FUTURE PREDICTION OF CARBON DIOXIDE EMISSION IN TOKYO GIVEN BY SPREAD OF ZERO ENERGY APARTMENT HOUSES

Tomoya Okishio, Tsunoo Satomi and Hiroto Takaguchi
Graduate School of Creative Science and Engineering, Waseda University, Japan

ABSTRACT

Based on the Paris Agreement which entered into force in 2016, target to reduce 39% of carbon dioxide emission of residential sector over the 2013 level by 2030 was declared. To reach the target, one of the policies which Japanese government showed is Zero Energy Houses for detached houses. This research is aimed to show the prediction of carbon dioxide emission between 2013 and 2030. Firstly, following the fact that the number of apartment houses is increasing in Japan, the definition of Zero Energy Apartment Buildings is proposed. Secondly, the number of detached houses and apartment buildings which will be constructed and removed is calculated using multiple regression analysis. Lastly, it is predicted how carbon dioxide emission in Tokyo will be reduced by spread of Zero Energy Apartment Buildings in 2030.

Keywords: *Zero Energy House, Apartment House,* Building Regulation, Carbon Dioxide Emission, Future Prediction

INTRODUCTION

According to the Paris agreement in 2016, Japanese government set a target of reduction of CO2 emission. Approximately 39% of energy consumption in Japanese household sector should be reduced by 2030 if compared to 2013. Therefore, Zero-Energy Building which consume no energy is getting more attention nowadays. In Japanese energy management plan, Japan declared that standard newly constructed detached houses will be built as ZEB by 2020, and all newly constructed detached houses will be built as ZEB by 2030. On the other hand, there is no any targets for ZEB of apartment buildings because it is difficult to install adequate amount of solar panels to realize ZEB due to the limited roof aria of apartment buildings.

However, according to the statistic in Japan, about 44.9% of all residential buildings were apartment buildings in 2013. In addition, compared to the statistic in 2008, the percentage of apartment buildings had increased by approximately 6.2%. Because of that, it is predicted that the number of apartment buildings will keep increasing. As a result, the Japanese declaration about ZEB should be verified because the declaration only mentioned ZEB of detached houses.

In this research, a definition of Zero-Energy Apartment Building which is not the target of the declaration is set. Then, how much amount of the CO2 emission from Tokyo will be reduced by the spread of Zero-Energy Apartment Building is predicted. Through this prediction, the possibility of the achievement of the target in the Paris agreement by the declaration of Japanese government about the spread of ZEB is verified. Finally, a plan of reduction of CO2 emission is suggested.

1. Realization of Zero-Energy Apartment Building

Overview of Action Plans for Realization of the Spread of ZEB in Japan and EU

Because ZEB has been getting more attention recently, a lot of countries have started making effort to realize the spread of ZEB. Action plans for realization of the spread of ZEB are researched. In Japan, Keyword "ZEH", "Nearly ZEH", and "Green Architecture" were searched. In EU, Keyword "ZEH", "Nearly ZEH", and "REHVA" were searched. In total, 25 documents were investigated.

Action Plans for Realization of the Spread of ZEB in Japan

In Japan, the government enforced a new regulation on energy consumption in building in 2015 to reduce the energy consumption from buildings. It will be mandatory to follow the regulation from 2021.

Regarding ZEB, the definition of ZEB in Japan was determined by ZEH Roadmap Committee[4)]. There are 4 conditions to be regarded as "ZEB". First, the building needs to reduce 20% of primary energy consumption from standard value. Second the building need to meet the requirement of thermal insulation of the envelope. Third, the building needs to install renewable energy resource. Forth, the building needs to reduce more than 100% of primary energy consumption include renewable energy resource. In order to be regarded as "Nearly ZEB", the building needs to reduce 75% of primary energy consumption. Figure 1 shows the definition of ZEB of detached houses. In addition, the target of the spread of ZEB in residential sector includes only detached house. Furthermore, Japanese government declared that standard detached houses will be built as ZEB by 2020. The definition of standard detached houses is that more than half of the houses which are built by house maker are ZEB.

Action Plans for Realization of the Spread of ZEB in EU

In EU, to realize the spread of ZEB, the target for the realization of ZEB was set. Therefore, each country set the concrete policy individually to meet the target. In addition to that, it is mentioned in Directive 2009 that it is obligated to install renewable energy resource in newly constructed buildings in EU. Furthermore, it is mentioned that all newly constructed public buildings after 2019 are Nearly ZEB and all newly constructed buildings are Nearly ZEB after 2021. The definition of Nearly ZEB is not same in each country in EU. Hence, each country set the definition individually. Most of the countries in EU set the maximum primary energy consumption(MJ/m^2) as the benchmark of Nearly ZEB. However, the way to calculate primary energy consumption is different depending on the country. France and Croatia have the Nearly ZEB definition for both detached houses and apartment buildings separately.

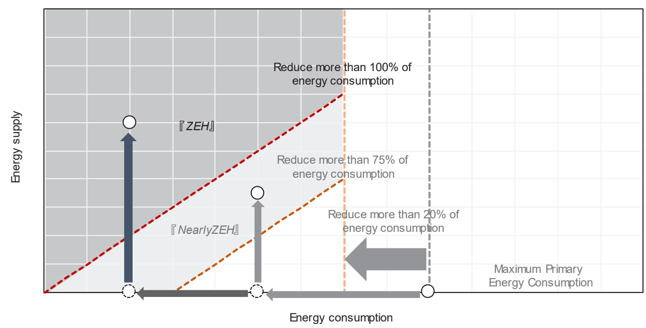

Figure 1. The Definition of Zero-Energy Detached House

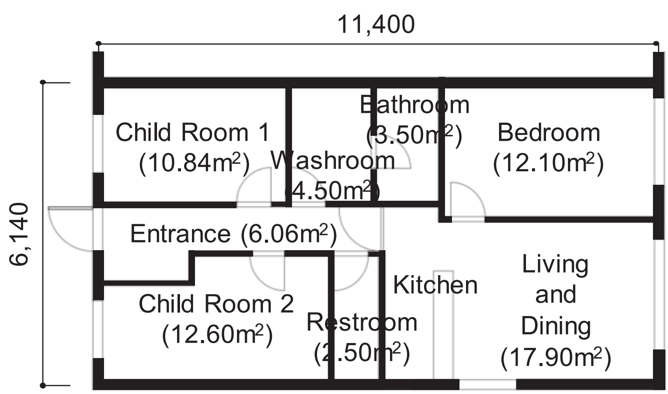

Figure 2. Model／Family Plan

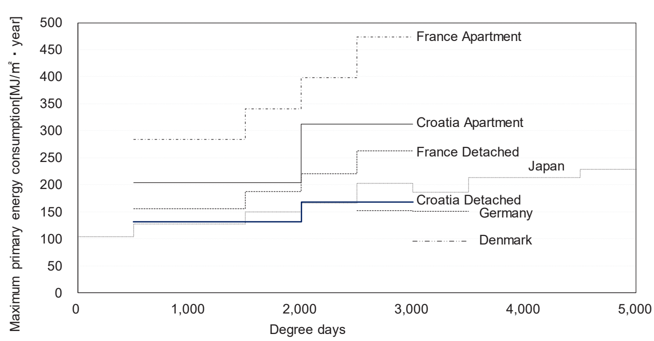

Figure 3. Comparison of Benchmark of Nearly ZEB

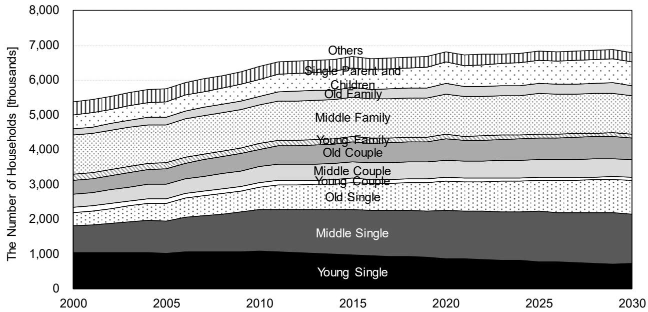

Figure 4. Household Structure in Tokyo

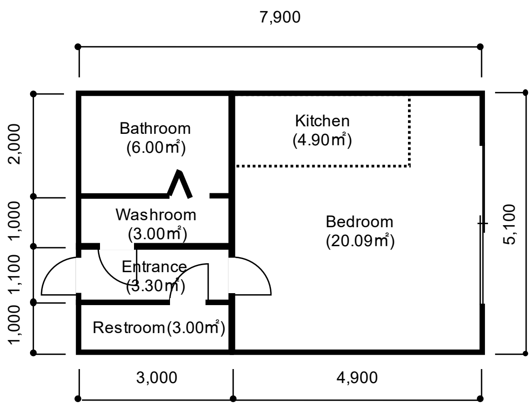

Figure 5. Single Plan

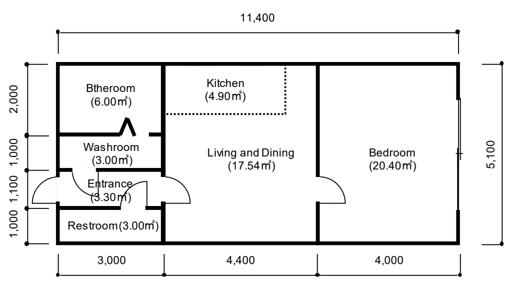

Figure 6. DINKS Plan

Comparison of the Definition of ZEB in Japan and EU

The benchmarks of ZEB in Japan and EU countries are compared to each other. A model building (Figure 2) is set and the primary energy consumption per aria in the model is calculated by “Programe for calculating primary energy consumption in house Ver 2.2.0”[1*]. Then the benchmark of Nearly ZEB in Japan is calculated. When primary energy consumption is calculated, 5 elements (heating, cooling, ventilation, lighting and hot water) are considered. In case that Nearly ZEB benchmarks in EU countries doesn’t include same those five elements above, the Japanese Nearly ZEB value is substituted into the missing element to calculate. The result of comparison is shown in Figure 3. Since benchmarks of Nearly ZEB for apartment buildings in France and Croatia are approximately double of Japanese benchmark, a benchmark of Nearly ZEB only for an apartment building needs to be considered.

ZEB Benchmark for Apartment Buildings

For the spread of Zero-Energy Apartment Buildings, setting the definition of it is required. In addition, installing adequate renewable energy resource is needed to meet the requirement of the ZEB definition in Japan. However, apartment buildings have limited space for renewable energy resource since roof aria accounts for small percentage of gross floor arias. Hence, it is impossible for apartment buildings to be ZEB. Therefore, the definition that regard buildings that don’t reduce 75～100% primary energy consumption as ZEB should be set. In this research, benchmark for Zero-Energy Apartment Buildings is set by using maximum primary energy consumption per unit aria which is already in use in EU. The benchmark should be possible to be achieved equally regardless of size and shape of buildings.

Estimation of the Structure Change of Household in Tokyo

Estimation of the number of households in Tokyo in each year until 2030 was conducted. The value that is estimated by National Institute of Population and Social Security Research [7] that conduct estimation once every five years was utilized. The number of households in the years that National Institute of Population and Social Security Research don’t have estimated values was estimated by collinear approximation. Households were divided into groups so that households in a same group have same family structure. The estimation of the number of households in each group in each year until 2030 was conducted (Figure 4). As a result, the total number of households in 2013 is approximately 6.56 million, on the other hand, the total number of households in 2030 is approximately 6.78 million. In 2030 approximately 45% of household is SINGLE, 18% of households is DINKS (double income no kids), and 32% of households is FAMILY.

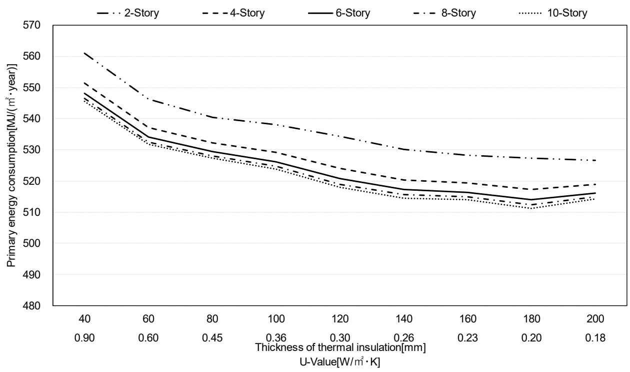

Figure 7. Result of Parametric Study (S Outside Corridor/wall)

Table 1. S Apartment Buildings

	U-Value	Thickness
Wall	0.23[W/m² ・ K]	160[mm]
Roof	0.26[W/m² ・ K]	140[mm]
Floor	0.30[W/m² ・ K]	120[mm]

Table 2. D/F Apartment Buildings

	U-Value	Thickness
Wall	0.26[W/m² ・ K]	140[mm]
Roof	0.30[W/m² ・ K]	140[mm]
Floor	0.30[W/m² ・ K]	120[mm]

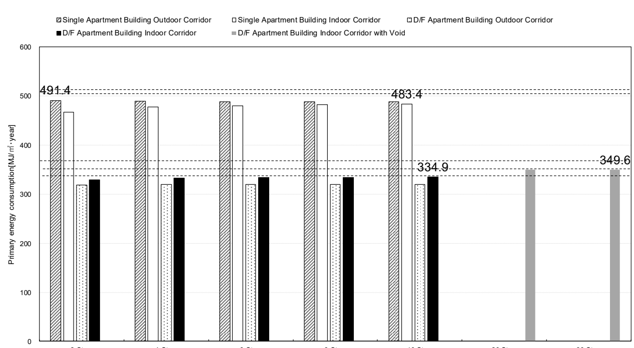

Figure 8. Primary Energy Consumption in Room per ㎡

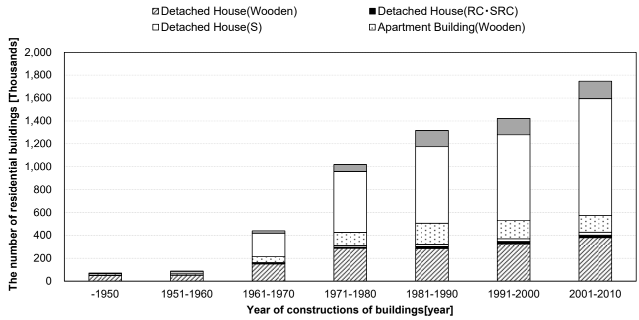

Figure 9. Existing Buildings Stock in Tokyo (2010)

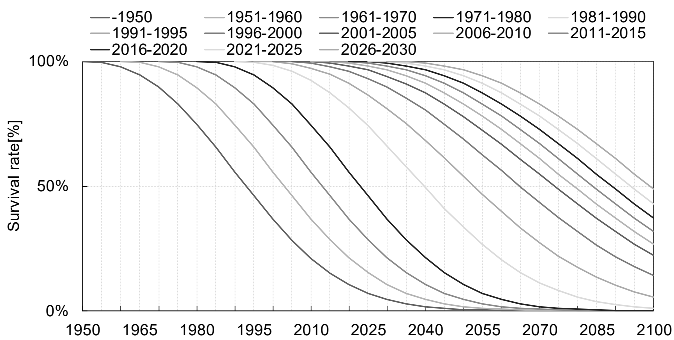

Figure 10. A Survival Rate Curve of Apartment Buildings

Creation of Room Models to Each Type of Household

Considering the diversity of layout in each unit in apartment buildings, S room for SINGLE household (40.29 ㎡, Figure 5), D room for DINKS (58.14 ㎡, Figure 6), and F room for FAMILY (70.00 ㎡, Figure 2) in total 3 model rooms were set.

Makeup of Apartment Building Models

By utilizing those 3 rooms in 3.2, model apartment buildings were set. From the estimation in 3.1, the number of each type of rooms in model apartment buildings were decided with considering the percentage of each household in the estimation. In the end, S model (Outside corridor and Inside Corridor) and D/F model (Outside corridor, Inside Corridor and Void) were set. Outside Corridor and Inside Corridor of S model and D/F model have 10 rooms on each floor. Regarding Outside/Inside Corridor D/F apartment buildings, there are 4 D rooms and 6 F rooms on each floor in total 10 rooms on each floor. There are 6 D rooms and 16 F rooms on each floor in total 22 rooms on each floor in Void apartment buildings.

2. Parametric Study of Environmental Performance

Overview of the Study

The parametric study was conducted by using "Programe for calculating primary energy consumption in house Ver 2.2.2" and "Envelope Sheet"[2*)] in order to verify how the grade of thermal insulation of each part of apartment buildings affects the primary energy consumption, and to calculate the most efficient grade of thermal insulation to reduce significant amount of primary energy consumption. The place of the model buildings was Aria 6, and the model building that was set in 2.8 was used. By setting the thickness of thermal insulation material (Grass wool 24K: 0.036[W/(m² ･K)]) as a parameter, the primary energy consumption in model buildings was calculated. Then, the thickness of thermal insulation that was most effective to reduce the primary energy consumption was determined. Finally, the U value was calculated from the thickness.

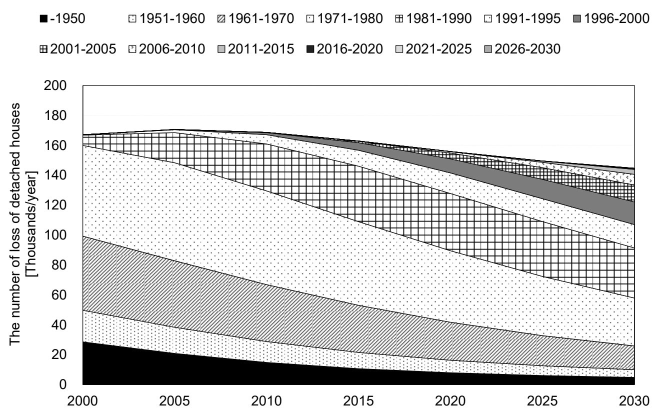

Figure 11. The Number of Disposed Detached Houses

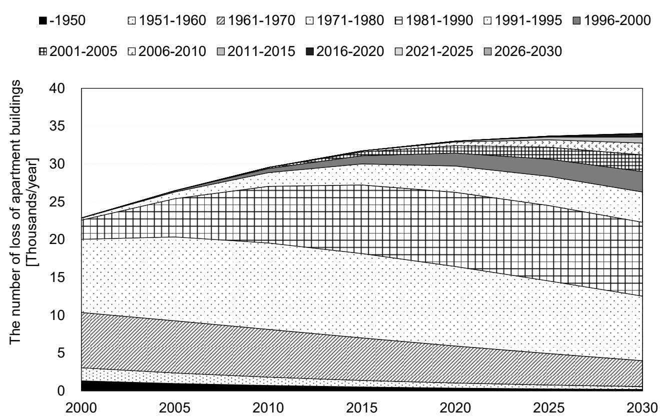

Figure 12. The Number of Disposed Apartment Buildings

Table 3. Correlation Coefficient of Factors that affects the Number of Newly Constructed

Category	Name of Factors	Correlation coefficient
Factors of Household Structure (Tokyo)	the total number of household	-0.79
	The increase/decrease ratio of Households	0.13
	Young households	0.31
	Middle households	-0.78
	Old households	-0.75
Factors of Stock of Residential Buildings Flow (Tokyo)	The total number of residential buildings	-0.73
	The number of residential buildings which are not vacant	-0.76
	The number of vacant houses	-0.6
	Vacant house rate	-0.43
	The number of disposed houses in the year	-0.78
	The number of disposed houses in the previous year	-0.76
	Average of life time of buildings	-0.3
Factors of Economic Growth (Japan)	Nominal GDP in the year	0.59
	A growth rate of nominal GDP in the year (Comparison in the year ago)	0.11
	A growth rate of real GDP in the year (Comparison in the year ago)	0.3
	Growth rate of Housing investment (Comparison in the year ago)	0.34

The Result of the Study

Figure 7 shows the relation between primary energy consumption and the thickness of thermal insulation in Outside Corridor S model. The most effective thermal insulation was 140mm insulation (U-Value 0.26[W/m^2·K]). For other parts of the model buildings were also studied and the effective thermal insulation grades were estimated (Table 1, 2). Regarding windows, the parametric study was not conducted because it is obvious that triple Low-E double windows is the most energy efficient solution. Subsequently, the windows' thermal insulation grade (U-Value) was 1.60[W/m^2·K].

Suggestion of the Definition of ZEB for Apartment Buildings

Apartment buildings basically include a residential part and a non-residential part. Hence, the benchmarks were set for both parts. A building that meets both requirements should be regarded as ZEB in this suggestion.

Firstly, the requirement of U-Value was set from the result of 3.2. Then the primary energy consumption in residential part of the model buildings that meet the requirement of U-Value was calculated. The primary energy consumption[MJ/㎡] is shown in Figure 8. Maximum primary energy consumption in S model that meets the requirement of U-Value is approximately 500[MJ/m2·year]. On the other hand, Maximum primary energy consumption in D/F model was 350[MJ/m2·year]. Finally, the benchmark of Zero-Energy Apartment Building is set by determining the maximum primary energy consumption. The maximum primary energy consumption of S model is 500[MJ/m2·year]. The maximum primary energy consumption of D/F model is 350[MJ/m2·year]. As a result, two benchmarks of Zero-Energy Apartment Building were set. One is the U-Value, another is maximum primary energy consumption. The building that meets both benchmarks is regarded as ZEB.

Regarding a non-residential part, a lot of factors such as the air conditioner in corridor and hall, or the existence of party rooms in the building affects primary energy consumption. Hence, it is considered that non-residential part shouldn't have maximum energy consumption as a benchmark. Instead of maximum primary energy consumption, U-Value requirement was used for the benchmark of non-residential part. Therefore, in the case that a building has both residential and non-residential part, the building must meet requirements for both parts to be regarded as ZEB.

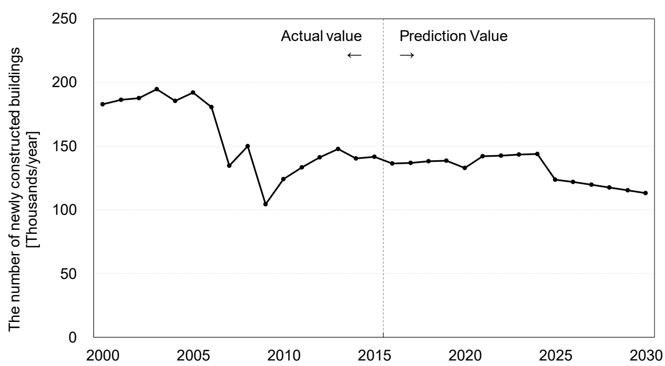

Figure 13. The Number of Newly Constructed Buildings

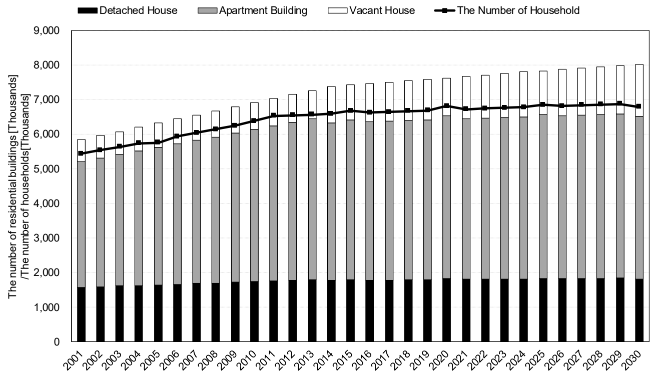

Figure 14. Stock of Existing Buildings in Tokyo

Table 4. S Apartment Building CO_2 Unit [t-CO_2/room]

	No Thermal Insulation	Thermal Insulation level in1980	1992 Standard	1999 Standard	ZEH
Material Production	33.8	33.8	33.8	33.7	34.2
Construction	10.0	10.0	10.0	9.9	10.1
Operation	125.7	125.4	125.7	84.5	76.1
Repair	23.9	23.9	23.9	23.9	23.9
Disposal	3.6	3.6	3.6	3.6	3.6

Table 5. D/F Apartment Building CO_2 Unit [t-CO_2/room]

	No Thermal Insulation	Thermal Insulation level in1980	1992 Standard	1999 Standard	ZEH
Material Production	46.5	46.6	46.7	45.8	46.3
Construction	13.7	13.8	13.8	13.6	13.7
Operation	170.1	144.4	143.0	94.8	87.8
Repair	34.8	34.8	34.8	33.1	33.0
Disposal	5.1	5.1	5.1	5.0	5.0

Table 6. Detached House CO_2 Unit [t-CO_2/room]

	No Thermal Insulation	Thermal Insulation level in1980	1992 Standard	1999 Standard	ZEH
Material Production	28.2	28.3	28.4	30.4	32.2
Construction	7.2	7.2	7.2	7.7	8.2
Operation	529.5	147.0	144.6	120.0	54.6
Repair	32.0	32.2	32.3	34.9	37.0
Disposal	1.6	1.6	1.6	1.7	1.7

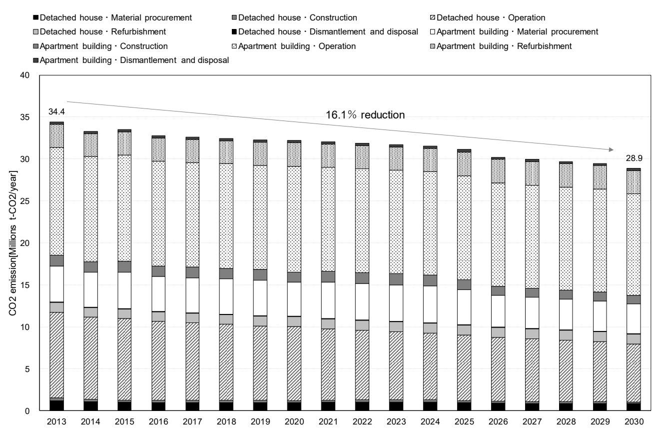

Figure 15. The Amount of CO_2 Emission (CASE3)

3. The Estimation of the Number of Existing Residential Buildings from Now to 2030

Analysis on the Situation of the Number of Existing Residential Buildings

By referring to 1988～2013 Housing and Land Survey [9] and 2007～2015 Statistical Survey of Construction Starts [10], the analysis on the existing residential buildings were conducted. The stock was divided into groups regarding the year of construction, a style of building and structure. Additionally, research on the grade of thermal insulation was also conducted according to Statistical Survey of Ministry of Economy and Ministry of Land, Infrastructure and Transport [11][12]. Figure 9 shows that the number of existing buildings in 2010 in Japan. Apartment buildings (RC, SRC) have tendency to increase. Apartment buildings account for approximately 52% of all residential buildings.

The Estimation of the Number of Disposed Residential Buildings

Form existing research[13][14][15], survival rate curves of residential buildings were calculated, based on the year of construction, a style of building and structure. Figure 10 shows that comparison in changes of the survival rate curve of apartment buildings (RC, SRC) year by year. Furthermore, the estimation of the number of disposed residential buildings until 2030 in each year were calculated, according to the survival rate curves. Figure 11 and Figure 12 shows that the number of disposed detached houses and disposed apartment buildings respectively.

Overview of the Estimation of Number of Newly Constructed Residential Buildings

The different measure is used to estimate the number of newly constructed residential buildings in each year. From 2000 to 2005, the same measure as existing research was utilized to estimate. The formula 1 was created.

The number of newly constructed buildings = The number of all residential building in the year − The number of all residential buildings in the previous year + the number of disposed residential buildings in the previous year ー(Formula 1)

Then, about the residential buildings constructed from 2006 to 2015, the actual value[10] were used. From 2016 to 2030, the prediction value which was calculated by multiple regression analysis was used. The detailed explanation about it is on 3.4.

Table 7. Scenarios to Reduce CO_2 Emission

	Scenarios	Objects		Overview	Target Year
		Detached Houss	Apartment Buildings		
CASE1	BAU Model	-	-	Business as Usual Model	-
CASE2	Standard Newly Constructed Zero-Energy Detached Houses	O		Realization of newly constructed Zero-Energy detached houses as standard	2020
CASE3	Average Newly Constructed Zero-Energy Detached Houses	O		Realization of newly constructed Zero-Energy detached houses as average	2030
CASE4	Standard Newly Constructed Zero-Energy Apartmnet Buildings		O	Realization of newly constructed Zero-Energy apartment buildings as standard	2020
CASE5	Average Newly Constructed Zero-Energy Apartment Buildings		O	Realization of newly constructed Zero-Energy apartment buildings as average	2030
CASE6	CASE2+4	O	O	Standard Zero-Energy Detached Houses + Standard Zero-Energy Apartment Buidings	2020
CASE7	CASE3+5	O	O	Average Zero-Energy Detached Houses + Average Zero-Energy Apartment Buidings	2030
CASE8	Increase of the Number of Apartment Buildings		O	Continuation of the tendecy of increase of the nember of apartmnet buildings	2020
CASE9	CASE2+4+8	O	O	Standard Zero-Energy Detached Houses + Standard Zero-Energy Apartment Buidings + Increse apartment buildings	2030
CASE10	CASE3+5+8	O	O	Average Zero-Energy Detached Houses + Average Zero-Energy Apartment Buidings + Increse apartment buildings	2030

Table 8. Results of Scenarios

	Scenarios	CO_2 emission in 2013 [million t-CO_2/年]	CO_2 emission in 2030 [million t-CO_2/年]	Reduction Rate in 2030 (Compared to 2013)
CASE1	BAU Model	34.1	28.3	17.7%
CASE2	Standard Newly Constructed Zero-Energy Detached Houses	34.1	27.6	19.8%
CASE3	Average Newly Constructed Zero-Energy Detached Houses	34.1	27.5	20.1%
CASE4	Standard Newly Constructed Zero-Energy Apartmnet Buildings	34.1	27.8	19.2%
CASE5	Average Newly Constructed Zero-Energy Apartment Buildings	34.1	27.8	19.3%
CASE6	CASE2+4	34.1	27.1	21.3%
CASE7	CASE3+5	34.1	26.9	21.7%
CASE8	Increase of the Number of Apartment Buildings	34.1	27.2	21.0%
CASE9	CASE2+4+8	34.1	26.9	21.8%
CASE10	CASE3+5+8	34.1	26.8	22.0%

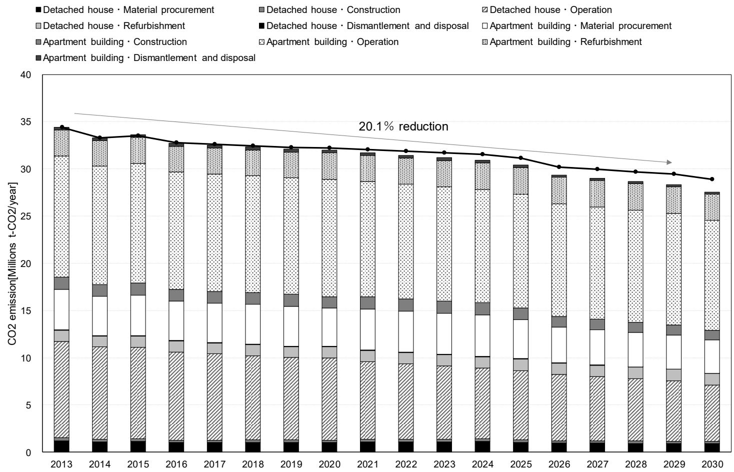

Figure 16. The Amount of CO_2 Emission (CASE3)

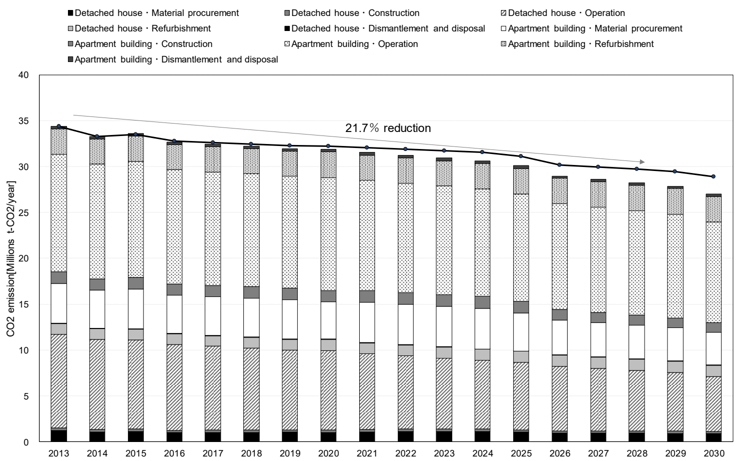

Figure 17. The Amount of CO_2 Emission (CASE7)

The Way to Estimate the Number of Newly Constructed Residential Buildings by Multiple Regression Analysis

The overview of multiple regression analysis on the estimation of newly constructed residential buildings is explained below.

① The Extraction of the Factors that Affect the Number of Newly Constructed Residential Building by Correlation Analysis

From Indexes of household structure, Indexes[18)19)] of stock of residential buildings and indexes of economic growth, the factors that have affected the number of newly constructed residential buildings were extracted. The extraction was conducted by using correlation analysis. Explained variable was the number of newly constructed residential buildings in from 1999 to 2013, and explanatory variable was actual value of each index. Then the factor that showed the biggest correlation in each category was extracted. Table3 shows that the factors and correlation coefficient. As a result of the correlation analysis, the total number of household (correlation coefficient -0.79), the number of the disposed residential buildings in the year (correlation coefficient -0.78) and nominal GDP of the year (correlation coefficient 0.59) were set as the factors that affect the number of newly constructed residential buildings.

② The Prediction Value of the Factor that is Extracted Above

The 3 factors that is extracted in ① prediction values of the total number of households and the number of the residential buildings that is disposed in the year which is calculated in 3.1, 4.2 were used for the factors. Regarding nominal GDP, the prediction values[18)19)] until 2024 which is given by Cabinet Office were used.

③ The Creation of the Formula for Prediction of the Number of Newly Constructed Residential Buildings by Multiple Regression Analysis

The formula (Formula 2*) for the prediction was created by setting the number of newly constructed residential buildings as explained variable and setting the 3 factor that is extracted in ① as explanatory variable.

The number of newly constructed residential buildings = the total number of households ×(-0.01977) + (the number of the disposed residential buildings)×(-2.730149) + (nominal GDP)×(2.34343).

By utilizing the formula above, the estimation of the number of newly constructed residential buildings was conducted. Prediction value of nominal GDP is estimated officially until 2024. Therefore, the estimation by using formula 2 was conducted to estimate the prediction value of 2017 – 2024. The prediction values of the number of newly constructed residential buildings in 2025-2030 were estimated by linear approximation of the prediction values in 2001-2024.

Result of the Estimation of the Number of Newly Constructed Residential Buildings

By using the method of estimation in 4.3 and 4.4, the estimation of the number of newly constructed residential buildings was conducted (Figure 13). the number of newly constructed residential buildings in 2030 in Tokyo was 113 thousand per year. As results of the estimation, compare to the value in 2013 (148 thousand per year), it is estimated that the number of newly constructed residential buildings in 2030 is decreased by approximately 23%. In addition, regarding styles of buildings, the newest actual value which is the value in 2015 was used and also the ratio of styles of buildings was postulated that the ratio will not differ until 2030.

The Model of the Stock in Tokyo until 2030

From results from 4.1-4.5, the model of the stock in Tokyo until 2030 was created (Figure 14). In 2030, the total number of residential buildings is estimated to increase to approximately 8.04 million. Additionally, in 2030, the total number of detached houses is assumed to be approximately 1.81 million, the total number of apartment buildings is assumed to be approximately 4.69 million, and the total number of vacant residential buildings is estimated to be 1.51 million. Detached houses account for approximately 23%, apartment buildings account for approximately 58%, and vacant residential buildings account for 14.4% of all residential buildings respectively.

4. Reduction of CO_2 Emission by the Spread of ZEB of Detached Houses and Apartment Buildings

CO_2 Emission from Each Type of Residential Building

The prediction of CO_2 emission from household sector in Tokyo in 2013-2030 was estimated. From the Policy of LCA of Buildings [20], CO_2 units of materials production, construction, operation, repair, and disposal were calculated. Regarding apartment buildings, the model in 3.4 was used.

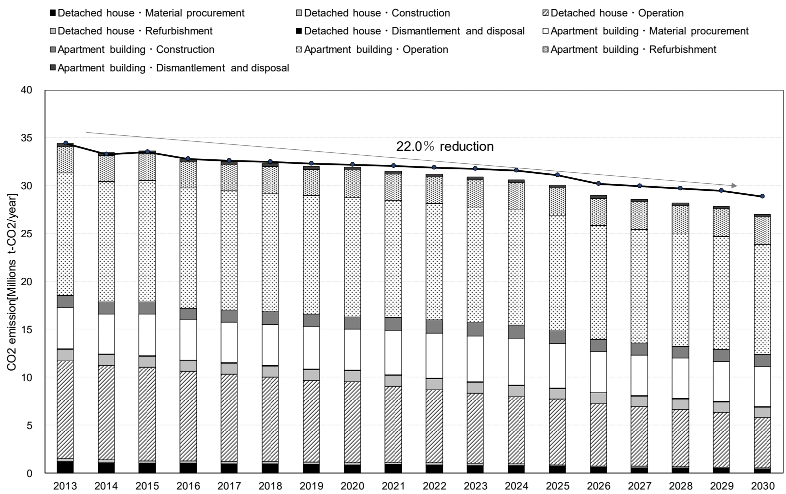

Figure 18. The Amount of CO_2 Emission (CASE10)

The structure was set as RC to calculate the units. JSBC model was used as the model for detached houses, and the structure was wooden. Furthermore, regarding apartment buildings, the average of CO_2 units of each type of model and size were used as the units of apartment buildings. In addition, operation unit was calculated as the building installing as many solar panel (245W) as possible on their roof. Table 4 shows the units of S Apartment Buildings, Table 5 shows that the units of D/F Apartment Buildings, and Table 6 shows the units of detached houses.

The Prediction of CO_2 Emission until 2030 of BAU Model

BAU model (Business as Usual) was created as a model of maintaining a status quo by using the calculated prediction value of stock in 4.6 and the CO_2 units of residential buildings in 5.1. Figure 15 shows that a transition of CO_2 emission of BAU model. CO_2 emission from Tokyo in Tokyo is estimated to decrease gradually. In 2030, CO_2 emission is estimated to be reduced by approximately 18% if compared to 2013.

Scenarios of Reduction of CO_2 emission CO_2

By implementation of policy to reduce CO_2 emission from household sector in Japan, the amount of reduction of CO_2 was calculated. Table 7 shows Scenarios. CASE2 and 3 are same as policy of government that means to spread Zero-Energy Detached Houses. However, CASE4, 5 is the scenario that considers only the spread of Zero-Energy Apartment Buildings but not the spread of Zero-Energy Detached Houses. CASE8 take the trend of increase of apartment buildings into account, therefore CASE8 is the scenario that the number of apartment buildings which is not green buildings is increasing. CASE6~8, CASE9~10 are the scenarios which is created by combination of each scenario. Table 8 shows that results of each scenario. Reduction rate of CO_2 emission of CASE3 (the spread of Zero-Energy Detached Houses) (Figure 16) is 20.1% if compared to 2013. Reduction rate of CO_2 emission of CASE7 (the spread of both Zero-Energy Detached Houses and Apartment Buildings) (Figure 17) is 21.7%. Additionally, the scenario that has the highest reduction rate of CO_2 emission is CASE10 that reduce 22.0% of CO_2 emission. It is predicted that the number of apartment buildings increases. Hence, a policy or an action plan to spread Zero-Energy Apartment Buildings should be considered. Furthermore, even in case that the spread of Zero-Energy Detached Houses and Apartment Buildings is realized, the target of the Paris agreement (Japan needs to reduce 39% of CO_2 emission from household sector) will not be achieved. Therefore, enforcement of action plans to reduce CO_2 emission form existing buildings is essential to achieve the target.

5. Conclusion

Based on the government's policy, CO_2 emission from household sector in 2030 is estimated to be reduced by 20.1% if compared to 2013. In case that the spread of Zero-Energy Apartment Buildings is taken into account in addition to the existing policy, CO2 emission is predicted to be reduced by 22.0%. The spread of Zero-Energy Apartment Buildings is the effective measure to reduce CO_2 emission. Furthermore, the measure to reduce CO_2 emission from existing buildings is necessary to achieve the target of the Paris agreement which Japanese government declared.

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Note

1*) Programe for calculating primary energy consumption in house Ver 2.2.2 of Building Research Institute

2*) Houses Envelope Sheet of Building Research Institute