12. Scenario-driven Policy Design and Evaluation System with GIS Based Regional Material Flow Analysis for Environmentally Sustainable Basin Regional Management

GISによるシナリオ誘導型の自然共生型流域圏マネジメントの計画・評価

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ABSTRACT; Research framework to evaluate alternative scenario-driven policy rograms characterized by pollution abatement facilities, infrastructures, activity management, and land use control are firstly presented. Followingly, structures of integrated regional GIS data base in basin-wide region are presented for a pilot survey in Muko River Basin in Osaka Metropolitan Region in Japan. Relative degrees of driving forces for environmental emissions in Basin Area are estimated by analyzing regional characteristics of socio-economic activities increased during the period from 1970's and 1990's. Fourthly, policy programs are designed and their environmental impacts are evaluated by CO2 emissions and solid wastes of landfill. Tentative policy recommendations are proposed in concluding chapter.
KEYWORDS; Basin Management, Material Flow Analysis, Policy Options, Material Recycle, Muko River Basin

1. BACKGROUNDS

Basin regions consist of various types of spatial spheres such as urban areas, agricultural areas and natural forestry areas, where natural resources, agricultural goods and industrial products support human activities. Intensive human activities located in urban areas, at the same time, generate enormous amounts of wastes and emissions that spill over the urban boundaries and affect both surrounding terrestrial and ocean spheres as well.

Faced with different types of natural disasters and environmental pollution problems, engineering technologies have made immeasurable contributions to the society for controlling the water runoff, improving contaminated water quality, developing water resources. Social management systems such as land use controls, waste treatments and recycling have also brought significant effects to increase quality of life in both urban and rural areas while offering a functional base for economic growth and industrial developments. Industrialization in Japan started virtually from 1950's through an economic recovery stage after World War Two. Nation-wide industrial investments caused massive population migration from rural areas to urban metropolitan regions, namely Tokyo, Osaka, Nagoya and Fukuoka Metropolises. Continuous industrial developments along with expansion of urban areas have brought various types of negative stocks for the fluvial regions in the 21st century.

First, decades-long industrial developments in metropolitan regions took away agricultural sites and natural forestry areas surrounding urban activities in the last half of a century. Secondly, massive material input from the distant regions and countries are presently increasing to support materially abundant urban lives as consumption and industrial products as well as energy supply and other urban services. Diminishing farms and lumbering industries in metropolitan regions, thirdly, retrieving their recycling potentials. As a result, urban activities are surpassing the natural environmental capacity of the metropolitan region, which might bring disastrous and irreversible results to the region and society.

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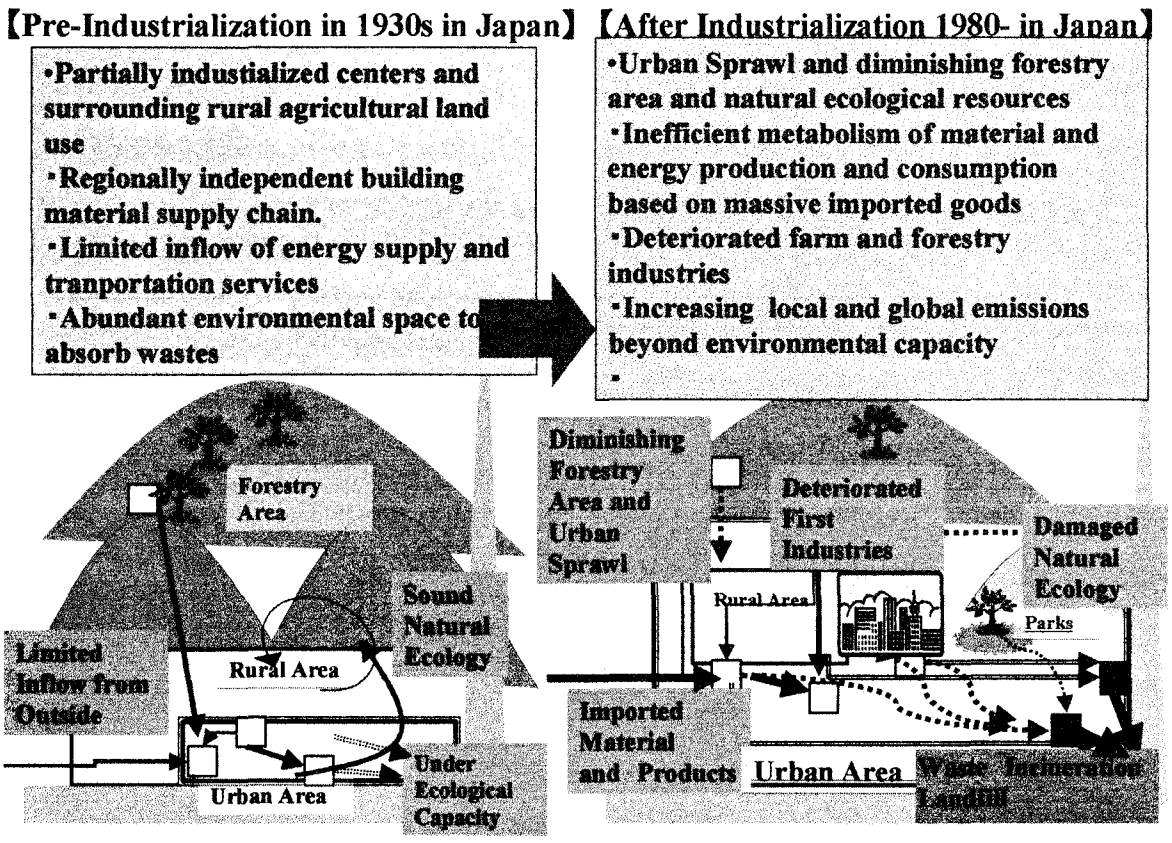

Fig. 1 Changes of Basin Region for Decades after Industrialization

2. OBJECTIVES

Basin region is a suitable terrestrial and aquatic scale to demonstrate sustainable regional governances that integrate water resource management, wastewater treatment, and solid waste management along with other regional policies such as land use controls and infrastructure developments. Research projects for analyzing policy impacts to control global warming risks and water resource management have started by several international co-operations. Among them, Global Scenario Group examines global scenarios based on three classes, namely environmental worlds, barbarization, and great transitions. World Business Council on Sustainable Development made scenario analysis to aim at helping corporate members reflect on the risks and opportunities for business of the sustainable development challenge[1]. Integrated policy approaches of regional scale have reached their implementation stages mainly in European governments and regions. Dutch system adopts vertical integration system to control local and regional land uses based on national scale environmental requirements[2]. Manchester Metropolitan governments took the comprehensive scenario approach of 'City-Region 2020'[3], which made comparative policy scenarios for six principle regional sectors, that is, built environments, transportation, land cover and ecology, wastes and pollution, energy and urban climate, and economy.

This paper attempts to show the framework of alternative policy planning and evaluation system on basin region management systems that contemplate wide range of policy options such as technology, infrastructure, and societal management as shown in Figure 1.

3. REGIONAL GIS DATABASE FOR BASIN

A prototype of regional database was designed to work as a platform for scenario-driven decision making for basin regional management focusing on the environmentally sustainable urban water and organic material cycles. Basin wide intervention scenarios are to comprehend several policy program fields such as advanced run-off and sewer management, advanced wastewater treatment system, wetland restoration, organic waste recycling and resource recovery system, promotion of factory and district-scale zero emission systems and land use management for sustainable urban forms. Alternative programs should consist of varied policy options from the technology application

to activity or spatial management need to be designed. By compiling the locational distribution data of material flows on GIS with alternative policy programs, their environmental improvement effects are evaluated (Fig. 2).

Regional GIS database are structured to cover comprehensive basin regional sectors in both of urban areas, industrial sectors and households and surrounding rural areas, forestry and agricultural farms. Considering the current availability of regional data, one-kilometer grids are set as basic units of the system. Fig. 3 shows usable data sources for different regional sectors in the field of spatial distributions, activities, water resource acquisitions waste water treatment systems, solid organic wastes and natural ecological habitats[4].

The database is made from digital database provided by public sectors and municipalities in the universal GIS format, namely shape files for ARC-INFO, as well as from digital table file data and paper maps and charts.

The database is made both for 1970s and 1990s to compare the environmental impacts of suburbanization in

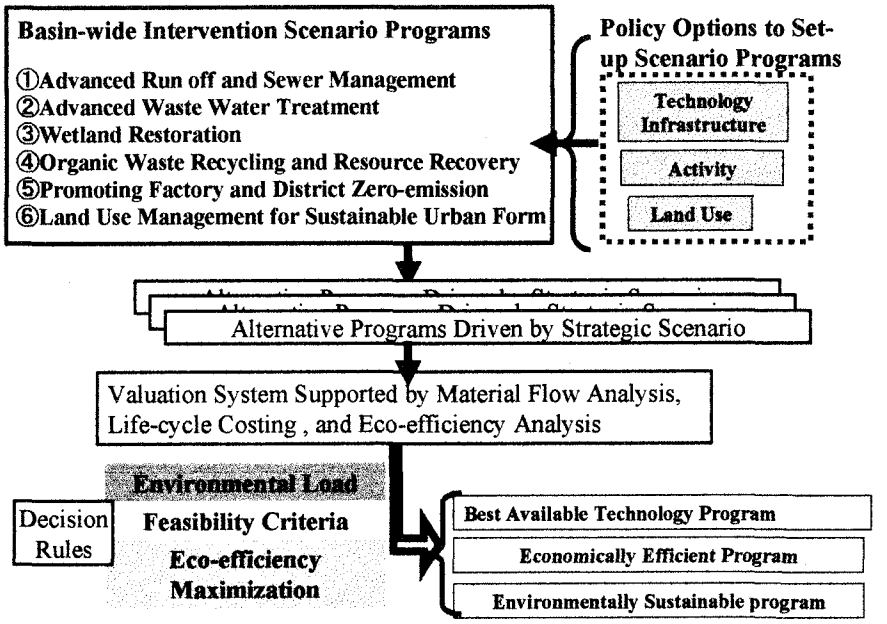

Fig. 2 Frame for Scenario-driven Planning System for Basin Region Management

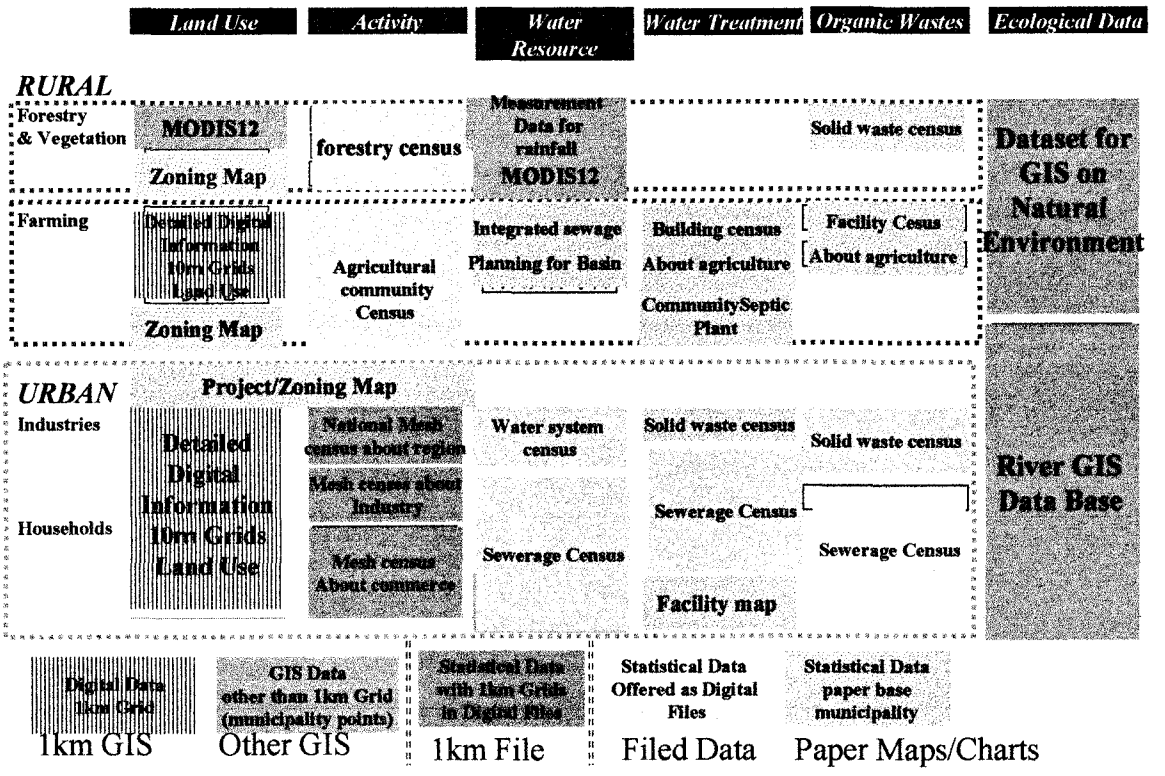

Fig. 3 Data Sources and Formats in Japanese GIS and Statistical Data System

Muko River Region. Non-GIS type data such as 1km grid table statistic data are converted into universal GIS data format.

Distributions of total organic wastes are estimated for seven regional sectors, agricultural farms, livestock feeders, food process industries, food retailers, households, lumbering industries and regional green park services. Emissions of organic wastes as garbage and sewage sludge are attributed to each regional sector for their spatial location of source point in each 1km grid. Fig.4 shows the estimation flow for total organic wastes at source points of attributable activities. Total organic wastes are estimated as totals of sewer sludge and solid garbage. Carbon dioxide emissions and discharged residues for dumping are evaluated from total organic wastes based on the alternative treatment technologies and management programs. (Detailed data sources are described in Reference 5))

4. ANALYSIS IN MUKO RIVER BASIN REGION

4.1 REGIONAL PROFILE

Muko River Basin hold 1.5 million populations, consisting of Amagasaki, Nishinomiya, Itami, Takarazuka, Sanda, North Ward of Kobe City, Sasayama, with catchments area of 496 km2 with main river length of 65.4km. As neighboring to Osaka City, the Basin Region absorbed a large amount of industrial facilities and employment population through economic growth ages from 1950s to 1970s. After then, the region has experienced relatively stable growth periods of these three decades, residential populations moved outward followed by the commercial facilities on suburban railways and highway networks while total populations have been stabilized with around 1.5 million scale. Faced with the serious water contaminations and air pollution in 50s and 60s, prevention policies were implemented such as wastewater treatment networks. Provided with two river-basin sewerage systems and three municipal sewerage systems, river water qualities have been improved after 1980s.

4.2 SPATIAL CHANGES OF ORGANIC MATTER

Organic wastes and sewerage sludge in 1970s and 1990s are distributed as 1 km grids of source points so that policy makers and planners are able to identify the spatial characteristics of material flow of the region, according to the evaluation process of Fig.4. Suburbanized population, for example, brought regionally more dispersed organic wastes emission patterns from households. Railway and road network development have also induced more organic wastes

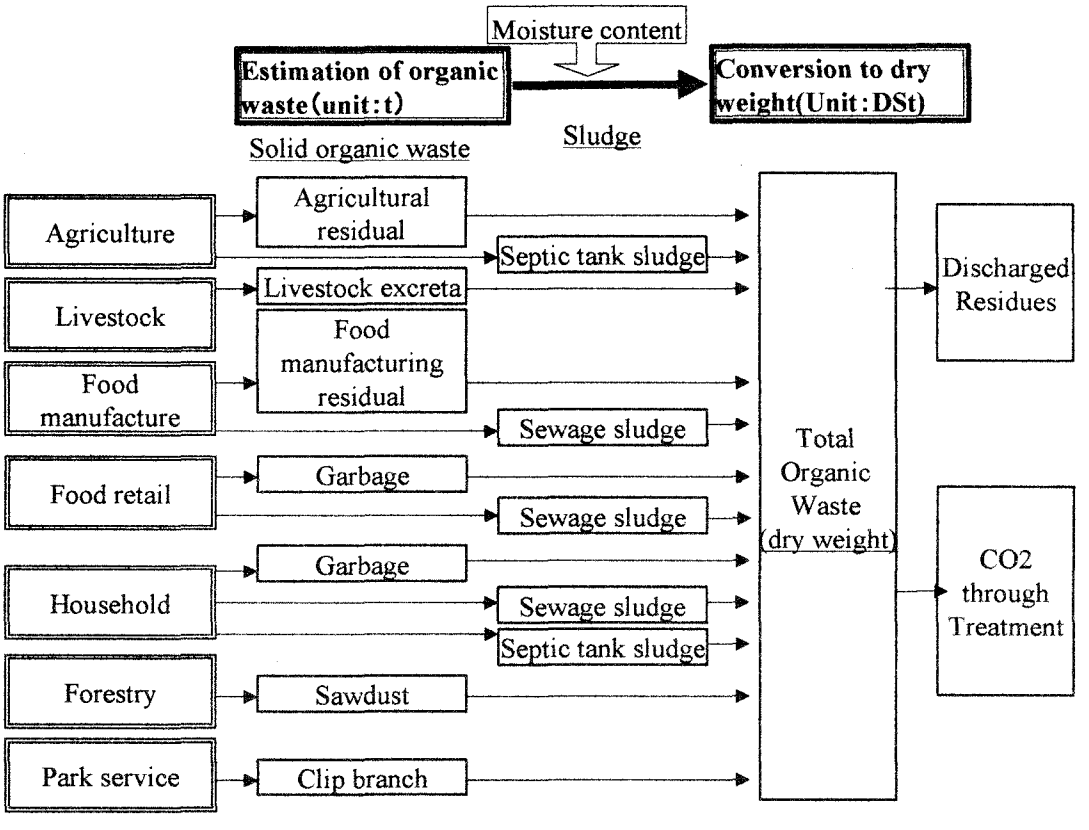

Fig. 4 Estimation Flow of Total Organic Wastes from Regional Sectors Industrialization

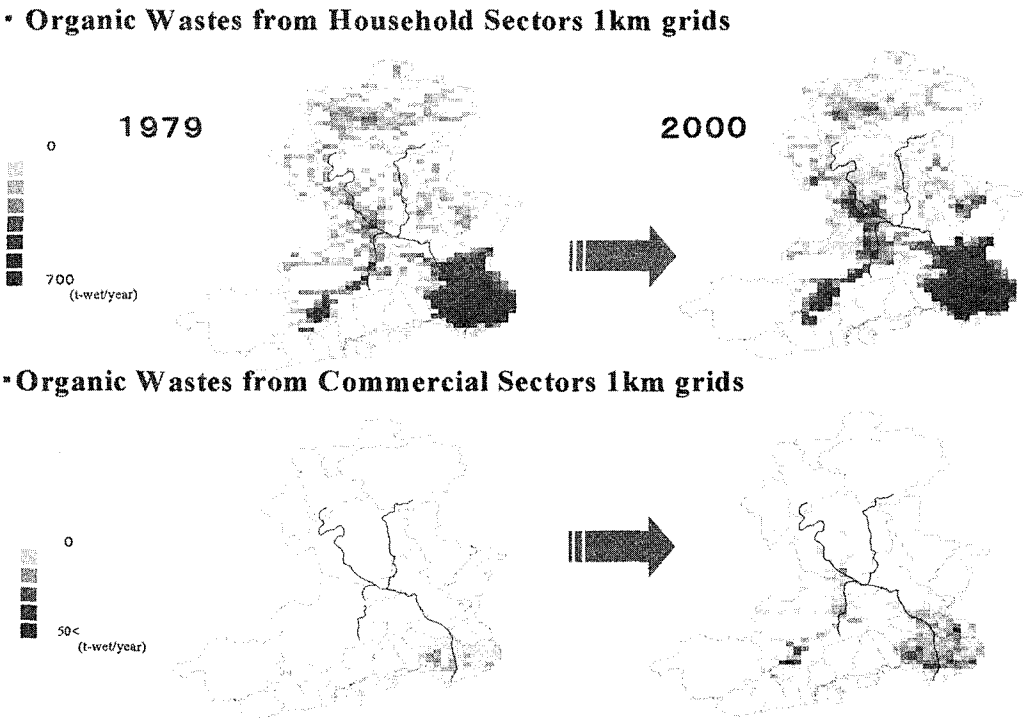

Fig.5 Changes Spatial Emissions Patterns of Organic Wastes in 1970s and 1990s

attributed to shops and other commercial activities in growing suburbs as is shown in Fig.5.

Regional GIS database is structured to provide time series spatial changes of organic material emissions and flows for decision makers and policy planners in the integrated basin management governances. The system is to show both aggregated and disaggregated organic consumptions and emissions for sectors of different activity patterns and material types such as solids, water dissolved and gasified emissions.

5. TENTATIVE PLANNING AND EVALUATION OF POLICY OPTIONS

5.1 TENTATIVE PLANNING OF POLICY OPTIONS

Fig.6 shows the range of policy options contemplating basin wide management from upper stream rural areas to downstream urban areas. Tentative policy options consist of the following three categories; 1) Infrastructure systems, 2) Technology systems. Infrastructure systems consist of basin-wide regionally concentrative treatment system and

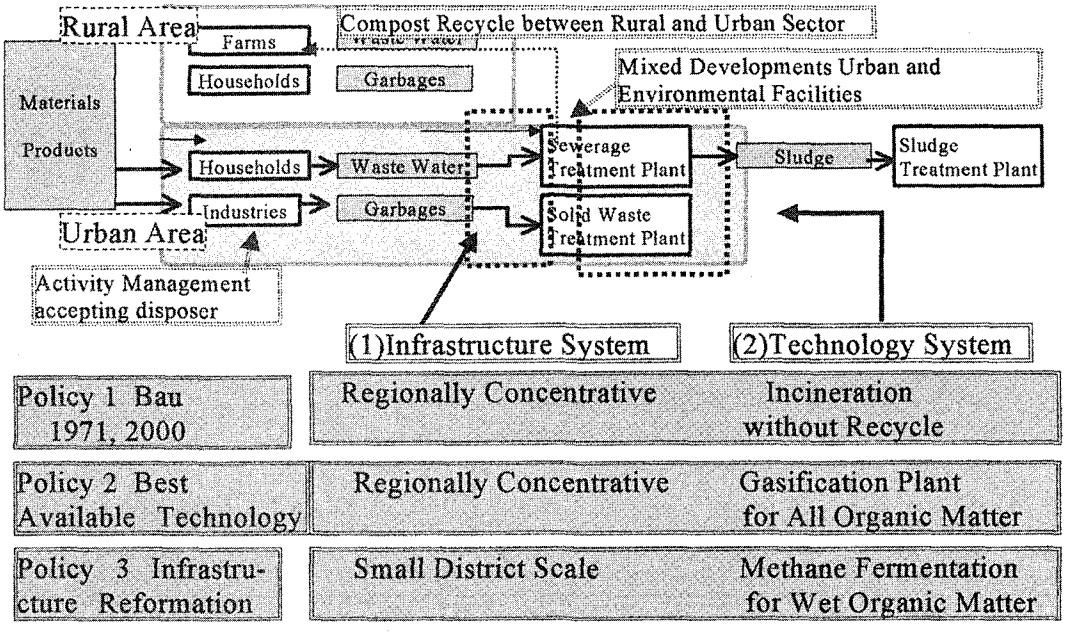

Fig. 6 Tentative Options and Alternative Policies for Basin Management

district-scale small treatment system. Technology system consists of treatment alternatives such as traditional incineration plants without resource recycling, gasification plants, and methane fermentation for wet organic matters. Other policy options are also considered such as mixed developments among urban buildings facilities and environmental facilities or compost recycles between rural and urban sectors, which are not included simulation studies in this paper.

As quantitative simulation studies, the following policy programs are evaluated: 1) Business as usual policy with current infrastructure networks and throwaway type incineration technologies. 2) Best available technology policy with efficient technologies such as gasification plants with regionally concentrative garbage and sludge collection. 3) Infrastructure reforming policy to convert the current system into small-scale treatment networks with methane fermentation for wet organic matter and their thermal recycle technologies.

5.2 MODELLING OF DISCHARGE, TRANSPORT, AND TREATMENT OF ENVIRONMENTAL EMISSIONS

Operational models for alternative policy options of the treatment of recycle are constructed by compiling with the emission distribution in GIS database system. The emission distributions are put as vector and transportation matrix that defines virtual transportation patterns of organic emissions. By combining them, vector variables for transported organic matter are obtained. By allocating the grid site of treatment plants, recycled material allocation vector acquired. Considering the spatial limitation of available recycled thermal energy, demand of the heat for each grid should be compared with recycled energy.

The spatial distribution of heat energy that is potentially recycled from sewerage sludge and solid wastes by methane fermentation plant in each source point are to evaluated by presuming a spatial scale of feasible heat distribution, availability of recycled thermal energy can be evaluated. Collection districts for sewerage network are tentatively adopted as thermal energy recycling units considering the practical implementation of developing thermal recycle facility in sewerage facilities such as pumping sites. The evaluation results suggest that as much as ten percent, particularly in downstream urban centers, of current energy consumption can be saved through district-scale thermal recycle of the Policy option3 in Fig. 6.

6. CONCLUSIONS

This paper attempts to present scientific base for approaching to sustainability management in basin from a viewpoint of reforming environmental infrastructure and sanitary engineering practices by showing the following procedures; 1) To specify framework of designing policy scenarios and planning options for integrated basin-wide management. 2) To prepare data-base in the manner of GIS for calculation, accounting, and summing up of basin-wide material flow and direct and indirect environmental burdens. 3) To model simultaneously discharging or loading of both of wastewater and organic solid waste. 4) To evaluating performance of expected advanced engineering practices such as methane fermentation and energy recovery.

Comprehensive systems approach to combine technological sub-model, societal systems sub-models and scientific models of scientific sub-models are found to be effective to design and evaluate policy recommendations for sustainable basin management.

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