the calculation is focused mainly on energy consumption, the material flow, for example between volume of production of the car industry and volume of production of each material industry, is not described in detail.

As the models based on the input/output analysis estimate the future as the extension of current business, i.e., amount of money, it is therefore very difficult to argue about the future related to technology innovation.

In general, because energy models focus on energy resources such as coal, oil and natural gas, material flow of mineral resources is not generally incorporated [3]. Therefore, they are not used to discuss long-term resource depletion.

The tasks to develop a material strategy model can be described practically as follows:

- a material strategy model has a larger number of resources compared with an energy model in which a small number of resources such as coal, oil and natural gas is taken on board;
- a general energy model handles flows and does not need to worry about stocks (energy resources are used and then disappear, but materials are left as a stock at the end of their use phase). One cannot discuss recycling and reuse of products without taking material stock into consideration.

2 Structure of a material strategy model

2.1 Scenario and optimization model

In this material strategy model, five end products such as cars, buildings/constructs, electric appliances, containers and others are considered as final industrial sectors. Scenarios for each final industrial sector, for example, about the kind of car, its material constitution and quantity of demand are assumed, and then a set of results of the scenario analysis is given as a set of inputs for the optimization model [4,5]. As a calculation result of the optimization model, it might be shown, for example, that cars are produced in the area where production cost is cheap and exported to the area where cars are needed.

A material strategy model should have the following scenarios:

- scenario of demand for five end products;
- scenario for substitution between materials;
- scenario of technology innovation for industries;
- scenario of technology innovation for recycling of products;
- scenario for energy supply and demand;
- scenario for production potential in each area;
- scenario of political issues.

2.2 Optimization model

The basic structure of the material strategy model proposed in this presentation is as follows:

- Area classification: three areas (Japan, Asia and the rest of the world).
- Simulation period: the start point is 2000, and every five years up to 2050.

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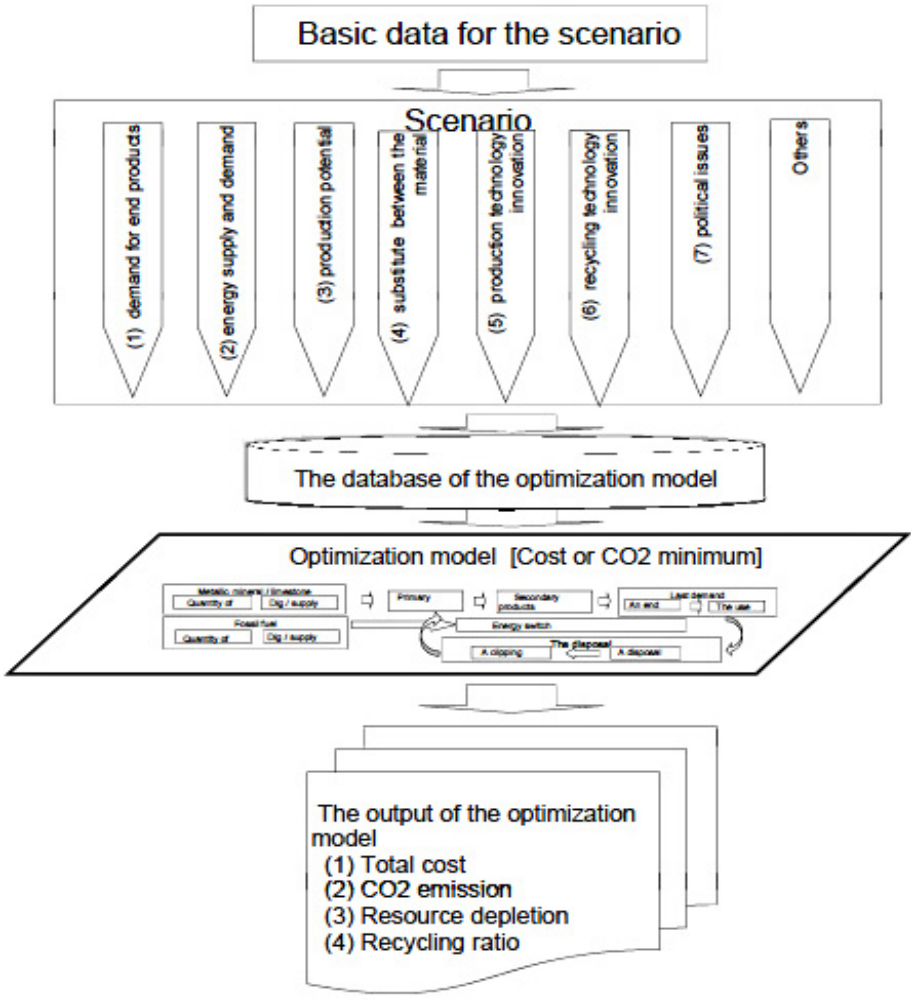


Fig. 1. Structure of a material strategy model.

– A model type: an optimization model (to minimize the total cost or the CO_2 emission. For example, the supply-demand balance of material is calculated so that the world total cost becomes the smallest by the cost minimization).
– Object material: iron, aluminum, copper, lead, plastic, glass, rubber, etc., which are used for end products, and in the model several kinds of products in each material are treated if necessary.
– Object element: Figure 4 shows the element to be included in the model for steel materials.

The parameter of each material should be described such as the name of material and the concentration of the elements such as % of the addition of manganese, % of the addition of zinc, and so on.

2.3 Data collection

2.3.1 The material and energy balance

The data of the material and energy balance of each process constituting the optimization model is quoted from the Life Cycle Inventory data of each material manufacturing process, and reviewed using the statistics data for the production and consumption of each material.

2.3.2 The cost of each process

It is necessary to discuss the resource depletion in this model. Therefore, the relations of the quality decrease in the ore and the increase in the price must be described,

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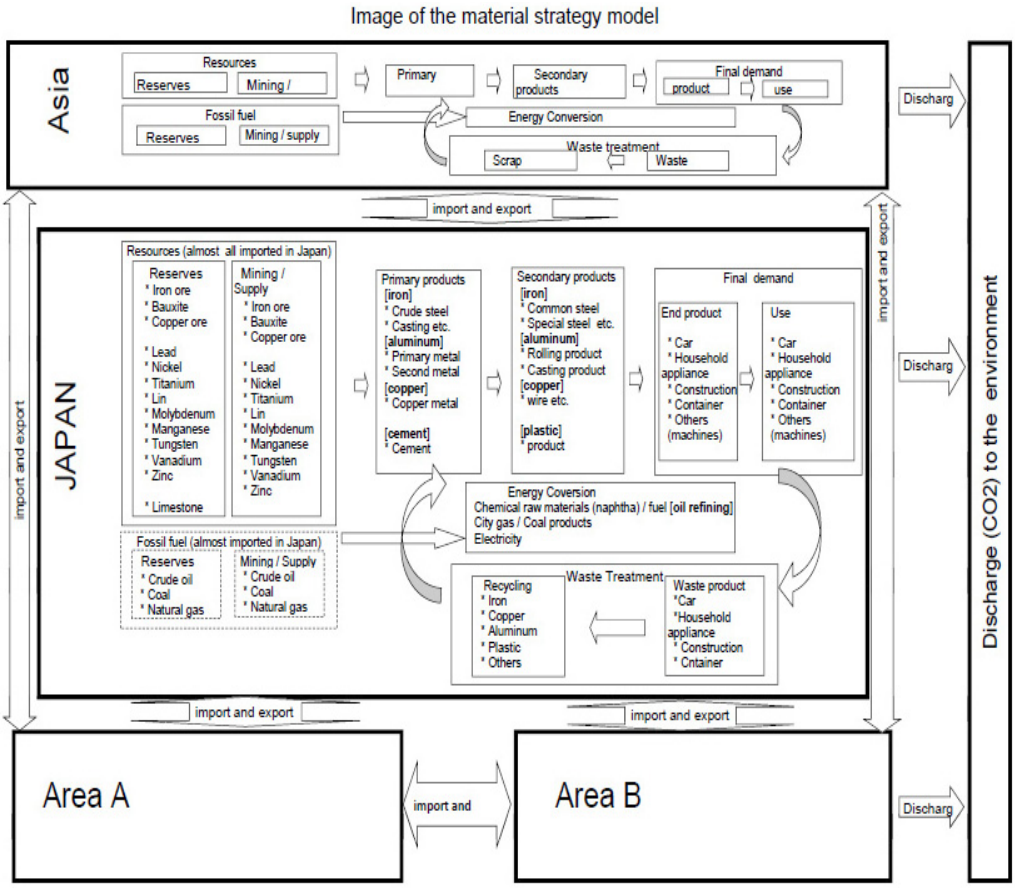


Fig. 2. Image of the material strategy model.

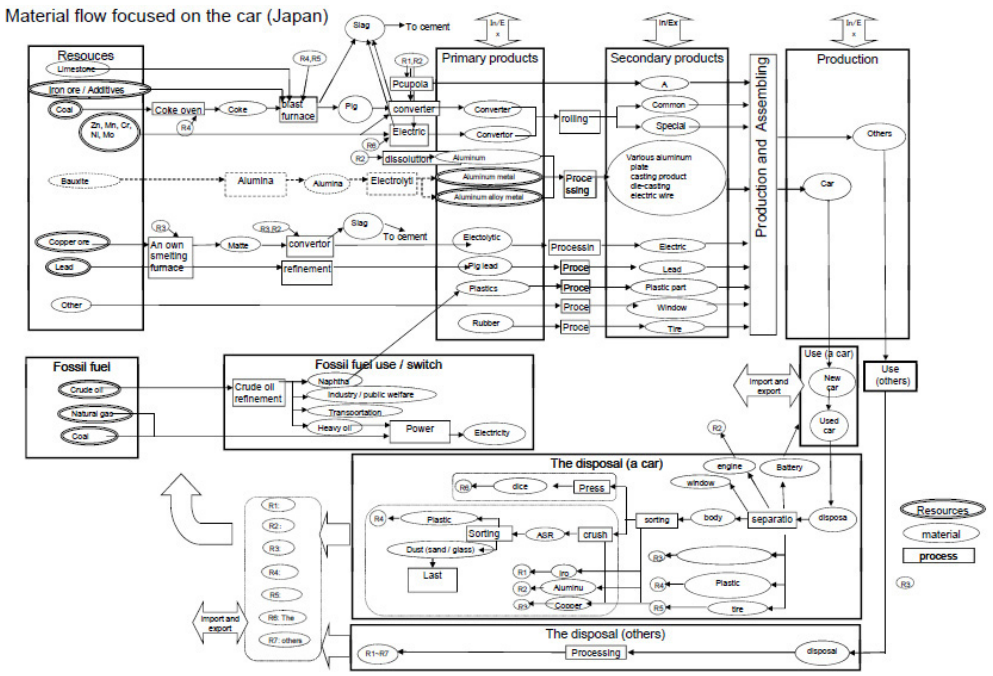


Fig. 3. Example of the material flow focusing on car production.

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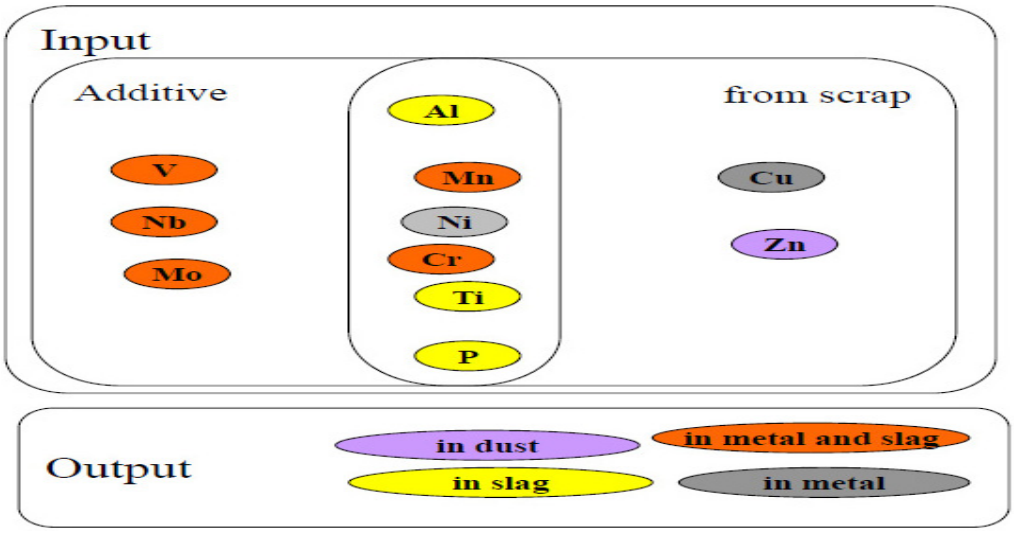
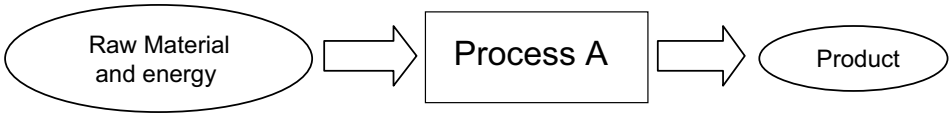


Fig. 4. Elements to be considered with an iron and steel product.



which are caused by the increase in the mining quantity of the ore. This relation in itself can be considered as one of the scenarios.

The cost of the manufacturing process of the material and the product is conveniently assumed to be [(shipment price of the product) – (raw materials price + energy price)]. The price of the product, raw materials and energy are provided by surveying the market data. Therefore, the added value of each process is included in this assumption.

The present process cost (PC1) is assumed as (Q1 X P1 – ∑ Mn X Cn– ∑ En X ECn) /Q1. The future price of the product is assumed as "the future price of raw materials (C2) + the present process cost". Here, Q1 = volume of shipment of the product, P1 = average shipment price of the product, Mn = raw materials consumption, Cn = raw materials price, En = energy consumption, ECn = energy price.

3 Relation to the energy models

Because energy resources are parts of many resources, the material strategy model must incorporate an energy model as a part. However, because the calculation in the optimization model becomes enormous, the prototype model, in which the part of the energy system is separated and the calculation result by the already existing energy model is used, should be developed for the time being. In other words, in the prototype model the energy is used endlessly and, for example, the future price of electricity and the CO_2 emission to produce electricity are used.

Because any energy model is not linked to the prototype model, the calculation result of the prototype model has the limit. For example, the energy demand in the automobile industry assumed in the energy model is not consistent with the energy demand in the automobile industry of the prototype model. As it is necessary to link the material strategy model to the energy model in the future, the prototype model should be developed considering the energy model to be linked in the future.

Furthermore, for example, a prototype model is able to be developed in which the volume of production of the car in each area is provided by the scenario instead of the demand for the car in each area. In this case, the import and export of the car are not calculated in the optimization model; they must be decided as the results of the scenario analysis.

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4 Conclusion

Many energy models have been developed in the last couple of decades, and the measures for global warming have been discussed using the relations of the inputs and outputs of the energy models.

Now, it has become necessary to discuss resource consumption as well as global warming. The consumption of products and the consumption of materials should lead to resource depletion in the future. We should have a common tool, with which we can discuss the consumption of resources including energy fuels.

The material strategy model proposed in this presentation is one of these tools. We are now proposing the development of this model to the government, hopefully to get a fund for the development.

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