CO_2 Reduction Potential in Japan through Saving Water

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Abstract

The CO_2 emissions when residential plumbing equipment is used make up 5% of CO_2 emissions in Japan; however, there has been no scenario created for reducing this CO_2 emission. On the other hand, in the residential plumbing equipment fields, the development of water-saving equipment has been advanced. We discussed the possibilities of CO_2 reduction by creating a water-saving society. In this discussion, the average performance of commercial equipment was obtained from shipments each year and the duration of use (remaining periods in the market) , and changes in water consumption, in combination with penetration rates of the equipment as well as life style models of the equipment usage, were estimated. In addition, by multiplying by a factor of CO_2 emission of water, changes in CO_2 emission associated with the residential plumbing equipment was estimated. Our estimated results revealed that CO_2 emissions associated with residential plumbing equipment would be reduced by 25% in 2020 compared to that in 1990, and the total amount of CO_2 emission in Japan would be reduced by 1%. It was also estimated that contribution rates of CO_2 reduction were 73% for improvement of the environment performance of the equipment, 25% for improvement of emission factors for water and energy and 2% for population decrease.

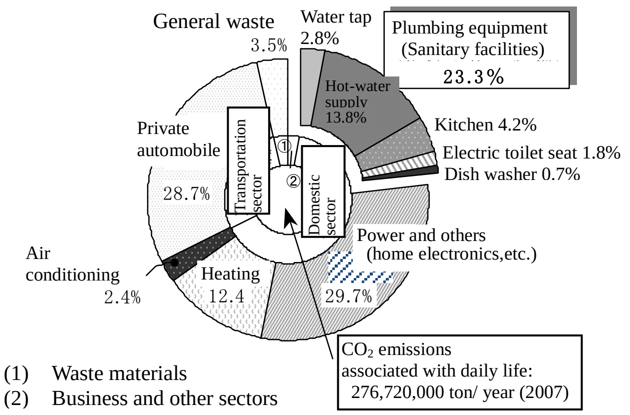
Keywords

saving water, measures against global warming, CO_2, estimation methods

1. Introduction

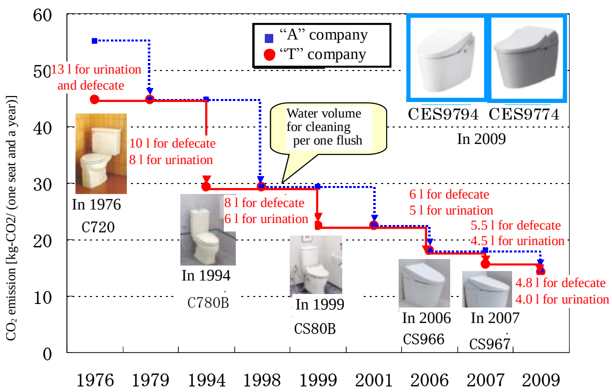
Ministry of the Environment has categorized CO_2 emission sources into "CO_2 emission sources related to companies and public sectors" such as industry sectors, transportation sectors, commercial and other sectors, and "CO_2 emission sources related to households" including domestic sectors, for controlling the CO_2 emissions. CO_2 emissions with electricity use at home are allocated to the usage end and are categorized into CO_2 emission sources related to households. Accordingly, the effects on the contribution to environment conservation by adopting energy saving household electrical appliances can be estimated and visualized as a CO_2 reduction amount. However, CO_2 emissions with usage of water in daily life are not allocated to the usage end, but to commertial and other sectors. This is because the CO_2 emissions occur in water desalination and water treatment processes; contribution to CO_2 reduction with saving water at home is outside of CO_2 emission sources related to households. It is essential to visualize reduction contribution to promote CO_2 reduction as a national movement. So CO_2 emissions with water consumption at home were incorporated into CO_2 emissions sources related to households, expressing it as "CO_2 emission associated with daily life" and the CO_2 emissions were reorganized, as shown in Figure 1. Figure 1 indicates that residential plumbing equipment is third after home electronics and automobiles among daily life, and the CO_2 emissions associated with residential plumbing equipment makes up 5% of the total amount of CO_2 emission in Japan.

The top runner approach based on Act on the Rational Use of Energy imposes the improvement of the energy saving performance of home electronics, resulting in improvement in the yearly performance in the whole home electronics industry. Although there is no inducement for improvement of energy saving by laws for residential plumbing equipment, trends of improvement of environment performance are shared by the whole residential plumbing equipment industry, with improvement efforts of the environment performance made by manufactures. Self-reliant efforts have been conducted, leading to continuous improvements. Figure 2 shows the improvements in saving water in toilet. There are estimation cases [4] of CO_2 reduction amounts with energy saving home electronics, penetration of high efficiency water heaters and improvement of heat insulating materials, as to penetration effects of equipment with good environment performances. Although changes in plumbing equipment, especially the ones that consume energy, have been estimated with the frequencies of usage for hot-water supply systems, and improvement of the efficiency of the equipment [5], a detailed analysis where performance of equipment and use models are set has not



Note: Created based on Greenhouse gas emission in 2007 (Ministry of the Environment).
Among "Power and others" of "CO_2 emissions from households", the ratios of electric toilet seat and dish washer described in "Power consumption of each equipment in home (estimated values in 2005)" are allocated to plumbing sanitary facilities.

Figure 1 CO_2 emission associated with daily life [1)−3)]



Note: Created based on the website of Japan Sanitary Equipment Association (February, 2010) (http://www.sanitary-net.com/trend/transition.html)

Figure 2 Improvements in water volume for cleaning per one flush

been conducted. This study used a summation method for an estimation of the CO_2 emissions based on environment performance estimations for residential plumbing equipment and estimated contribution to reduction of the total amount of CO_2 emission in Japan through the penetration of such equipment.

2. Estimation Methods

Formula (1) expresses how to estimate the past and future changes in CO_2 emissions associated with residential plumbing equipment.

CO_2 emissions associated with residential plumbing equipment throughout Japan in the year of n

$$=\Sigma(k_n \times PP_n \times Um) \times Po_n \times Cf \times 365 \text{ days} \quad \ldots(1)$$

k_n : CO_2 emission factors for electricity, water and hot-water supply energy in the year of n

PP_n : Average value of environment performance of market goods groups in the year of n (Consumption amount of energy and water per use)

Um : Equipment use model (Use of a product a day per person)

Po_n : Population in the year of n

Cf : Correction factor from reported value by National Institute for Environmental Studies (total amount of CO_2 emission)

2.1 CO_2 Emission Factor

Actual values of power generating end factors announced by the Federation of Electric Power Companies of Japan and estimated values announced by Japan Business Federation were used for electricity emission factors. Announced values [6] by Ministry of the Environment were used for emission factors of water as emission factors associated with energy consumption during clean water generation and sewage treatment. As for hot-water supply energy, changes in the future composition rate were estimated based on the previous reported values [7] of changes in energy composition rates of hot-water supply at home, and the estimated rate was multiplied by the CO_2 emission intensity by energy source (Table1) to calculate CO_2 emission factors in associated with hot-water supply. Actual and estimated values of electricity emission factors stated before were used for electricity for hot-water supply. Table 2 Evaluation target and equipment use models

Table 1 CO_2 emission intensity by energy source

Energy sources	Calorific Value	CO_2 emission intensity
Crude oil	38.2 MJ/L	69.0 g-CO_2/MJ
Gasoline	34.6 MJ/L	68.8 g-CO_2/MJ
Kerosene	36.7 MJ/L	68.5 g-CO_2/MJ
Light oil	38.2 MJ/L	69.2 g-CO_2/MJ
A Heavy oil	39.1 MJ/L	71.6 g-CO_2/MJ
C Heavy oil	41.7 MJ/L	71.6 g-CO_2/MJ
Liquid petroleum gas(LPG)	50.2 MJ/kg	58.6 g-CO_2/MJ
City gas (natural gas)	41.1 MJ/m^3	51.3 g-CO_2/MJ

Note: New Energy and Industrial Technology Development Organization: CO_2 emission intensity by energy source, (February, 2010) http://www.nedo.go.jp/nedata/17fy/14/e/0014e001.html

Table 2 Evaluation target and equipment use models

	Evaluation target	Use model[9]
Common	–	Number of users: 4 (2 males, 2 females) Annual number of days of use: 365 days Conditions of increase in water temperature: Rise of water temperature from 15℃ to 42℃.
Toilet	Toilet Electronic toilet seat Faucet for basin	Number of use: 1 for defecation/(per person/·per day), 3 for urination/(per person/per day) Number of use for bottom washings: 1/(per person/ per day) Number of use for bidet (only females): 4/(per person/per day) Hand washing : 4 /(per person/per day)
Bathroom	Bathtub Shower fixture Illumination	Baths: 1/ (per person/per day) Showers: 1/(per person/per day) Reheating: 1/ (per household/ per day) Amount of hot water: 80% of the full capacity Length of use of illumination: 2.0 hours/(per household/ per day)
Kitchen	Faucet for kitchen Dish washer Stove burner Exhaust fan Illumination	Washing dishes by hand[†1]: 71L/ washing, 2 times/ (per household/ per day) Length of use of exhaust fan [†2]: 6.6 hours/ (per household/ per day) Stove burner[†3](large burner(4.8kw) and small burner(2.69kw)) : 10,313kJ/ (per household/·per day) Length of use of illumination[†4]: 4.37 hours/ (per household/ ·per day)
Sink	Faucet for lavatory Defroster (toilet mirror) Illumination	Number of use: 1/(per person/ per day) Length of water faucet use: Double levers: 1 min. 30 sec./ per use Single lever: 1 min.05 sec./ per use Length of defroster use: 20 min./ per use Length of use of illumination: 20 min./ per use

2.2 Average Value of Environment Performance of Market Goods Groups

A duration of use (remaining periods in the market) of residential plumbing equipment is said to be around 20 years [7]. We assumed that 1/20 of the stock on the market would change to new products every year, and estimated average environment performance of the market good stock on the market each year, based on the history of the previous sale of new products and the estimation for the sale of products in the future.

Environment performance was set to water and energy consumption with the usage of equipment used in daily life where water is used in toilets, bathrooms, kitchens and sinks. Table 2 shows the products evaluated in each location.

Among the evaluated products, average values of environment performance of toilet after 2008 were estimated while actual values of the usage rate of flush toilet announced in " Waste Disposal in Japan" published by Ministry of the Environment were adopted as the penetration rate of toilet and the usage rate of flush toilet in 2020 was assumed to be 95%. As for the electronic toilet seats and dish washers, the actual values of "Annual Report on Consumer Confidence Survey covering all of Japan" published by Cabinet Office, Department of Business Statistics were adopted and average values of environment performance of the electronic toilet seats as well as dish washers after 2008 were estimated in accordance with our surveys of the market. As there was no description in the annual report on a penetration rate of the dish washers from 1990 to 2003, it was estimated based on the published values [8] and the actual values after 2004. Since other products are necessary in daily life, their penetration rates were set to 100% in all of the years.

We assumed that products with the highest environment performance (top runners) and products of one generation earlier became popular and were adopted when the stock on the market were renewed every year. Among the renewal rate of the stock on the market, 1/20, adoption rates of top runners were set as parameters and the impact to CO_2 emission total amount were evaluated.

2.3 Equipment Use Model

Models of the equipment, such as the amount of use, were discussed at the “Committee to promote household energy efficiency and home security” [9] founded by Ministry of Economy, Trade and Industry, Economy in 2005 and have been used in the standard of the subsequent environment label (Japan Environmental management Association for Industry : Eco Leaf). This study complied with that standard and adopted the use model per person indicated in Table-2.

2.4 Population and Corrective Factor

Demographic changes were estimated according to a national census, Annual report on current population estimates and “Future Population Projections in Japan (estimated in December in 2006) published by National Institute of Population and Social Security Research, and the number of households were done in the same manner.

From these estimations, the total amount of CO_2 emission associated with residential plumbing equipment in Japan can be calculated. On the other hand, National Institute for Environmental Studies announced the CO_2 emissions from households in Japan (associated with daily life), and CO_2 emissions associated with water and heat use can be extracted from the announcement. Differences between the reported values by National Institute for Environmental Studies and estimated CO_2 emissions associated with water and heat use were compared, and the comparison results were seen as the corrective factor (*Cf* in the formula (1)).

3. CO_2 Reduction Potential in Japan

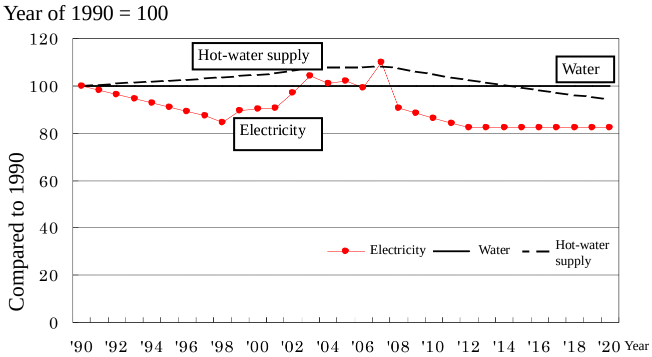
3.1 Changes in CO_2 Emission Factors for Energy and Water

Residential plumbing equipment such as toilets and bathrooms generate an environment load (CO_2) with consumption of energy and water when the equipment is used. Figure 3 shows changes in CO_2 emission factors for energy and water.

CO_2 emission factors for electricity change depending on the composition rates of electric power production sources such as nuclear power and hydraulic power. Especially, as improvement of introduction rates of renewable energy, including solar and wind power, has been promoted for the future as a national policy, CO_2 emission factors for electricity are expected to be dramatically improved in the future. The major improvement of CO_2 emission factors for electricity in 2008 was contributed by CDM.

As for water emission factors, the value of 0.59kg-CO_2/m^3 announced by Ministry of the Environment in 1996 is the only overall value of clean water generation and sewerage treatment [6]. Since then, only clean water generation emission factors have been announced. Hence, a fixed water emission factor (0.59kg-CO_2/m^3) was used for the estimation in this study. As energy consumption for water and sewerage treatment processes greatly depends on electricity, water emission factors may reduce with improvement of electricity emission factors. We hope that overall emission factors of water and sewerage treatment processes will be announced in future.

For hot-water supply energy, based on the reported values of changes in energy composition rates for home use hot-water supply [7], changes in future composition rates were estimated as in Table 3. In the estimation, expansion of heat pump highly-efficient water supply was incorporated as a shift from kerosene to electricity in rural districts and a shift from LPG to electricity in urban districts. We assumed that there was no change in solar heat and city gas. From the above statement, as to CO_2 emission factors in 2020, electricity reduced by 18% and hot-water supply energy by 6%, compared to 1990.



Unit: Electricity kg-CO_2/kW·h
Water kg-CO_2/m^3
Hot –water supply kg-CO_2/10,000kcal

Year	Electricity	Water	Hot-water supply	Year	Electricity	Water	Hot-water supply
'90	0.371	0.59	2.678	'06	0.368	0.59	2.887
'91	0.364	0.59	2.689	'07	0.407	0.59	2.899
'92	0.357	0.59	2.701	'08	0.335	0.59	2.874
'93	0.350	0.59	2.712	'09	0.328	0.59	2.840
'94	0.344	0.59	2.724	'10	0.320	0.59	2.806
'95	0.337	0.59	2.736	'11	0.313	0.59	2.773
'96	0.330	0.59	2.748	'12	0.305	0.59	2.740
'97	0.323	0.59	2.760	'13	0.305	0.59	2.711
'98	0.314	0.59	2.771	'14	0.305	0.59	2.682
'99	0.332	0.59	2.790	'15	0.305	0.59	2.654
'00	0.335	0.59	2.805	'16	0.305	0.59	2.627
'01	0.336	0.59	2.824	'17	0.305	0.59	2.600
'02	0.360	0.59	2.850	'18	0.305	0.59	2.574
'03	0.387	0.59	2.875	'19	0.305	0.59	2.548
'04	0.374	0.59	2.891	'20	0.305	0.59	2.523
'05	0.379	0.59	2.891				

Figure 3 Changes in CO_2 emission factors of energy and water

Table 3 Changes in composition rates of energy for hot-water supply at home

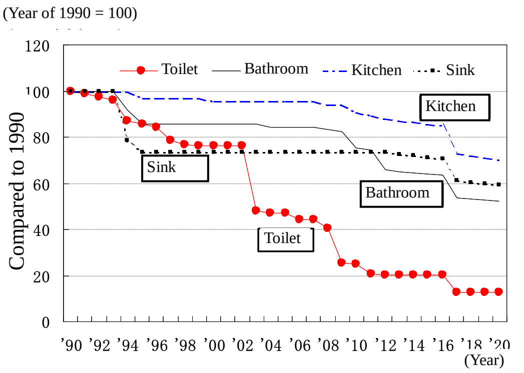
Unit [100 million MJ/ year]

Fiscal year / *Heat sources*	1990		2000		2004		2008		2012		2016		2020	
Solar heat	1,004	9%	661	6%	426	4%	304	3%	285	3%	271	3%	254	3%
Kerosene	2,454	22%	2,862	26%	2,767	26%	2,533	25%	2,282	24%	2,081	23%	1,865	22%
LPG	3,124	28%	3,192	29%	3,405	32%	3,142	31%	2,852	30%	2,623	29%	2,373	28%
City gas	3,570	32%	3,633	33%	3,512	33%	3,446	34%	3,233	34%	3,076	34%	2,882	34%
Electricity	893	8%	661	6%	532	5%	709	7%	856	9%	995	11%	1,102	13%
Total	11,045	100%	11,009	100%	10,642	100%	10,134	100%	9,508	100%	9,046	100%	8,476	100%

3.2 Improvement of the Environment Performance of Equipment, and Changes in the Environment Load of Market Goods Groups

Based on the data for changes in the improvement of environment performance for residential plumbing equipment being sold to date, the environment performance models of equipment which will be brought to market by 2020 were set. Figure 4 shows those models. CO_2 emissions when using the models was set so that by 2020 the emissions would be half (when considering the improved effects of CO_2 emission factors) of what it was in 1990. The reason why this target amount was set is because people would tend to purchase environment-conscious equipment due to the national movement, "Challenge 25", resulting in design for environment being shared in the residential plumbing equipment fields. Gradual improvements of environment performance of equipment being supplied to the market will reduce the CO_2 emissions from the stock on the market. Figure 5 shows the changes in the average values of environment performance of the stock on the market, assuming that 1/20 of the stock on the market is renewed every year. In the estimated changes, an adoption rate of the top runners was set to 30% among the renewal rates of 1/20 of the stock on the market every year, and equipment from one generation earlier became popular and was adopted for the remaining 70%.

Estimations with the adoption rates of the top runners of 50% and 80% are indicated in Figure 5 as the effects, if measures are taken, including promotional measures of environmentally efficient equipment, such as housing eco points, and an obligation to adopt water and energy saving equipment, such as the Energy Policy Act in the U.S. These results revealed that the reduction performance of CO_2 emissions from residential plumbing equipment stock on the market in 2020 would be improved by 83% compared to that in 1990. Figure 6 shows the estimated penetration rates of toilet, electronic toilet seats and dish washer used for the evaluation.



Unit [kg-CO_2/ per person per year)]

Year	Toilet	Bathroom	Kitchen	Sink	Total
’90	44.5	341.5	241.4	77.5	704.8
’20	6.0	197.5	169.7	46.0	419.1

Note: Improvement effects of CO_2 factor of electricity and hot-water supply are not considered.

Figure 4 Environment performance estimation of newly-marketed residential plumbing equipment

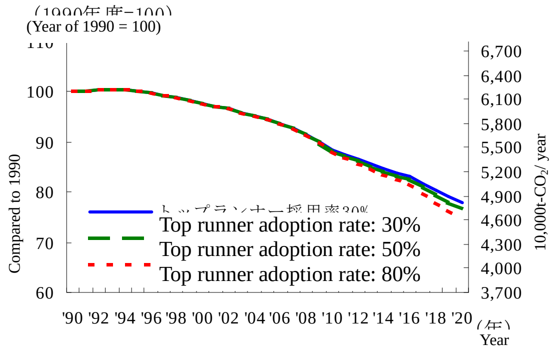


Figure 5 Environment performance estimation of residential plumbing equipment stock on the

3.3 Future Estimation of CO_2 Emission Associated with Residential Plumbing Equipment

Changes in the CO_2 emissions associated with residential plumbing equipment were calculated in taking the population projection into the estimated CO_2 emission factors stated above and the estimated environment performance of residential plumbing equipment stock on the market. Figure7 shows the calculated changes. Data on CO_2 emissions associated with water and heat collected from 1990 to 2007 by National Institute for Environmental Studies, and the differences between the data and the counterpart of the future estimation were incorporated into the calculation as corrective factors. The calculated values in this study were larger by 30% in all years than the reports by National Institute for Environmental Studies.

Dissociation from the actual status of the equipment use models could be the reason why the calculated values were larger than reported values by National Institute for Environmental Studies. This study adopted the standard model for equipment performance evaluation (Table 2), and the number of days of use (365 days) as well as the time of use could be elements of the excessive estimation of CO_2 emissions. It is difficult to validate and revise all items of the models at present; therefore, differences between the calculated values in this study and reported values by National Institute for Environmental Studies were verified.

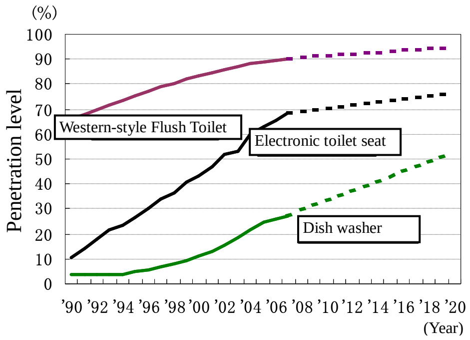


Figure 6 Estimated changes in penetration levels

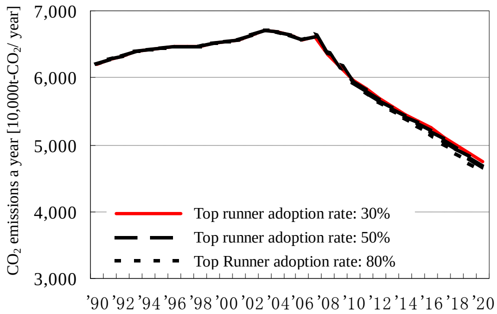


Figure 7 Estimated CO_2 emissions associated

Excessive estimation of the model will have an impact in the first order proportion to the calculated CO_2 emissions, but differences between the calculated values and reported values by National Institute for Environmental Studies were almost constant. Accordingly, by correcting the differences, assuming that the differences were an excessive estimation of the models, we determined that an outline of the changes in CO_2 emissions associated with residential plumbing equipment, could be estimated, where improvement of the environment performance of equipment, changes in penetration rates of the equipment, improvement of emission factors from electricity, etc. as well as population changes, were integrated. In order for the calculated values in this study to match the reported values by National Institute for Environmental Studies, the calculated values in this study were corrected with the latest difference values in 2007 (corrective factor: 0.74).

To improve the accuracy of the estimation, it is necessary to establish the use models along with the actual state by examining usage time, the number of days of use for equipment, ages and the number of people per household.

CO_2 emissions where an excessive estimation of the model was corrected, is in Figure 6 as well for the environment performance estimation of residential plumbing equipment stock on the market. To classify the contributions for the improvement of energy CO_2 emission factors, the estimation formula was expressed with the fixed emission factor in 1990.

From the above results, CO_2 emissions associated with residential plumbing equipment stock on the market would be reduced by 23% by 2020 compared to 1990, when design for environment by housing facility suppliers is s advanced. Also, CO_2 would be reduced by 26% when mechanisms which promote the adoption of higher environment performance equipment are introduced (top runner adoption rate: 80%). The reduction amount was calculated to 1% (top runner adoption rate: 30%) against the total amount of emission in Japan in 1990. Contribution to the reduction was composed of 73% for improvement of environment performance of equipment, 25% for improvement of emission factors during energy and water supply and 2% for decrease in population. In Japan, CO_2 emission reduction by 25% compared to 1990 has been set as the goal, and reduction in households is a priority. Future estimations, with the introduction of the new generation of vehicles, insulated houses, photovoltaic and high efficiency hot-water supply system are suggested as the AIM model, but there had been no suggestions for a study on the future images of CO_2 emission reduction associated with residential plumbing equipment. This study showed that contribution of residential plumbing equipment to CO_2 reduction was large. As residential plumbing equipment is used for an average of about 20 years, CO_2 emission would hover for 20 years if, after building new, or renovating old houses, we do not select environment-conscious equipment for these houses. For this, it is important to adopt environmentally efficient mechanisms. In the calculations of this study, the contribution of CO_2 reduction can be set larger if there is a mechanism which promotes the adoption of environmentally efficient products.

Since no data required for the estimation was disclosed as to improvement effects by energy suppliers, such as photovoltaic at home, smart grids and fuel batteries, the effects were not incorporated into this evaluation. It is necessary to revise the estimation when roadmaps of energy suppliers are published, because changes in CO_2 emission factors of energy suppliers have a significant impact, as can be seen in the increased amounts of CO_2 emissions from the stock on the market from 2002 to 2007, where electricity emission factors were worse in the CO_2 emission estimation in Figure 7.

4. Conclusion

We suggested methods to estimate past and future changes in the CO_2 emissions associated with residential plumbing equipment stock on the market by 2020. As a result, we could obtain the general direction of CO_2 emission reduction associated with residential plumbing equipment, although some issues remain concerning estimation accuracy, because of water CO_2 emission factors, and outdated equipment use models. Water CO_2 emission factors and equipment use models have been examined and studied to improve estimation accuracy.

With the assistance of the clarification of the relationship between saving water and CO_2 reduction in this study, a study has been initiated on the amount of CO_2 reduction in houses due to expansion of water-saving equipment, as in the Domestic Clean Development Mechanism and Bilateral Offset Credit Mechanism. We hope that the expansion of measures against global warming, through the establishment of a water-saving society, will expand worldwide.

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