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Review Article

Study of Effective Energy Improvement for Area Management to Optimize Low-Carbon Cities

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Abstract

Japan has the technological potential to reduce its CO2 emissions by 70% compared with its 1990 level, a reduction that would also allow the country to satisfy its expected demand for energy services in 2050. Japan must now demonstrate possible ways of putting these government targets into practice through technical and political measures. We consider the dependence of residential functionality on tertiary industries and determine ways to manage district efficiently from an energy-use standpoint. We formulate a strategy for building low-carbon cities that focuses on how to optimize area management and reduce energy consumption 50% in a given district. Our research not only reveals the potential for energy savings, but also identifies the basic data for different types of buildings needed to guide informed urban planning.

Keywords: Energy improvement; Area management; Low-carbon cities; Urban planning; Residential functions

Introduction

Japan has the technological potential to reduce its CO_2 emissions by 70% as compared with its 1990 level [1]. We must now demonstrate possible ways of implementing this target through technical and political measures. Grubler (2009) postulated a hierarchical strategy for urban energy and CO_2-emission reduction as follows:

1. Spatial division of labor (trade, industry structure)

2. Urban configuration (mixture of functions, public transportation, car ownership, etc.)

3. Efficiency of energy end use (buildings, appliances, processes)

4. Integration of energy systems (co-generation, heat-cascading)

5. Fuel substitution (renewables, nuclear).

It has been said that the most important indicator of urbanization is the spatial division of labor (trade, industry structure) [2]. First, we focused on high density district [3]. It is therefore possible to create a low-carbon city by designing commercial buildings that occupy a small area. Such a city is called a compact city. Nowadays, future population is decreasing in Japan. We therefore studied different types of cities with the goal of identifying measures to effectively reduce energy consumption 50% in the building sector. In this research, we calculate the energy consumption by considering spatial form of labor, and study effective energy improvement for area management. We devise a strategy for building low-carbon cities that focuses on how to optimize area management.

About a model of residential functions

There is also a strong correlation (R^2 >0.9) between nighttime population and people employed in many kinds of tertiary industries, as shown in Figures 1, 2 and 3.

On the other hand, major cities have a data for results of establishments for Japanese cities [4], and we create a data about area

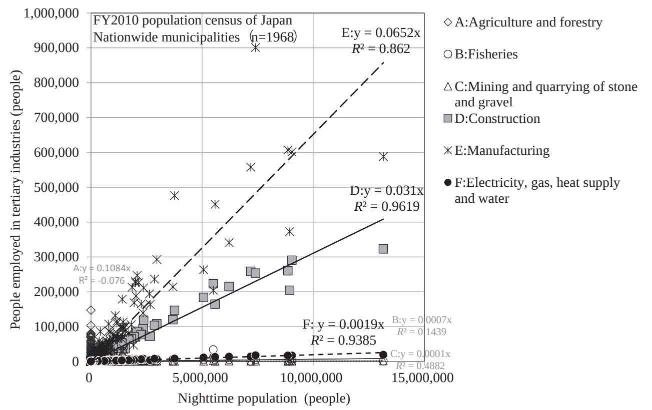

Figure 1: People employed in tertiary industries and nighttime population in Japanese cities.

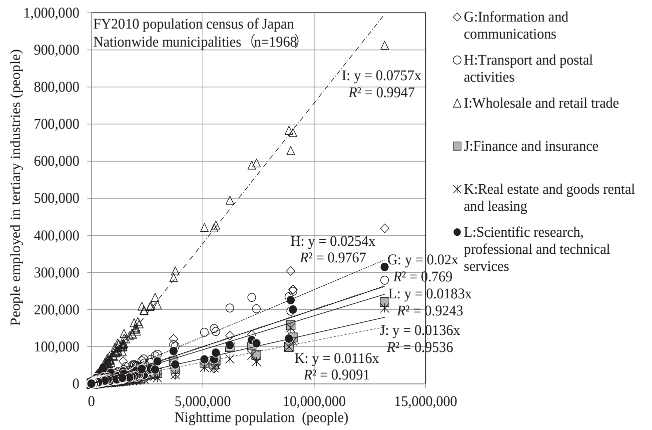

Figure 2: People employed in tertiary industries and nighttime population in Japanese cities.

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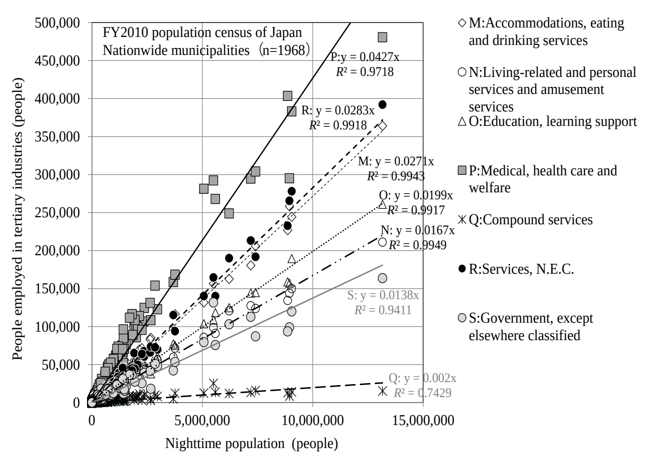

Figure 3: People employed in tertiary industries and nighttime population in Japanese cities.

associated with each employee in various industries and Japanese cities. Table 1 shows the area associated with each employee in many industries in several large Japanese cities. Saitama City has the lowest average area for all industries followed closely by Tokyo 23-ku in Table 1.

The percentage of commuting employees and persons attending school 15 years of age and older was 47% in the FY2010 population census of Japan based on the usual place of residence of Japanese people.

Therefore, we can get the correlating equation between nighttime populations and people employed in tertiary industries as shown as Table 2. In this study, we focused on people employed in tertiary industries and constructed a functional model of commercial buildings in a district. The total floor area taken up by the nighttime populations are related to the corresponding building types in the commercial sector. When office buildings in Table 3 are related Construction, Manufacturing, Telecommunication, Transportation, Retail trade, Finance and Real estate in Table 2. And, store buildings in Table 3 are matched retail trade in Table 2. Hotel and restaurant buildings in Table 3 are Restaurant, Lodging in Table 2. Hospital is Medical treatment and welfare. Community center is a kind of service. School is a type of employees for education.

Nighttime populations need a place of residence. The average number of people per household according to the FY2010 population census of Japan was 2.46. The government of Japan has said that the average floor space in residences was 94.13 m^2 in FY2010.Given this information, if the nighttime population is assumed to be 10,000, there would be 4065 households which means needing 382,638.45 m^2 of total floor space in a district.

Total floor area calculated based on residential function in a district: A_F

A_F= (1) Total floor area of commercial/government buildings for inhabitants: A_C

+ (2) Total floor area of households for inhabitants: A_H . . . (a)

Total floor area of commercial buildings for inhabitants: A_C

When a person who is living in a given district, he or she needs commercial services such as retail stores and schools as part of everyday residential functions. The total floor area of commercial buildings for inhabitants (nighttime population) (A_C, m^2) was calculated as follows.

$A_C = P_1 (A_3 + . . . A_{18} + A_{19})$ . . . (e)

P_1: nighttime population for districts

A_3: junior high school and high school floor space per person-inhabitant

A_4: elementary school floor space per person-inhabitant

A_5: day-care center and kindergarten floor space per person-inhabitant

A_6: clinic floor space per person-inhabitant

Table 1: Area associated with each employee in various industries and Japanese cities (m^2 per person).

Type of industry (m^2/person)	Average without Tokyo 23ku	Sapporo City	Sendai City	Saitama City	Chiba City	Yokohama City	Kawasaki City	Niigata City	Hamamatsu City	Nagoya City	Kyoto City	Osaka City	Sakai City	Kobe City	Hiroshima City	Kitakyushu City	Fukuoka City	Tokyo 23ku
Construction	75	93	184	51	40	45	17	108	76	25	29	31	55	176	108	98	58	26
Manufacturing	230	713	257	43	371	78	257	199	154	73	71	89	378	143	239	534	84	68
Tele-communication	20	27	29	7	10	9	5	35	34	22	21	12	15	17	28	36	14	20
Transportation	99	65	116	42	139	65	122	167	104	71	41	59	106	257	57	101	69	38
Retail trade	52	247	63	21	21	24	17	96	44	24	40	27	18	31	21	109	26	13
Finance	35	59	33	15	25	10	12	31	47	30	31	29	18	140	18	31	24	23
Real estate	587	346	494	142	568	197	128	284	3346	261	301	242	416	824	540	941	365	139
Restaurant, Lodging	8	15	22	3	5	2	2	13	8	5	10	3	7	6	3	9	11	4
Medical treatment and welfare	17	18	20	8	17	12	8	24	43	13	13	7	12	31	10	32	11	8
Education	139	265	236	78	137	86	52	193	147	82	182	45	56	122	176	175	200	67
Service	281	480	215	74	249	144	67	462	828	127	658	89	110	197	181	391	222	89
Average of all industry	140	212	152	44	144	61	62	147	439	67	127	58	108	177	126	223	99	45

Table 2: Estimated floor area associated with each employee in Saitama City (m^2 per person) ∗Reference [5], x: Floor area (m^2).

Type of industry	People employed in 10000 daytime populations (people) x: Nighttime population		Each employee ownership area in Saitama City (m^2/person)	Floor area of commercial buildings (m^2)	Energy consumption of commercial buildings for 10,000 people in a district (GJ/Year)	
Construction	310	[y=0.031x]	51	15955	35	[y=0.00219x-4.47525]∗
Manufacturing	652	[y=0.0652x]	43	27851	61	[y=0.00219x-4.47525]∗
Telecommunication	200	[y=0.02]	7	1411	3	[y=0.00219x-4.47525]∗
Transportation	254	[y=0.0254x]	42	10673	23	[y=0.00219x-4.47525]∗
Retail trade	757	[y=0.0757x]	21	15904	46	[y=2.36x+8E+03]∗
Finance	136	[y=0.0136x]	15	2019	4	[y=0.00219x-4.47525]∗
Real estate	116	[y=0.0116x]	142	16447	36	[y=0.00219x-4.47525]∗
Restaurant, Lodging	271	[y=0.0271x]	3	884	2556	[y=2.8919x+34.938]∗
Medical treatment and welfare	427	[y=0.0427x]	8	3578	13	[y=0.0037x-21.671]∗
Education	199	[y=0.0199x]	78	15542	34	[y=0.00219x-4.47525]∗
Service	283	[y=0.0283x]	74	21012	46	[y=0.00219x-4.47525]∗
Sum of all Industry	3605		485	131275	2857	
Other (students)	1095	47% of nighttime population (10,000) – sum of employed population	-	-	-	

Table 3: Base line of estimated energy consumption for 10,000 people in a district.

10,000 people in a district	total floor area	office	store	hotel and restaurant	hospital	community center	school	detached houses [default=0.6]	housing complex [default=0.4]
estimate value [m^2]	513,913	74,355	15,904	884	3,578	21,012	15,542	229,583	153,055
Percentage of total floor area [%]	100.0%	14.5%	3.1%	0.2%	0.7%	4.1%	3.0%	44.7%	29.8%
default energy consumption unit [MJ/m^2]	-	1,962	3,045	3,060	2,877	1,109	1,239	561	555
estimate energy consumption [TJ]	464	146	48	3	10	23	19	129	85
Percentage of area energy consumption [%]	100%	31%	10%	1%	2%	5%	4%	28%	18%

A_7: meeting place floor space per person-inhabitant

A_8: retail store floor space per person-inhabitant

A_9: post office floor space per person-inhabitant

A_{10}: library floor space per person-inhabitant

A_{11}: management office floor space per person-inhabitant

A_{12}: community center floor space per person-inhabitant

A_{13}: fire station floor space per person-inhabitant

A_{14}: administration liaison office floor space per person-inhabitant

A_{15}: hospital floor space per person-inhabitant

A_{16}: senior daycare floor space per person-inhabitant

A_{17}: home care center floor space per person-inhabitant

A_{18}: special nursing home floor space per person-inhabitant

A_{19}: restaurant floor space per person-inhabitant

Total floor area of households for inhabitants: A_H

The total floor area of households for inhabitants (A_H, m^2) was calculated as follows.

$A_H = P_1 (A_1X_1 + A_2X_2)$ . . . (d)

A_1: average floor space ÷ number of residents in a housing complex

A_2: average floor space ÷ number of residents in detached houses

P_1: nighttime population for districts

X_1: housing complex floor space ratio for districts (default = 0.6)

X_2: detached house floor space ratio for districts (default = 0.4)

Results and Discussion

Table 1 then shows the numbers of people and the total floor area of commercial buildings on the assumption that Saitama City has a nighttime population of 10,000 persons. This amount of floor area is proportional to energy consumption and results in low-carbon cities.

We calculated the total floor areas for 10,000 people, as shown in Table 3. These calculated areas provide an estimate of the relationship between various residential functions and associated floor areas. The values for stores, restaurants, and schools, however, are small compared with the total floor areas. This is not considered to be the total floor area of commercial buildings because the calculations do not take into account employees who commute from other areas. Using this model, we estimate the total floor area calculated based on the residence function in a standardized 10,000 persons.

We calculated the total floor areas on the basis of (1) and (2) (vide supra) for 10,000 people, as shown in Table 3. These calculated areas provide an estimate of the relationship between various residential functions and associated floor areas. The values for stores, restaurants, and schools, however, are small compared with the total floor areas. Using this model, we estimate the total floor area calculated based on the residential functions in a standardized 10,000 person's district (A_F) to be 513,913 m^2 [= 131,275 m^2 (A_C) + 382,638 m^2 (A_H)].

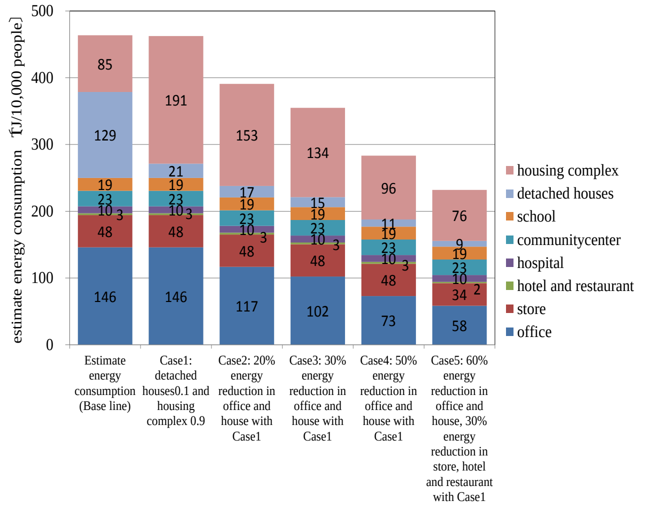

Figure 4: Case study for energy reduction target in a 10,000 people district.

By using default energy consumption per unit area, we estimated energy consumption in a district, as shown in Table 3. If all employees worked and lived entirely in this compact district, the city would produce a minimum of CO_2 emissions. Furthermore, the cost of maintaining the residential functions would be a minimum. This strategy is also a model for a developed country, the population of which is shrinking, in which case the city size might need to be adjusted.

We can now consider the target of energy reduction, when advanced technologies and materials are installed in some of the offices and houses in Figure 4. Recently, LED lightings dramatically reduce energy consumption. Therefore, offices, houses and commercial buildings have high potentials to save energy. A 60% energy reduction in offices and houses and a 30% energy reduction in stores, hotels, and restaurants is necessary to reduce energy consumption by 50% in a district. And, substantial energy reduction requires the deliberate and efficient improvement of the operation of the heat source equipment and the introduction of more efficient equipment after the operation of the indoor air conditioning system has been improved.

Conclusion

Our results reveal the relationship between nighttime population and tertiary industries and show that a district can be managed efficiently. We devised a strategy for building low-carbon cities and thus managing space in an energy-efficient manner. The basic data for different building types can be applied to any district. Japan would be going to decrease population and raise average ages in 2050. We focus on public building to improve schools, libraries, and community center. Sustainable building would be need in sudden disaster. And, we devised a strategy for building low-carbon cities and thus optimize area management. Our research reveals not only the energy saving potential, but also basic data for different building block types in different parts for building sustainable planning.

Acknowledgement

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References

1. National Institute for Environmental Studies. Japan Scenarios and Actions towards Low-Carbon Societies (LCSs), “2050 Japan Low-Carbon Society” scenario team. 2008.
2. Arnulf Grubler. Challenges for Analyzing Urban Energy and Carbon. International Workshop: Towards Low Carbon Cities - Understanding and Analyzing Urban Energy and Carbon. Urban and Regional Carbon Management, Global Carbon Project, Nagoya, Japan. 2009.
3. Yukiko Yoshida, Masaya Okumiya, Akio Onishi, Osamu Higashi, Toshiaki Ichinose, Hiroki Tanikawa, Hidefumi Imura. Study on the effective energy improvement for area management to build low-carbon cities in Asia, REHVA world congress Clima 2010 Sustainable Energy Use in Buildings. 2010.
4. Results of Establishments for Japan, Statistics Bureau, Statistics Japan. 2006.
5. The Energy Conservation Center. Japan.

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