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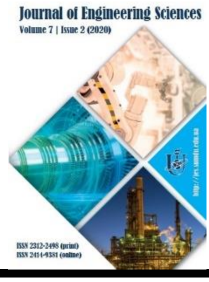

Low-carbon City Inventory Method for the Local Scale

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Abstract. Greenhouse gas (GHG) inventory has played a fundamental role in providing scientific political-making evidence in mitigation. For a particular case study, Japan offers a positive performance in reducing GHG emissions since an early age, and the GHG Inventory Office of Japan was established in 2002 and is making efforts on publishing both "National GHGs Inventory Report of Japan" and "GHGs Emissions Data of Japan" annually. This paper covers local Japanese inventory development from a global range to a domestic level and offers its general reporting criteria nationwide. Furthermore, through a case study of recalculating 2010 Saga Prefecture's GHG emission, local inventory methodology is investigated in six GHGs (including CO_2, CH_4, N_2O, HFC, PFC, and SF_6) and forestry sectors. In this section, recalculating methodologies, especially regarding calculated fields and basic formulations categorized by GHG types, are introduced in detail. Then, it provides limitations and improvements of the inventory reformation. Further, future research directions are discussed as well. This research exhibits an inventory method at the local scale and offers its improvements by the author to provide some experiences and lessons for the research and mitigation policy-making practices in other parts of the world.

Keywords: low-carbon society, climate change, greenhouse gas inventory, local scale.

1 Introduction

Japan offers a positive performance in mitigation due to the climate change issue. For example, in 2008 Japanese government drew worldwide attention by declaring its ambitious plan for realizing a "Low-carbon Society" [1, 2] (LCS) in the year 2050 by reducing 60–80 % of its CO_2 emissions (compared with 1990 level). As is known that greenhouse gas (GHG) inventory [3–6] has been playing a fundamental role in providing scientific policy-making evidence, the GHG Inventory Office of Japan (GIO) [7–9] was established in 2002 and is making efforts on publishing both "National GHGs Inventory Report of Japan (NIR)" and "GHGs Emissions Data of Japan" annually.

This paper provides a recalculating result of 2010 GHG local inventory through a case study of Saga Prefecture and sets out to answer questions: what the limitations and issues of GHG inventory for the local level are, and what improvements should be made. Meanwhile, the research will also evaluate the inventory menu at a global range to provide a broader view of the inventory reformation. This research exhibits an inventory method at the local scale and offers its improvements by authors to provide some experiences and lessons for the research and mitigation policy-making practices in other parts of the world.

With the awakening of global consensus on reducing greenhouse gas (GHG) emissions to combat global warming, to cope with climate changes and the related challenges, international treaties such as the United Nations Framework Convention on Climate Change (UNFCCC) and protocols of different magnitudes such as Kyoto Protocol (KP) [10, 11] were set up to facilitate and assist the implementation of those efforts. On an international level, there are currently 192 Parties to the Kyoto Protocol, and each country is mandated to establish and maintain a national system for the GHG emission estimations and removals (UNFCCC, 2008). They apply the Intergovernmental Panel on Climate Change (IPCC) methodology and IPCC good practice guidance to prepare their GHG inventories, which is the fundamental framework for most GHG inventories applied globally.

Various protocols and methodologies are established on subnational and local levels in response to the differentiated needs and local conditions. Despite that, the US's absence in ratifying the Kyoto Protocol, the Local Government Operations Protocol (LGOP) adopted by the California Air Resources Board [12], is a state-level endeavor to inventory the GHG emissions (CARB, 2010). Other examples include the GHG Protocol developed by the World Resource Institute (WRI) and World Business Council for Sustainable Development, the most widely used international accounting tool for local government and business leaders. Besides, a Local Government Operations (LGO), which is designed to allow local governments to quantify and report GHG emissions resulting from their operation, is established by California Climate Action Registry (CCAR), the (CARB), and Local Governments for Sustainability (ICLEI). The ISO 14064 is an international standard targeted mainly for local government and business, regions, and organizations with an integrated set of GHG emissions accounting and reporting tools.

2 Research Methodology

2.1 Research background

Japan is advanced in reducing GHG emissions since Kyoto Protocol (1997), and it is one of the earliest countries in the world which was concerned and made efforts regarding global warming issues. In 2008, then Prime Minister Fukuda made a speech at the G8 Hokkaido Toyako Summit press conference, which gained attention to the world's recognition. He pointed out that developed countries are obliged to take the lead in mitigating climate change and to make efforts for achieving a greenhouse gas (GHG) reduction target of at least 50 % globally by 2050 from the 2008 level. Meanwhile, the Fukuda Government also declared Japan's ambitious long-term plan for building 2050 low-carbon society (LCS), aiming to achieve a 60–80 % GHG mitigation target from the 2008 level. Later in 2009, then Prime Minister Hatoyama further announced a mid-term plan to reduce 25 % CO_2 emissions by 2020 from the 1990 level [13].

To report GHG amount and offer scientific policy-making evidence, the Japanese Ministry of Environment established GHG Inventory (National Scale) in 1999. National Institute for Environmental Studies Japan (NIES) announced the latest emission amount was 1,343 million tonnes, which is increased by 6.5 % compared to emissions in the base year under the Koto Protocol (1990).

Furthermore, according to Japan's law, large and medium-sized cities (over 0.2 million) must set up GHG reduction plans. To provide effective assistance, MOE offered specific instructions since 2008 and stipulated that each plan must conclude contents like calculating and analysis of its GHG emission, defining mid and long-term goals, implementation, and supervision.

Meanwhile, in Japan, and inventory reporting system is set up based on the population reference to IPCC regulations (SBSTA/2006/9) [14, 15]. As is shown in Table 1. "Must" means those prefectures (cities, towns, and villages) which are obliged to report required items. "Optional" means the item is selectable to be covered.

Saga Prefecture, where the case study is conducted, Saga Prefecture is in the northwest part of Kyushu, Japan.

Table 1 – Criteria of inventory reporting Japan

Item	Prefecture (over 0.5 million)	Core city, (0.2–0.5 million)	Other cities (below 0.2 million)
Resources CO_2	must	must	must
Industry (CH_4, N_2O)	must	must	optional
Waste	must	must	must
Agriculture	must	must	optional
HFC, PFC, and SF_6	must	optional	optional

According to the criteria, Saga Prefecture must report all items (including CO_2 sources, CH_4, N_2O Industry, Waste, Agriculture and HFC, PFC, SF_6). This prefecture area is 2439 km^2, and many enterprises are contributing to low carbon society building.

2.2 Method of recalculating Saga prefecture's inventory

To examine the feasibility of inventory at the local level and identify limitations of the inventory and explore improvements in creating a more efficient and convenient calculating methodology, this research recalculated the 2010 Saga Prefecture's inventory. Recalculating is based on sources that are mainly from the provincial level and national level. For example, sources like energy consumption data and electricity consumption for livelihood and Saga Statistical Yearbook are frequently used. Besides, the recalculating process uses Excel software.

In general, there are three main processes of recalculating. First is accessing to the consumptions, which caused GHG emissions. Second is transmitting consumption to GHG emissions of each field (e.g., from TJ: ton joules to CO_2) by using formula and emission factors. The third is adding up all outcomes.

Recalculating Saga Prefecture's inventory covers six GHGs (CO2, CH4, N2O, HFC, PFC, SF6), encompassing nine sectors. As is shown in Table 2, GHGs are calculated in nearly 30 fields, through which final annual GHG emissions are summed up.

3 Results and Discussion

Furthermore, as is shown in Table 3, it can be concluded that some sectors like the waste sector and automobile sector are not only calculated in CO_2 but also CH_4 and N_2O for their emissions. Detailed descriptions are provided in the following paragraphs.

Recalculating follows the formulation of Saga Prefecture. In CO_2, for example, Energy Industry Sector concludes four categories (Table 4).

Energy Industry Sector Example is provided in Table 5. In CH_4 and N_2O, for example, Automobile Sector follows the formulation: "Emission = Annual Distance Traveled (km) × Emission Factors (gCh_4/km)" (Table 6).

In HFC, PFC, and SF_6, it mainly follows the formula: "number of user × Emission factor", while adding up emissions directly provided by specified business operators.

Table 2 – Saga Prefecture inventory general contents

Sectors	Calculated GHG category	Fields
Energy Industry	CO_2	1. Manufacturing Industry 2. Agriculture, Forestry and Fisheries 3. Construction and Mining
Residential	CO_2	Residential energy consumption
Commercial	CO_2	1. Commercial Sewage Waste 2. Finance and Real Estate 3. Public Service 4. Specified Business Operators Services 5. Individual Services
Industrial Process: cement	CO_2	Cement
Transportation	CO_2, CH_4, N_2O	1. Automobiles (CO_2, CH_4, N_2O) 2. Railway (CO_2) 3. Shipping (CO_2) 4. Aviation (CO_2)
Waste	CO_2, CH_4, N_2O	1. Municipal Solid Waste 2. Industrial Waste 3. Solid Waste Disposal on Land 4. Organic Waste 5. Water Treatment
Agriculture	CH_4, N_2O	1. Livestock breading process 2. Livestock waste 3. Emission from paddy field 4. Burning of crop residue 5. Cultivation of organic soils
HFC, PFC, SF_6	HFC, PFC, SF_6	1. Household refrigerator 2. Air conditioners (automobile use) 3. Specified business operators
Forestry	CO_2	1. Private Forests 2. National Forests

The forestry sector contributes to mitigation through absorbing CO_2 emission, and it is divided into private and national forests. Regarding the calculating contents, Intensively Managed forest and semi-natural forests are calculated in both two categories. It follows the formulation:

$$\Delta CLB = \Sigma_k[(c_{t2} - c_{t1})/(t_2 - t_1)]_k, \qquad (1)$$

where ΔCLB stands for annual carbon stock change in living biomass [t-C/year]; t_1,t_2 means time points of carbon stock measurement; c_{t1} refers to total carbon in biomass calculated at time t_1 [t-C] while c_{t2} stands for total carbon in biomass calculated at time t_2 [t-C]; k means the type of forest management.

Through recalculating via "MS Excel" software, five limitations of inventory are discovered during the process. They can be summarized as: time delay, high expense, international prefectural issues, complex formulation, missing of contents, and incorrect consumption data.

Firstly, a series of latest data cannot be accessed due to time delay, which brought a great challenge to reporting and updating GHG emission. For example, in the waste sector regarding incineration amount, the latest data (Comprehensive Report on the Review Results of Calculating the Emission Amounts of GHG) is from 2004. Besides, when recalculating the residential sector, the Single Household Number's latest data (Saga Prefecture) is from 2010 [16]. Further, the consumption amounts of electricity, gas, and town gas utilized in the residential sector, can only be found in 2011. Therefore, it is a considerable obstacle for the government to report 2012 due to the absence of information, let alone the reporting of 2014 GHG inventory.

Table 3 – Recalculating GHG categories and related sectors

GHG category	Sectors
CO_2	1. Energy Industry Sector 2. Residential Sector 3. Transportation Sector (Automobiles; railway; shipping; aviation) 4. Waste Sector 5. Industrial Process Sector 6. Forestry Sector (absorb)
CH_4, N_2O	1. Automobile 2. Waste Sector 3. Agriculture Sector
HFC	1. Household Refrigerator 2. Air conditioning (automobile use) 3. Specified Business Operators
PFC, SF_6	Specified Business Operators

Table 4 – Energy industry sector calculating formulation

Energy Category	Method
Fuel	Consumption（TJ）× Emission Factors（tc/GJ）×1000×44/121
Electricity	Consumption (10^6 kWh) × Emission Factors (kg-CO_2/kWh) × 1000
Heat	Consumption (TJ) × Emission Factors (tCO_2/GJ) × 1000
Town Gas	Consumptions（million kcal）× Emissions Factors (tc/GJ) × 1000 × × 44/12 × 0.004192 Consumption (TJ)× Emission Factors (tc/GJ)×1000×44/12

For resolving this issue, a timely sampling survey conducted in the prefecture is recommended. Prefectural average data is expected to be estimated through investigation consequences of each Saga City. For instance, to access 2014 data of single household number and consumption amount of electricity in Saga prefecture's Beppu city, a certain number of Beppu households can be surveyed. Similarly, the 2014 incineration amount can be calculated through a sampling investigation conducts in each region. This survey should cover all range of residents (including young and elder) and include foreign households. Furthermore, the season of doing a survey is expected to set in a reasonable timeframe, which is available to guarantee data accuracy and allow sufficient time for calculating.

Secondly, a large amount of budget is spent on purchasing data. For example, calculating in the residential sector, the inventory team must pay for Saga Gas Company Annual Reports (Government Publication). The annual amount of industrial wastewater (Saga Prefecture) needs to be purchased from Japan Sewage Works Association in the waste sector. Meanwhile, railway track length (Saga Prefecture) must be bought from JTN Timetable in the transportation sector. For addressing this issue, national subsidies are expected to be provided. Besides, data, which need to be paid, are recommended to be accessible from other free channels. Moreover, to save budget, estimation through previous years' data can also be applied.

The third is the international prefectural issue in terms of aviation routes. Currently, Saga airport provides services for several domestic flights and an international flight (Saga – Seoul by Korean Air). Domestic services (including inter-prefecture flights) are calculated through aircraft fuel consumption charged in Saga Airport. Nonetheless, due to the unclear boundary issue between Saga-Seoul, the GHG emission has not been calculated. For solving the issue, an explicit menu and agreement between the two cities must be negotiated.

Fourthly, complex formulations need to be modified. For example, in the agriculture sector, when recalculating Saga Prefecture's dairy cattle waste, the current method is feces emission of all dairy cattle (CH_4) + urine emission of all dairy cattle (CH_4) ＋ mixed emission of all dairy cattle (CH_4), which is detailed and accurate. Nevertheless, the method is time-consuming. Therefore, a new computing method of CH_4 emission of individual Cattle × number of all dairy cattle is recommended.

Lastly, through recalculating and comparing 2010 Saga government released results, it is found that some required contents are missed, and incorrect consumption data are employed. Therefore, accuracy is required for future inventory. For example, regarding solid waste disposal on land, both CO_2 and CH_4 emissions of the anaerobic landfill and semi-aerobic landfill must be reported according to the Ministry of the Environment (MOE).

Table 5 – Energy industry sector example: construction and mining

Energy Category	Consumption		Emission Factors		Emission（tCO_2）
Fuel	N/A	TJ	N/A	N/A	96,691
Coal	2	TJ	0.0247	tc/GJ	181
Coal Product	6	TJ	0.0294	tc/GJ	647
Oil	0	TJ	0.0187	tc/GJ	0
Light Oil Production	1,078	TJ	0.0187	tc/GJ	73,915
Heavy Oil Production	315	TJ	0.0189	tc/GJ	21,830
Petroleum Gas	2	TJ	0.0161	tc/GJ	118
Natural Gas	0	TJ	0.0135	tc/GJ	0
Town Gas	271	TJ	0.0136	tc/GJ	13,514
Electricity	117	10^6 kWh	0.3850	kg-CO_2/kWh	45,045
Total	N/A	N/A	N/A	N/A	155,250

Table 6 – Automobile (light passengers' vehicle and bus) recalculating result

Content Category	Annual Distance Traveled (km)	Emission Factors (gCh4/km)	Emission（tCH4）	Emission Factor（gN2O/km）	Emission（tN2O）
Light Passengers Vehicles					
Petroleum	1,906,881,437	0.005	9.53	0.005	9.53
Natural Gas	748,966	0.013	0.01	0.0002	0.00
Total	N/A	N/A	9.54	N/A	9.55
Buses					
Petroleum	2,192,183	0.035	0.08	0.041	0.09
Light Oil	52,311,420	0.017	0.89	0.025	1.31
LPG	41,714	0.035	0.00	0.041	0.00
Hybrid	164,189	0.035×0.5	0.00	0.041×0.5	0.00
Natural Gas	301,944	0.05	0.02	0.0384	0.01
Total	N/A	N/A	0.99	N/A	1.41

However, the Saga government only reported CH_4 emissions. Another example is about HFC, which refers to MOE, household refrigerators, air conditioning (both automobile and business use), and vending machines are required to be calculated. Nevertheless, Saga missed the information about vending machines. Further, in calculating solid waste disposal on land, waste textiles percentage was wrongly used (Saga used: 85 %; Correct 80 %). For improvement of the accuracy, the Saga inventory team's supervision is highly recommended, and timely data, which MOE instructs, should be updated in local inventory.

Conclusions

Climate change indicates that GHG inventory and supervision system has played a fundamental role in mitigation.

Although local inventory is still in a developing stage currently, there is an inevitable trend for creating and applying a more convenient and efficient calculating method in the future. Due to inadequate studies on the GHG inventory for local scales, various inventory issues like time delay, high expense, complex formulation, international issues, missing required contents, and wrongly employed data are found in the research. Therefore, related inventory improvements, like designing sample survey's contents and enforceable conduction plan, the definitive agreement between Saga and Soul, simplify the inventory calculating method, and accuracy improvement and strengthening supervision are recommended.

Future research direction is expected to focus on individual-based inventory investigation and its related applications.

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