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Societal metabolism in Northeast China: Case study of Liaoning Province

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ABSTRACT

Societal metabolism is now the outstanding emphasis of the study of sustainability. Although a great deal of studies have been done for national socio-economic systems, few results are available for subdivision level, especially in China which is the world manufacture center and one of the most important economic entities of the world. Based on the method of material flow analysis (MFA), societal metabolism in Liaoning Province, one of subdivisions of Northeast China, is studied in this article. This research can be regarded as the first attempt for studying societal metabolism of provincial socio-economic systems in China. A set of MFA indicators are measured to illustrate the quantity and quality of societal metabolism in Liaoning Province because of the lack of imports and exports data for provincial socio-economic systems. The study covers the time period from 1990 to 2003 when the Chinese central government was making great efforts to vitalize the Northeast China's traditional industrial base. MFA indicators are integrated with economic and demographic indicators to scale the material intensity and efficiency of Liaoning's socio-economic system. The results show that the quantitative development of societal metabolism in Liaoning is similar with that of China in the same period, which can be divided into three phases highly matching up to the Eighth, Ninth, and Tenth Five-Year National Economy and Social Development Plans implemented by Chinese central government. The results prove that the societal metabolism of a socio-economic system is greatly dominated by the macro-policy in China. Moreover, the relative amount of societal metabolism in Liaoning is higher than the average level of China. However, the quantitative advantage of societal metabolism did not succeed to satisfied economic and social return. The efficiency of societal metabolism in Liaoning is lower than the average level of whole China, and of course extremely lower than that of developed countries. For instance, Liaoning's Gross Domestic Product (GDP) generated by unit input of natural resources in 2003 is roughly equal to 30% of the average level of 15 main countries in European Union in 2000 and 10% of the average level of Japan in 1996. The methodology development for MFA in subdivision level is discussed and future research is proposed.

1. Introduction

The development of human society relies on consumption of natural resources, which also brings on emission and waste to the environment. It is the material flows that connect the environment and the socio-economic system, which is so-called societal metabolism or social metabolism (Fischer-Kowalski and Haberl, 1993; Fischer-Kowalski, 1998; Fischer-Kowalski and Hüttler, 1998), or industrial metabolism (Ayres, 1989; Ayres and Simonis, 1994; Erkman, 1997). In this article, the term of societal metabolism is chosen to emphasize integration of human and natural systems.

The method of material flow analysis (MFA) is one of the most widely used approaches to study societal metabolism (EUROSTAT, 2001; Bringezu et al., 2003). The material flows between the socio-economic system and the ecological system are counted and analyzed by MFA methodology. A set of quantitative indicators are also developed to describe the status of societal metabolism of a socio-economic system. MFA has been widely applied worldwide to study societal metabolism for developed countries (e.g. Adriaanse et al., 1997; EUROSTAT, 2002; Matthews et al., 2000; Weisz et al., 2006), and for transition economies (e.g. Ščasný et al., 2003; Giljum, 2004). In China, the societal metabolism of national socio-economic system was also study using MFA (Chen and Qiao, 2000; Chen et al., 2003; Liu et al., 2005; Sun et al., 2007; Wang et al., 2005; Xu and Zhang, 2004, 2005, 2007; Xu et al., 2008). Most previous MFA research focuses on national socio-economic systems, and regarded the system as a "black box". Material exchange occurred

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at the box's boundary is the only research target. Therefore, the metabolism activities within the box cannot be described properly. One of the current development directions of MFA methodology is to "white" the "black box", which can be implemented by two options. On one hand, the material flows between economic sectors can be studied. On the other hand, one can also study the material flows of sub-systems of the whole national socio-economic system.

Liaoning Province, one of the three provinces in Northeast China, is studied as a case in this article in terms of societal metabolism from 1990 to 2003. Located in the southern part of China's Northeast, Liaoning has 145,900 square kilometers area and about 42 million population as reported in the end of 2006. Liaoning has the most iron, magnesite, diamond, and boron deposits among all provinces of China. It is also an important source of petroleum and natural gas in China. Liaoning is one of most important industrial bases in China which covers a broad range of industries, such as machinery, electronics, metal refining, petroleum, chemical industries, construction materials, coal, and so on. However, the problems of resource scarcity and environmental pollution also arise along with economic growth in Liaoning. Nowadays, those problems become the biggest constrain of sustainable development in this region. Therefore, the study on material is meaningful for sustainability for the provincial socio-economic system. This study can also be regarded as an effort on research of societal metabolism from the second option discussed above.

2. Methodology

According to mass balance principle, material input into the system is equal to the summation of material output from the system and the changes in stocks in a certain time period. For the integrated socio-economic-ecological system, material inputs from the ecological system are processed to net material accumulation in the system and material outputs back into the ecological system, as showed in Fig. 1.

To quantify the societal metabolism of socio-economic systems, MFA provides a set of physical indicators. The most important indicators are:

Direct material input (DMI) refers to materials input into the socio-economic system and processed by economic activities, such as fossil fuels, minerals, biomass, and so on. DMI includes Domestic Extraction (DE) and imports from other systems.

Total material requirement (TMR) refers to total materials required by economic activities. TMR includes not only DMI but also so-called hidden flows (Adriaanse et al., 1997), ecological rucksacks (Schmidt-Bleek, 1993), or unused extraction (EUROSTAT, 2001), which are materials without economic value generated during economic activities.

Domestic processed output (DPO) refers to waste and emission to the environment from the socio-economic system.

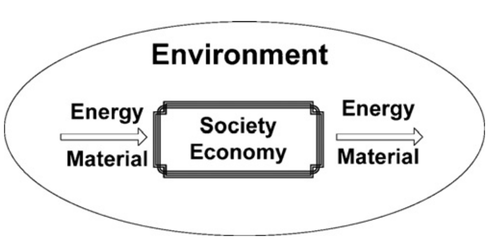

Fig. 1. Conceptual model of the economy-environment system, modified from EUROSTAT (2001).

Because of lack of data regarding to material exchange of Liaoning with other socio-economic systems, the indicators of DE, TMR excluding imports, and DPO are measured in this article.

3. Quantity analysis for societal metabolism in Liaoning Province

In this section, material flow indicators for Liaoning Province are compiled based on statistics. The development of DE is illustrated in Fig. 2. Minerals take the most part of direct material input in Liaoning, which is about 62% of total DE. Fossil fuels run after minerals, taking 23%. Biomass takes the smallest portion of DE, about 15%.

There are three phases in development of DE, which is mainly caused by dominating minerals:

From 1990 to 1995: DE increased from 229 to 346 billion tons, by 8.66% annually.

From 1995 to 2000: DE decreased from 346 to 287 billion tons, by 3.69% annually.

From 2000 to 2003: DE increased from 287 to 327 billion tons, by 4.43% annually.

This three-phase has the same time division with the Eighth, Ninth, and Tenth Five-Year Plans for National Economy and Society Development implemented by Chinese central government. Therefore, the macro-policy has a great deal of impacts on societal metabolism statuses in Liaoning.

As an important industrial base of China, Liaoning requires a great amount of fossil fuels. The composition of fossil fuels extracted from 1990 to 2003 remains almost the same. Coal has been taking about three-quarters of total fossil fuels by weight, while petroleum is about 20% generally.

Before 2000, biomass from harvestry has been taking major proportion of total biomass generated in Liaoning, as showed in Fig. 3. Other types of biomass, forestry, hunting, and fishing, have all been increasing. In 2003, biomass form forestry takes about 45% of total biomass. One of the major contributions for increase of forestry biomass is the growth of apples and peaches in Liaoning which takes three-quarters of China's exportation. Quality dairy and seafood in Liaoning are known worldwide and increasingly exported domestically and internationally, which cause the growth of biomass from hunting and fishing.

Ferrous metals and non-metal minerals dominate the extraction of minerals in Liaoning, as showed in Fig. 4. The decrease of ferrous metals and non-ferrous metals after 1995 is caused by the policy of vitalizing the Northeast China's traditional industrial base proposed by the central government. Liaoning decided to improve

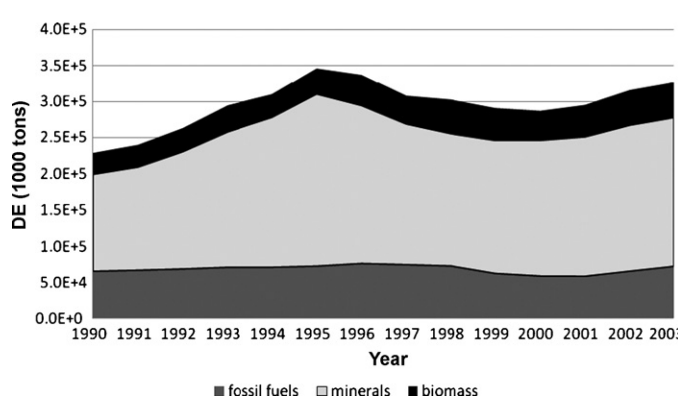

Fig. 2. Compositions of DE in Liaoning Province from 1990 to 2003.

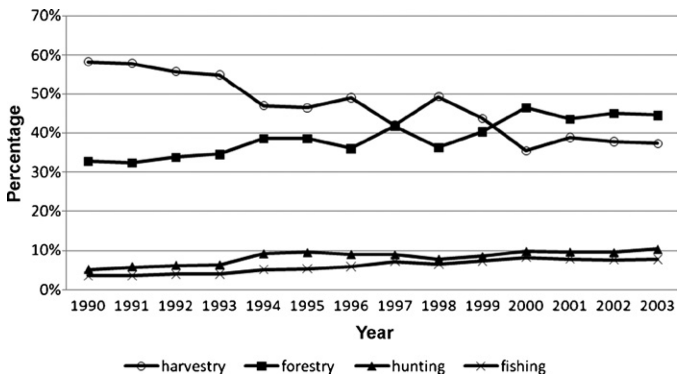

Fig. 3. Compositions of biomass in Liaoning Province from 1990 to 2003.

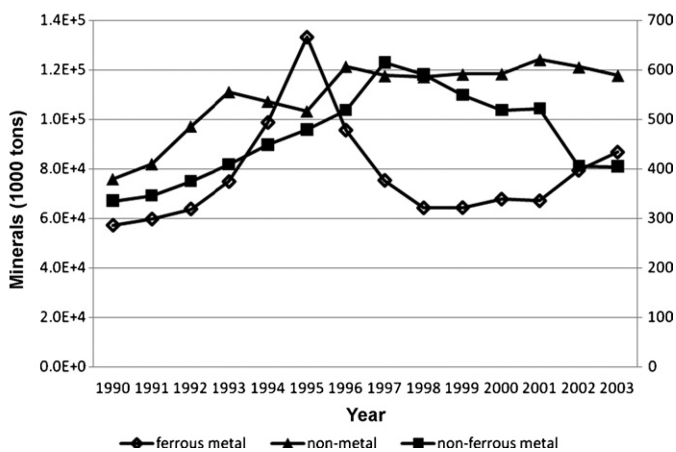

Fig. 4. Compositions of minerals in Liaoning Province, with non-ferrous metal indexed by the right axis, from 1990 to 2003.

the high technology industry and cut down raw material processing industry to implement the policy. Meantime, the continuous infrastructure construction and the development of real estate in big cities have supported the requirement for non-metal minerals.

Similar with DE, TMR excluding imports in Liaoning also has a three-period development, illustrated in Fig. 5. There are still, however, some differences with DE because hidden flows take a major portion in TMR excluding imports, about 90%.

From 1990 to 1994: TMR excluding imports increased from 2179 to 2663 billion tons, for 5.14% annually. Hidden flows increased from 1950 to 2353 billion tons, by 4.80% annually;

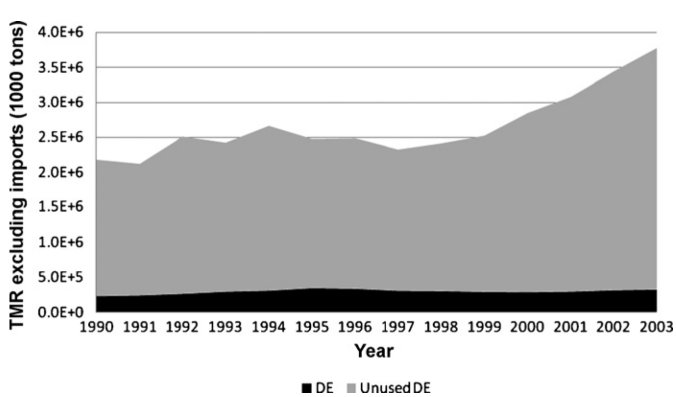

Fig. 5. Compositions of TMR excluding imports in Liaoning Province, from 1990 to 2003.

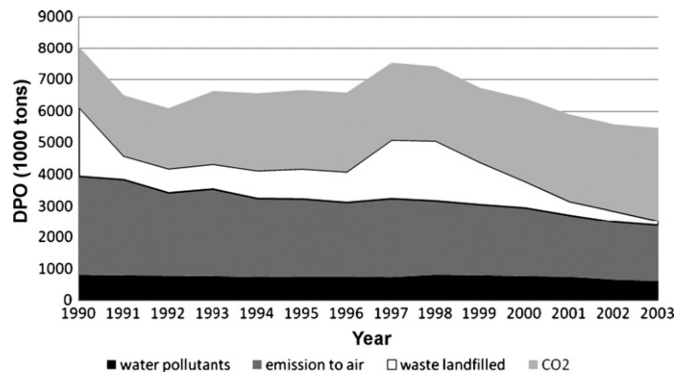

Fig. 6. Compositions of DPO in Liaoning Province, from 1990 to 2003.

From 1994 to 1997: TMR excluding imports decreased from 2663 to 2323 billion tons, for 4.45% annually. Hidden flows decreased from 2353 to 2015 billion tons, by 5.01% annually;

From 1997 to 2003: TMR excluding imports increased from 2323 to 3773 billion tons, for 8.42% annually. Hidden flows increased from 2015 to 3446 billion tons, by 9.35% annually. Additionally, TMR excluding imports has much more increase after 1999, by 10.58% annually.

Differing with DE and TMR excluding imports, DPO in Liaoning has only two phases in development, illustrated in Fig. 6, where the amount of carbon dioxide (CO_2) in Liaoning is estimated by emission factor of energy consumption.

From 1990 to 1997: DPO kept constant around 7.5 billion tons, except for 9 billion tons in 1990 and 8.5 billion tons in 1997.

From 1997 to 2002: DPO decreased except for slight increase in 1998, from 8.6 to 5.8 billion tons, by 7.44% annually.

Solid waste takes the largest proportion, about 60%, among all three compositions of DPO in Liaoning. Air emission runs after for about 30%. Water pollutants are the smallest portion, about 10% of total DPO.

Sulfur dioxide (SO_2) and soot take major proportion of air emission in Liaoning, as showed in Fig. 7. All three types of air emission, SO_2, soot, and industrial dust, generally decrease from 1990 to 2003 by annual percentages of 1.30%, 6.71%, and 5.14%, respectively.

The societal metabolism process in Liaoning Province is similar with that in the whole China, illustrated in Fig. 8. It can be concluded that the development of DE and TMR excluding imports in Liaoning Province is similar with those of China. The only exception is in the second phase when DE and TMR excluding imports in China were slowly increasing while those in Liaoning slightly decreased. DPO is also almost the same for China and Liaoning, fluctuating before 1998 and decreasing after 1998.

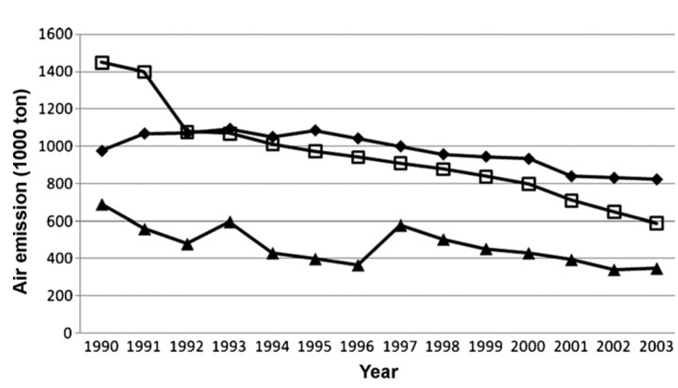

Fig. 7. Compositions of air emission in Liaoning Province, from 1990 to 2003.

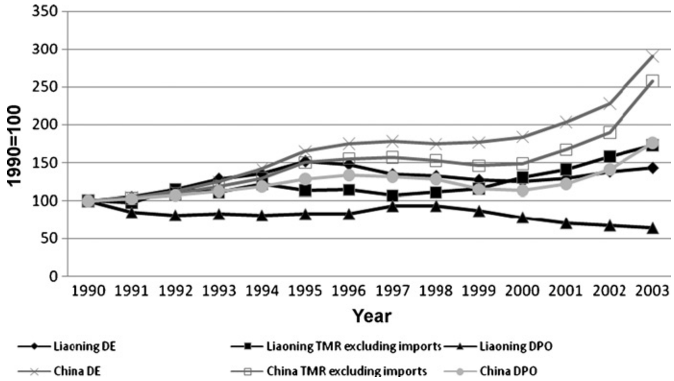

Fig. 8. Trends of DE, TMR excluding imports, and DPO for Liaoning and China, from 1990 to 2003 (source of data for China: Xu and Zhang, 2007).

4. Quality analysis for societal metabolism in Liaoning Province

Societal metabolism influences sustainability from not only quantity aspect but also quality aspect. The quality of societal metabolism can be indicated by the integration of physical indicators with social and economic indicators.

Gross Domestic Product (GDP) produced by unit material input can be used to evaluate the resource productivity of the socio-economic system. Monetary indicators should be converted into constant price which are comparable upon time. In this research, the GDP data of China and Liaoning Province are converted into constant price data based on RMB in 2003 referring to the International Monetary Fund (IMF) database (IMF, 2006).

From 1990 to 2003, GDP produced by unit DE in Liaoning and China increased (see Fig. 9), which means that the natural resource productivity was increasing. Before 2001, the natural resource productivity of Liaoning is lower than that of China, about 70–95%. After 2001, the natural resource productivity of China began to be lower than that of Liaoning.

The natural resource productivity of Liaoning is compared with international data by converting GDP data of Liaoning, China, Japan and 15 countries of European Union (EU-15) into constant price based on 2003 U.S. dollar (see Fig. 10). It can be clearly concluded that the natural resource productivities of Liaoning and China are greatly lower than those of Japan and EU-15. Taking GDP produced by unit DE of Liaoning in 2003 as example, it is only equal to 30% of natural resource productivity of EU-15 in 2000, or 10% of that of Japan in 1996.

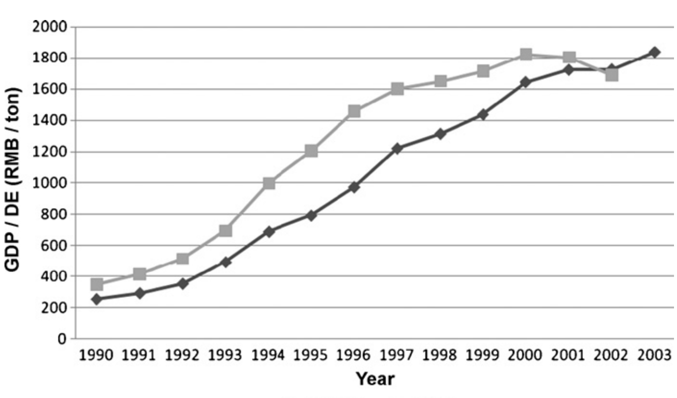

Fig. 9. GDP per DE for Liaoning and China from 1990 to 2003 (data sources for GDP: IMF, 2006, and China: Xu and Zhang, 2007).

Fig. 10. International comparison of GDP per DE (data sources for EU-15: EUROSTAT, 2002; GDP: IMF, 2006; Japan: Matthews et al., 2000; and China: Xu and Zhang, 2007).

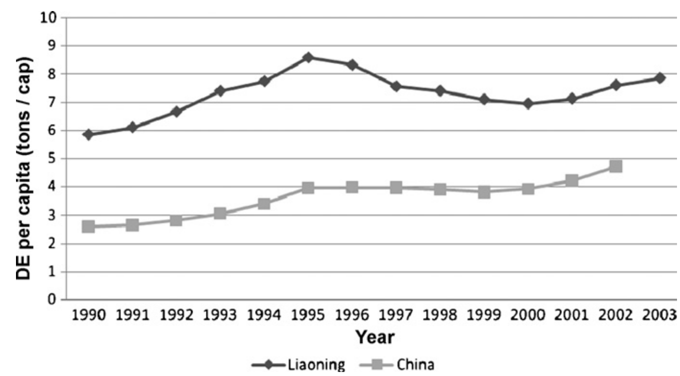

Fig. 11. DE per capita for Liaoning and China from 1990 to 2003 (data source for China: Xu and Zhang, 2007).

Fig. 11 presents the amounts of DE per capita of Liaoning and China. The development of both DE per capita of Liaoning and China are similar, though that of Liaoning is much higher than that of China. For instance, the DE per capita of Liaoning is 7.60 tons in 2002, while that of China is only 4.72 tons which is only about 60% of the former.

The amount of DPO produced by unit GDP can be used to indicate the material production efficiency. From 1990 to 2003, the DPO produced by unit GDP was decreasing (see Fig. 12). Taking Liaoning as example, GDP of per million RMB (constant price in 2003) produced 9.7 tons of DPO in 2003, which decreased for about 93.82% compared with that in 1990. Additionally, the DPO per unit GDP of Liaoning before 2000 was higher than that of China. After 2000, the situation was conversed.

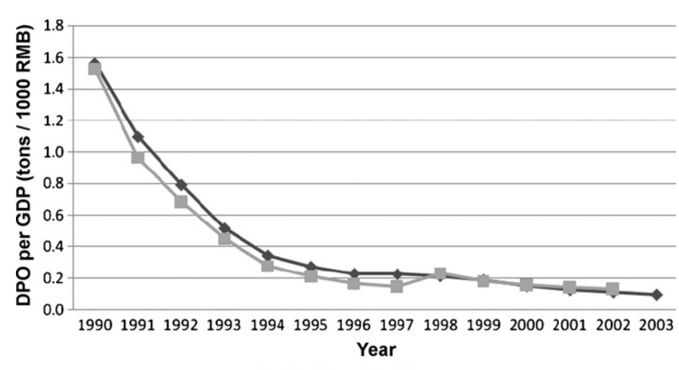

Fig. 12. DPO per GDP for Liaoning and China from 1990 to 2003 (data source for China: Xu and Zhang, 2007).

Based on above discussions, it can be concluded that both absolute and relative quantities of natural resources consumed by Liaoning Province is high within the period from 1990 to 2003. However, the large number of quantity was not translated into economic efficiency. From 1990 to 2003, the material production efficiency of Liaoning is not only lower than that of some industrialized countries, but also lower than that of China. In a word, high quantity of consumption for natural resources in Liaoning Province did not receive positive enough feedback.

5. Discussion

In this research, all data regarding Liaoning are from the statistics of Liaoning Environmental Protection Bureau (LNEPB) and Statistics Bureau of Liaoning (SBLN), which are the most reliable sources providing statistic data for societal metabolism in Liaoning. Most data required for conducting MFA indicators can be directly obtained from the statistics of LNEPB and SBLN, except unused domestic extraction data for fossil fuels and non-metal minerals which are estimated based on Xu and Zhang (2007). Data regarding other regions are from various sources indicated as references.

This research applied the MFA approach to study societal metabolism in the socio-economic system of Liaoning Province in Northeast China. According to the results, the consumption of natural resources in Liaoning has been increasing from 1990 to 1995, decreasing from 1995 to 2000, and re-increasing after 2000. On the other hand, the amount of waste generated by Liaoning socio-economic system has been fluctuating around certain amount from 1990 to 1997, and decreasing after 1997. Compared with societal metabolism in China, the amount of natural resources consumption of Liaoning is higher. The material production efficiency, however, has been lower than the average level of China. Additionally, the amount of waste produced by unit GDP of Liaoning has been decreasing, which became lower than that of China in 2000. Referring to related international research, it can be concluded that the quantity of societal metabolism of Liaoning Province is higher than that of China, while the quality is lower than either China or international advanced level.

For regional systems which are lack of statistic data regarding material exchange with other systems, it is difficult to conduct a full MFA research. In this article, we use indicators of DE, TMR excluding imports, and DPO to measure the physical dimension of the socio-economic system of Liaoning. The approach avoids quantitatively estimating material exchange with other systems, and provides the possibility to compare patterns of societal metabolism of Liaoning with other socio-economic systems. On the other hand, however, material exchange is important for studying societal metabolism in subdivisions of a national socio-economic system. Future work on societal metabolism research in regional level should pay special attention to data availability and standardization of related statistics which are also helpful for other sustainability and industrial ecology research.

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