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Towards Green Transformation to Achieve Hitachi Zero-Carbon City Vision for 2050

Yukiko YOSHIDA[1*], Yujiro HIRANO [2]

1* Ibaraki University

2 National Institute for Environmental Studies
(Corresponding Author: yukiko.yoshida.uz27@vc.ibaraki.ac.jp)

ABSTRACT

The goal of concurrently addressing green transformation (GX), in this study, we aimed to reconcile exploring regional optimization in smart grids and renewable energy variability in Hitachi, Japan. The breakdown of CO_2 emissions among Hitachi City's sectors was estimated because of the lack of detailed data in the Ministry of Environment's Municipal Emissions Carte. To foster GX, solar power generation using renewable energy are unstable because they are affected by the weather, and depending on the scale of installation, EVs are equipped with storage batteries, and depending on the time of day, they can be charged as a buffer for surplus electricity from renewable energy. If Hitachi City were to install about 1,000MW of solar panels, it could become a zero-carbon city by 2050.

Keywords: GX, Zero-Carbon City, Energy consumption, EV, Local government

INTRODUCTION

The Green Transformation (GX)[1)] aims to change the global social structure towards achieving carbon neutrality by 2050. With Europe mandating EPDs (Environmental Product Declarations) [2)] for the construction industry, particularly through EN15804, the importance of lifecycle assessment for ZEB (Zero Energy Building) and ZEH (Zero Energy House) in new construction projects is being emphasized not only in Europe but also in the Americas and Asia. Furthermore, the investment objectives of ESG (Environmental, Social, Corporate Governance) have expanded to include the introduction of renewable energy into existing buildings, contributing to local revitalization efforts in Japan amidst declining population. The significance of information systems, particularly those managed by municipalities involving citizens, energy managers, and infrastructure providers, is increasing, particularly for advanced utilization (CO_2 emissions visualization). For instance, efforts regarding ZEB/ZEH in new construction projects have been summarized by Paolo Olasolo-Alomso et al.[3)], who reviewed the impact of EPBD energy performance indicators in Southern European countries like Spain and Italy. Additionally, embodied carbon assessments, including LCA evaluations, have been categorized by Ruijiun Chen et al[4)]. and Gnaga A. Warrier et al.[5)], with Egle Klumbyte et al.[6)] attempting to integrate BIM-LCA and constructing digital twin technologies. U.G.D. Madushikara et al.[7)] categorized GHG assessment methods for existing buildings based on economic factors of developing and developed countries into five categories: (1) performance evaluation, (2) performance optimization, (3) adoption, (4) policies and incentives, and (5) stakeholder engagement. Related to (1) and (2), Krithika Panicker et al.[8)] examined the balance between energy demand and solar panel output installed on rooftops of existing residential buildings in India, considering the impact of COVID-19 using real data through Energy Performance Index (EPI) and Energy Generation Index (EGI). Giuseppe Aruta et al.[9)] reported that the investment costs increase by €150 to €200 per square meter with the increase in sustainability when considering the installation of solar panels on buildings aiming for sustainability as the goal of smart grids. Zhang Deng et al.[10)] developed Auto mated Building Performance Simulation (AutoBPS) using building information from GeoJSON files to conduct energy efficiency and PV installation considerations from individual building simulations to city-scale energy simulations based on 3D information of 3633 buildings in Changsha, categorizing the analysis by building types such as residential, office, and hotel but lacking data for hospitals, schools, and mixed commercial facilities. Myeong-in Choi et al.[11)] constructed a system for regional energy optimization using AI based on Weather Index (WI) such as sunny and cloudy conditions, in addition to

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constructing energy visualization systems for energy managers, aiming to utilize information systems extensively. Arva Arsiwala et al.[12] developed a visualization system for 3D building information using small sensors to measure real-time temperature, relative humidity, and CO2 concentration in living rooms, kitchens, and bedrooms per household, verifying accuracy with predictive models. Georgios Chantzis et al.[13] are considering achieving decarbonization from both electricity and heat using demand response functions, indicating the energy transition goals that various European countries should aim for. Seyeh Niloufar Mousavi et al.[14] consider the introduction of adaptive technologies such as rooftop greening to improve comfort as part of GX technologies, which also encompass the pursuit of well-being.

In Japan, the installation of PV panels on existing building rooftops is often challenging, leading to considerations for installation in fields, parking lots, etc. It is necessary to consider not only energy self-sufficiency at the building level but also at the community level. Additionally, forecasting outdoor environments can improve the accuracy of predicting indoor environmental behaviors, making it crucial to disseminate information to citizens regarding heatstroke prevention during high temperatures, preparation for typhoons, and changes in behavior during snowfall when considering the balance between energy demand and renewable energy introduction. Therefore, this study conducted an examination on the advanced utilization of information systems, including CO_2 visualization of energy demand and PV introduction, and the comfort of outdoor environments, as part of the broader GX technological development unique to Japan.

The Japanese government is simultaneously promoting both the Ministry of the Environment's "Regional Decarbonization Roadmap"[15] and the Cabinet Office's "Digital Agrarian City National Concept"[16]. Local governments, except for Ibaraki Prefecture, that declared their intention to achieve nearly zero carbon dioxide emissions by 2050[17] cover over 90% of the total population across all prefectures (as of the end of December 2023). Furthermore, on 21 December 2023, Hitachi City and Hitachi, Ltd. concluded a comprehensive cooperation agreement regarding a co-creation project aimed at realizing a "next-generation future city (smart city)" utilizing digital technology.

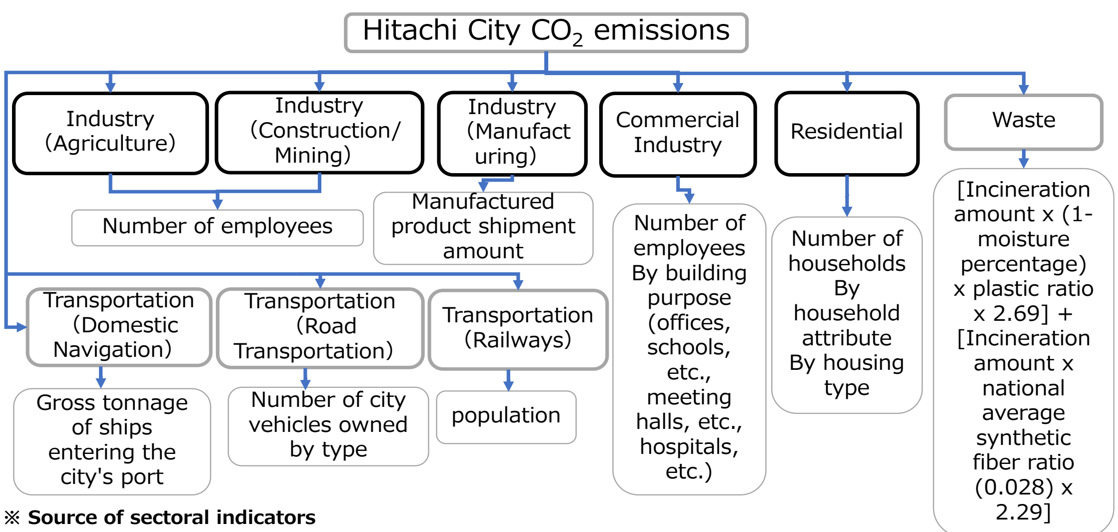
In this report, based on the example of CO_2 emissions in Hitachi City, we introduce initiatives for understanding the breakdown of CO_2 emissions and promoting GX for stakeholders and citizens. We hope that these efforts, including the introduction of renewable energy and the promotion of decentralized energy spread, such as by employing smart grids, will contribute to achieving a zero-carbon city by 2050.

1. MATERIAL AND METHODS: LOCAL GOVERNMENT INITIATIVES TOWARD A ZERO-CARBON CITY

Hitachi City declared the Hitachi Zero-Carbon City vision in March 2022 and formulated the 3rd Hitachi City Global Warming Countermeasures Implementation Plan (Regional Policy Section) [18] in March 2023.

1.1 Ministry of the Environment's Values Published in "Municipal Emissions Carte"

The CO_2 emissions of municipalities were reported based on the "Municipal Emissions Carte"[19) 20) 21)] published



※ Source of sectoral indicators
Manufactured product shipment value, etc. (manufacturing industry): Industrial statistics survey
Number of employees (construction/mining, agriculture/fisheries, commercial and other sectors) : economic census(Statistics Bureau of Japan)
Population, vital statistics and number of households survey based on the Resident Registration System (Ministry of Internal Affairs and Communications)
Number of cars owned (transportation sector) : Automobile Inspection and Registration Information Association "Number of Cars Owned by Municipality" and National Federation of Light Motor Vehicle Associations "Number of Light Motor Vehicles by Municipality"
Gross tonnage of ships entering the port (vessels) : Annual port survey report

Fig. 1 Hitachi City CO_2 emissions calculation flow

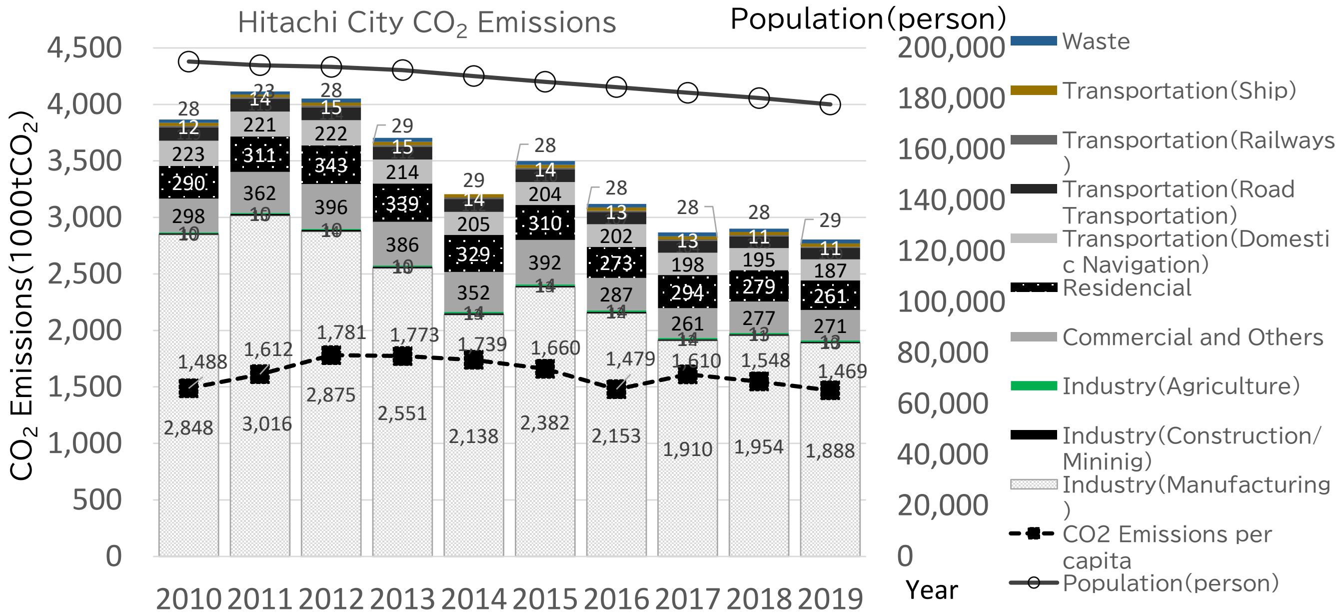


Fig. 2 Hitachi City CO_2 emissions of MOE

by the Ministry of the Environment, following policy formulation for decarbonization, with implementation reports for fiscal year 2023. The estimated flow (*Fig. 1*) and values (*Fig. 2*) of CO_2 emissions in Hitachi City are shown.

In this study we estimated the breakdown of emissions among various sectors.

1.2 Industrial Sector in Hitachi City

The CO_2 emissions from the industrial sector in Hitachi City account for approximately 70% of total emissions (*Fig.2*). After requesting the Ministry of the Environment to disclose CO_2 emissions from specific emitters, it was found that specific emitters account for about 50% of the industrial sector, and that there is a decreasing trend in their workforce. These emissions are calculated based on the amount of manufactured goods shipped within the city and are thus influenced by corporate economic activities.

Currently, the development of a factory model has been initiated through a collaborative research effort between Hitachi, Ltd. and Ibaraki University.

1.3 Residencial, Commercial and Other Sectors of Hitachi City

Emissions from the commercial and other sectors of Hitachi City's specific emitting businesses amount to 138.8 thousand tons of CO_2 (68 thousand tons from public offices, 8.2 thousand tons from hospitals, 2.9 thousand tons from universities, etc.). This constitutes half of the CO_2 emissions in the commercial and other sectors, totaling 271 thousand tons (*Fig. 2*) as per the Ministry of the Environment's published data, with an unknown breakdown. Hence, by comparing the estimated CO_2 emissions (*Table.1*) obtained by multiplying the annual energy consumption per unit of use by the floor area and the Ministry of the Environment's published data, a total of 292.5 thousand tons of CO_2 emissions was obtained, closely matching the assumption. The total floor area was determined from the Zenrin building point data (2022) in Table 1.

Table. 1 Estimated breakdown of CO_2 emissions in Hitachi City commercial and other sectors

Annual energy intensity by use	Primary energy consumption intensity [MJ/㎡・year] Weighted average value	CO_2 emissions intensity [kgCO_2/㎡・year]	Total floor area [m²]	Primary energy consumption [TJ/year]	CO_2 emissions [1,000tCO_2/year]
ApartmentHouse	638.0	26.3	1,879,626	1,199.2	49.4
Office	1,292.0	51.6	2,155,103	2,784.4	111.2
LargeScaleRetailStore	1,862.0	92.0	190,486	354.7	17.5
Store・Restaurant	1,745.0	82.0	484,513	845.5	39.7
Hotel	1,368.0	75.0	78,474	107.4	5.9
Hospital	2,614.0	131.0	366,709	958.6	48.0
MeetingPlace	669.0	26.7	236,899	158.5	6.3
School	1,560.0	62.3	446,207	696.1	27.8
Cultural facility	1,075.0	42.9	57,898	62.2	2.5
Sports Facilities	975.0	38.9	51,837	50.5	2.0
Others	1,247.0	93.0	338,289	421.8	31.5
Total			4,406,415	6,439.7	292.5

2. ATTEMPT for GX VISUALIZATION

2.1 Adaptation of Evaluation Methods for GX

From annual CO_2 emissions determined using Zenrin's 2022 building point data [23] (*Fig.3*), we constructed a visualization system with QGIS

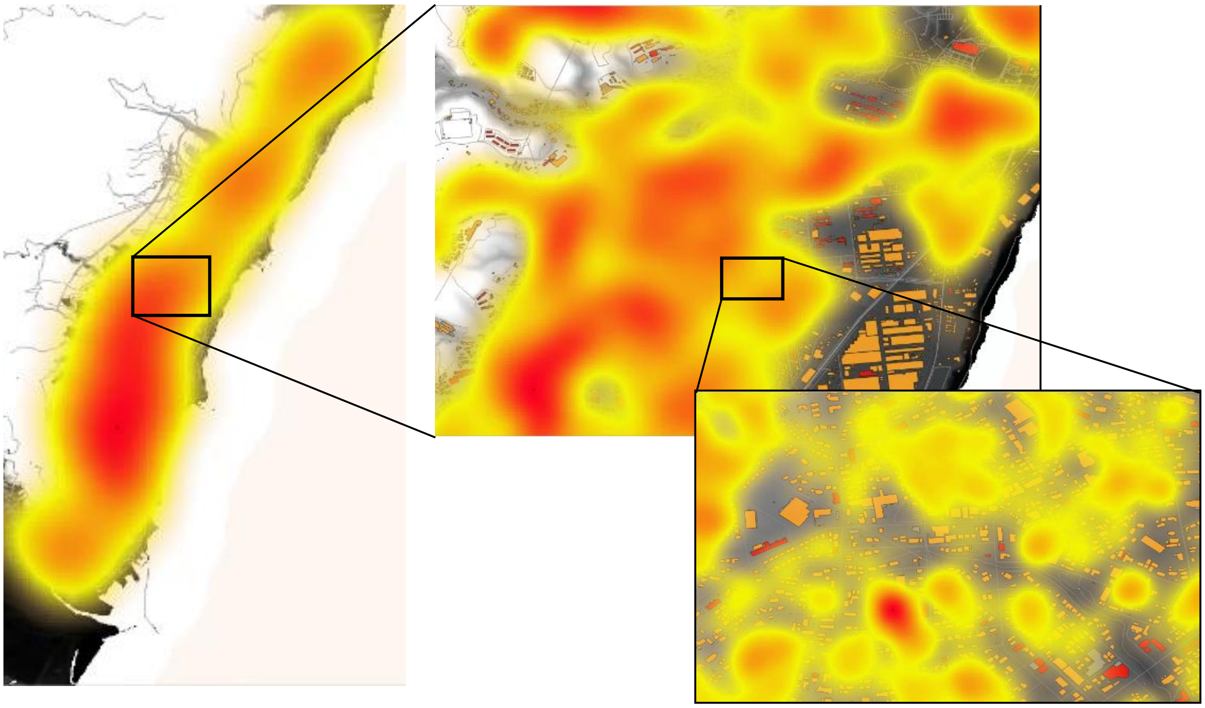


Fig.3: Attempt to transform Hitachi Zero-Carbon City GX in QGIS Ver3.22.11

(Ver3.22.11) for heatmap functionality to visualize energy consumption units by building usage and floor area for each sector breakdown (see Table 1 for the commercial sector and Figure 4 for the household sector) in FY2020. Our aim is to progressively expand the information system to include data on the industrial sector, transportation sector, waste management sector, and the introduction of renewable energy.

2.2 Estimation for the Introduction of Renewable Energy

We calculated the monthly solar power generation capacity for Hitachi City based on data from the "Hitachi City New Energy Vision" [24] formulated[25] in 2017. Assuming 18.2 MW of solar power from mega solar and 6 MW from roof installations on residential buildings, we calculated the monthly solar power generation for Hitachi City as a whole (*Fig.4*).

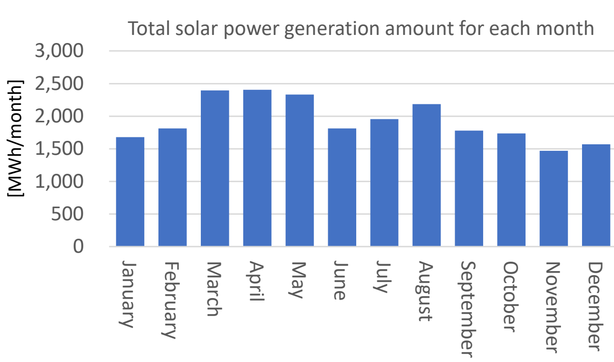


Fig.4 Monthly solar power generation for Hitachi City In 2017

Table. 2 Setting for heating and cooling demand of COP

Residential hot water demand by gas	Gas fired water heater COP（80℃）	0.7
Cooling demand by electricity	Electric chiller cold water COP(7℃)	3.2
Heating demand by gas	Gas absorption chiller/ heater machine hot water COP （60℃）	0.75
Cooling and heating demand by gas	Gas absorption chiller/ heater cold water COP	1.3
hot water demand by gas	hot water boiler COP（80℃）	0.75
Genelink (chilled water production)	The maximum waste heat recovery amount is 40% of the total capacity. The remaining 60% is equivalent to gas absorption chiller/heater COP	0.8 when recovering waste heat 1.4 when using gas
Genelink (hot water production)	Gas only for hot water production COP	0.85 when using gas

Moreover, based on the area breakdown by building usage (*Table.1 and2*), we estimated the monthly electricity demand for Hitachi City as a whole (*Fig.5, 6*).

In this paper, we use the following conversion values. Electricity: Purchased amount of electricity [kWh] × Primary energy equivalent value (9.76 [MJ/kWh) for approximately 2.9% of the total electricity demand for the city, underscoring the necessity for further promotion of GX in 2017.

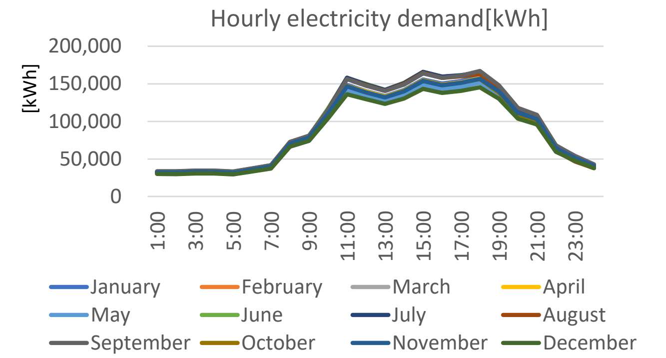


Fig.5 Monthly average daily power demand by time of day for Hitachi City in 2017

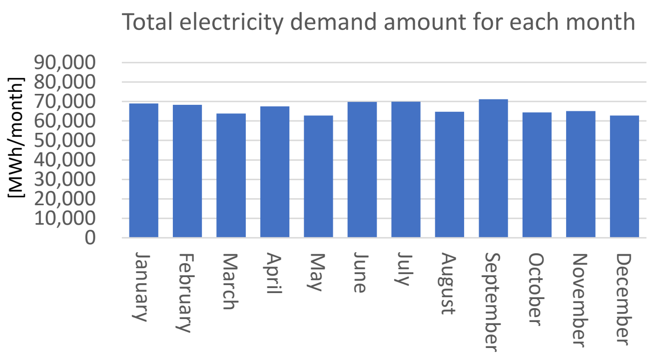


Fig.6 Monthly electricity demand for Hitachi City in 2017

Hitachi City's solar power generation accounts

3. RESULTS

If Hitachi City were to install about 870,000 kW of solar panels, it could become a zero-carbon city by 2050 (*Fig.7*).

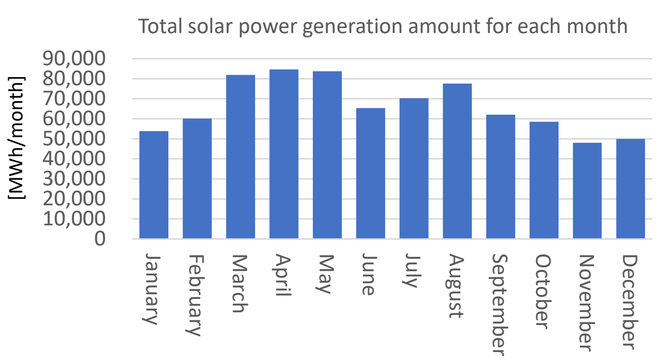


Fig.7 Predicted monthly solar power generation for Hitachi City in 2050

4. DISCUSSION

It has been found that to make the entire city of Hitachi zero-carbon, large-scale solar panels and other renewable energy sources will be required. Therefore, it is necessary to consider the balance between demand and supply of storage batteries by increasing the number of EV vehicles, and to consider the uncertainty of energy supply, which is affected by weather conditions. It was also found that the updating of gas-based systems through the diffusion of carbon recycling technologies such as hydrogen and methanation is also urgently needed.

5. CONCLUSIONS

In this study, we estimated the CO_2 emissions breakdown among sectors in Hitachi City using various statistics. We also verified the capability of the energy calculations and visualized annual values for the entire city using the heatmap functionality in QGIS.

To attempt to reconcile data with estimations, we estimated the energy consumption by building usage on an hourly basis and continue to explore regional optimization in smart grids and the hourly variability of renewable energy balances. If Hitachi City were to install about 870,000 kW of solar panels, it could become a zero-carbon city by 2050 without the industry sector. We aim to simultaneously address GX and disaster response scenarios. Using renewable energy are unstable because they are affected by the weather, and depending on the scale of installation, EVs are equipped with storage batteries, and depending on the time of day, they can be charged as a buffer for surplus electricity from renewable energy. We aim to simultaneously address GX and disaster response scenarios installing EVs. Furthermore, predictive control for operational optimization based on weather forecasts would being conducted using data from satellite images and observation values obtained in real time for the future.

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