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Variation of Energy Consumption in Barracks through Simulation by Year of Completion

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ABSTRACT

Purpose: The purpose of this study is to analyze & suggest the variation of energy consumption consequent on thermal insulation performance strengthening from early 2000s when modernization of barracks began until the present targeting a large barracks. **Method:** To carry out this research, this study surveyed the standard of thermal insulation by year, which is being applied to a barracks by conducting literature search, and selected the standard model for a barracks. Also, this study analyzed energy consumption by year & region by performing simulation(ECO2)of the selected standard model. **Result:** As a result, it was analyzed that in case of a building which was completed in 2015, the energy consumption for air-conditioning & heating, lighting, and hot water supply over the year 2000 reduced by 11% on the average in central district, 10% on the average in southern district, and 17% on the average in Jeju, respectively.

KEYWORD

에너지 소요량
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1. Introduction

1.1. Background and Purpose of Study

Recently, Korean government implements a variety of policies such as building certification system with the aim of energy saving in buildings. For military facilities, however, policy on energy saving is not established.

Barracks are integrated facilities which include quarters for soldiers and some of administrative facilities which represent high percentage of all military facilities as typical defense and military facilities. In particular, barracks are being modernized since the early 2000s and they become large as gross area increase.

Although insulation design standards are determined and insulation guidelines are proposed as they are also residential areas, study on evaluation of energy consumption or energy saving is not sufficient due to confidentiality and security of military facilities if compared with common civil buildings.

This study intends to select a standard model for barracks and analyzed the change of energy consumptions according to the change of insulation performance from the early 2000s until now.

1.2. Method of Study

This study uses the following method to calculate energy consumptions of barracks.

First, literature search is performed to investigate insulation standards applied to barracks and analyze the trend of annual change.

Second, a standard barrack model is selected for simulation by literature search and investigating the plane of barracks constructed since the early 2000s.

Third, simulation (ECO2) is performed by applying annual and regional insulation standards in order to analyze energy consumptions for the selected standard model (barracks).

2. Consideration of Relevant Regulations and Standards

2.1. Standards on National Defence and Military Facilities

Standards on defense and military facilities were established in 1969 which become the standard for barracks and as of 2014, there are 97 rules of which 57 are standards and 37 are guidelines.

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Table 1. Standard of heat transmission coefficient of a barracks

Division		Region	Heat transmission coefficient(W/㎡K)									
			1979	1980	1984	1987	2001	2008	2010	2013.9	2013.10	2015
Exterior wall	Case of directly facing the open air	Central region 3										0.20
		Central region 2	1.05	0.58	0.58	0.58	0.47	0.47	0.36	0.27	0.27	0.24
		Central region 1										0.27
		Southern region	1.05	0.58	0.58	0.76	0.58	0.58	0.45	0.34	0.34	0.34
		Jeju	1.05	0.58	1.16	1.16	0.76	0.76	0.58	0.44	0.44	0.44
	Case of indirectly facing the open air	Central region 3										0.27
		Central region 2	1.05	0.58	0.58	0.58	0.64	0.64	0.49	0.37	0.37	0.32
		Central region 1										0.37
		Southern region	1.05	0.58	0.58	0.76	0.81	0.81	0.63	0.48	0.48	0.48
		Jeju	1.05	0.58	1.16	1.16	1.10	1.10	0.85	0.64	0.64	0.64
Roof of the top floor	Case of directly facing the open air	Central region 3										0.17
		Central region 2	1.05	0.58	0.58	0.41	0.29	0.29	0.20	0.18	0.18	0.18
		Central region 1										0.18
		Southern region	1.05	0.58	0.58	0.52	0.35	0.35	0.24	0.22	0.22	0.22
		Jeju	1.05	0.58	1.16	0.76	0.41	0.41	0.29	0.28	0.28	0.28
Lowest floor	Non-heating indirectly facing an open air	Central region 3										0.39
		Central region 2	1.74	1.16	0.58	0.58	0.58	0.58	0.58	0.41	0.41	0.40
		Central region 1										0.41
		Southern region	1.74	1.16	0.58	0.76	0.64	0.64	0.58	0.41	0.47	0.47
		Jeju	1.74	1.16	1.16	1.16	0.76	0.76	0.58	0.41	0.55	0.55
Window & Door	in case of the rest of an apartment directly facing the open air	Central region 3										1.65
		Central region 2	3.49	3.49	3.49	3.37	3.84	3.40	2.40	2.10	2.10	1.87
		Central region 1										2.10
		Southern region	3.49	3.49	3.49	3.60	4.19	3.80	2.70	2.40	2.40	2.40
		Jeju	3.49	3.49	3.49	5.81	5.23	4.40	3.40	3.00	3.00	3.00

1) Central region 1 : Seoul, Incheon(Including Baengnyeongdo), Gyeonggi(Suwon, Hwaseong, Anseong, Osan, Pyeongtaek, Siheung, Guri, Seongnam, Gwacheon, Icheon, Uijeongbu, Goyang, Ansan, Yeoju, Yongin, Yangpyeong, Gimpo, Bucheon, Anyang), Gangwon(Wonju, Hoengseong), Chungbuk(Cheongju, Cheongwon, Chungju, Boeun, Goesan, Okcheon, Jeungpyeong, Danyang, Jincheon), Chungnam(Cheonan), Gyeongbuk(Cheongsong), Gwangju
2) Central region 2 : Gyeonggi(Dongducheon, Paju, Gapyeong, Namyangju, Yangju, Pocheon, Yeoncheon), Gangwon(Chuncheon, Yeongwol, Inje, Hongcheon), Chungbuk(Jecheon, Eumseong), Pocheon(Excluding Yeongbuk)
3) Central region 3 : Gangwon(Cheorwon, Taebaek, Hwacheon, Hoengseong, Jeongseon, Yanggu, Pyeongchang), Pocheon(Yeongbuk), Excluding Hoengseong

The change of insulation design standards for military quarters applied to barracks[1] is as follows.

Building Code Article 23 Section 4, "Energy Saving in Buildings" was established in December 1975 to stipulate that measures shall be taken to prevent heat loss when building a structure and Building Code Enforcement Ordinance Article 16, "Prevention of Heat Loss in Buildings" was established to stipulate heat control method for prevention of heat loss such as structure, material and construction method of wall, ceiling and openings, which are specified by the Minister of Construction.

Standard on Heat Transmission Coefficient was established in September 1979 to stipulate that the ceiling of top floor and outer wall of residential structures shall be constructed to have less than 0.9kcal/㎡h℃, outer wall of structures other than residential ones shall be built to have less than 1.8 kcal/㎡h℃ and windows of residential structures which have contact with ambient air shall be made as double window or pair glass.

Standards on heat transmission coefficient was reinforced in December 1980 to stipulate that the outer wall of living room and the ceiling or roof of living room in top floor shall be constructed to have less than 0.5kcal/㎡h℃ of heat transmission coefficient, floor (including floor which has contact with the ambient air of living room) of living room in the bottom story shall be constructed to have less than 1.0kcal/㎡h℃ or insulated by using an insulation material of more than a half of separately specified thickness and the windows which have contact with the ambient air of living room shall be constructed to have less than 3.0kcal/㎡h℃ of heat transmission coefficient or built by using double window or pair glass.

Regions were divided into two areas of Jeju-do and other areas in December 1984. Regions were divided again into three areas of central region, southern region and Jeju-do in June 1987.

Standards on classification of insulation materials were reinforced in December 1988 and were classified as "Rules on Design Standards, etc. of Buildings" in June 1992.

Standards on energy saving design have been transferred from Building Code to Green Building Establishment Act and heat transmission coefficients were reinforced to less than 0.18 ~ 0.47 W/㎡K in October 2013 and some revisions were made in April and October 2013 and September and December 2014.

Central regions were sub-divided again into three regions in May 2014 by considering insulation conditions suitable for climate characteristics.[2]

1) Defense Installations Agency, A Study on Efficient Thermal Insulation Design Plan in the light of Regional Characteristics of a Military Camp, Defense Installations Agency, 2014

2) Ministry of National Defense, National defense & Military Facility Standard DMFC 4-20-50 Thermal Insulation Standard of Military Housing Facility(2014.5.22., established), Ministry of National Defense, 2014

2.2. Standards on Insulation of Military Quarters

This study applied insulation standards stipulated by relevant regulations and those for military quarters. Table 1 shows standards on heat transmission coefficient of barracks based on standards on insulation of military quarters in the central region.

3. Selection of Standard Model

3.1. Analysis of Current Status of Barracks

The current status of barracks and progress of change[3)] were analyzed to select a simulation model for analyzing load in barracks.

one-story buildings of middle size were used before 1982 and minimum convenience facilities were installed outside. Since then, two- or three-storied integrated barracks of medium and large size were built up until early 2000s and convenience facilities such as baths, PX were placed inside the building.

Since early 2000s, squad-specific bed-type barracks of three- or four-storied large size have been built and multi-purpose hall, cyber knowledge room, space for women, etc. were expanded. It indicates that soldiers had standing lifestyles before entering the service, social infrastructure related to computer system was highly developed and the number of woman soldiers increased.

Fig. 1 shows the annual change of gross area of large barracks.

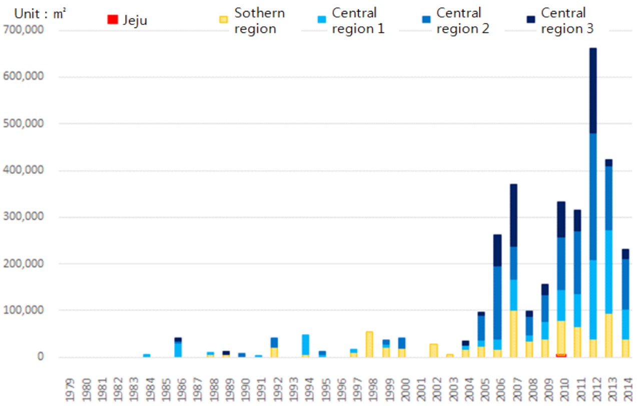


Fig. 1. Gross area for a large barrack by year

3.2. Selection of Standard Barrack Model

In order to calculate energy consumptions by using simulation, this study uses a standard model based on large barracks which greatly increase since 2000s as shown in Fig.2.

The gross area (9,065㎡) of large barracks provided by standards on floor area of defense and military facilities was used for the size of the standard model[4)].(Table 2) Based on the basic modules in the reference floor, rooms were placed according to uses in each floor through vertical and horizontal zoning[5)] and as a result, a standard model has been selected which has 2,189㎡ of building area and 9,049㎡ of gross area as shown in Table 3.

Table 2. Energy load use profile for a barracks

Room name	Military facilities standard (㎡)	Use profile
Total	9,065	-
Living space	3,213	Living space
Medical office	240	
Private office(1)	17	Small office
Private office(2)	100	
Private office(3)	17	
Private office(4)	45	Large office
Office(1)	131	
Office(2)	243	
Meeting room	50	Meeting room
Officer room	270	
Counseling office	75	
PC room	224	
Command and control center	51	
Operating room	60	
Classified document room	7	Reading room (library)
Library	66	
Toilet	231	Toilet, Shower room, etc.
Wash room	124	
Laundry room	36	
Laundry room	40	
Laundry room	36	
Drying room	41	
Shower room	106	
Fitting room(shower)	45	
Bathhouse	36	
Fitting room(Bathhouse)	23	
Bathhouse(bath)	7	
Military boots wash room	84	
Sewing room	65	
Lounge	83	Lounge, Gym, etc.
Table tennis room	27	
Billiard room	31	
Gym	125	
Woman convenience facility	21	
Barbershop(soldier)	61	
Barbershop(officer)	34	
PX	150	
Multi-purpose auditorium	535	
Area of common use space	2,061	Hall, Lobby, Corridor, Stair hall, etc.
Supply room	61	Storehouse, Machine Room, etc.
Storehouse	61	
Machine room	134	

3) Ministry of National Defense, National Defense & Military Facilities Design Collection, Ministry of National Defense, 2009

4) Ministry of National Defense, National defense & Military Facility Standard DMFC 3-30-10 Building Area Standard(2014.8.1., revised), Ministry of National Defense, 2014

5) Ministry of National Defense, National defense & Military Facility Standard DMFC 5-10-10 Residence Hall Design Guidelines(2014.4.1., revised), Ministry of National Defense, 2014

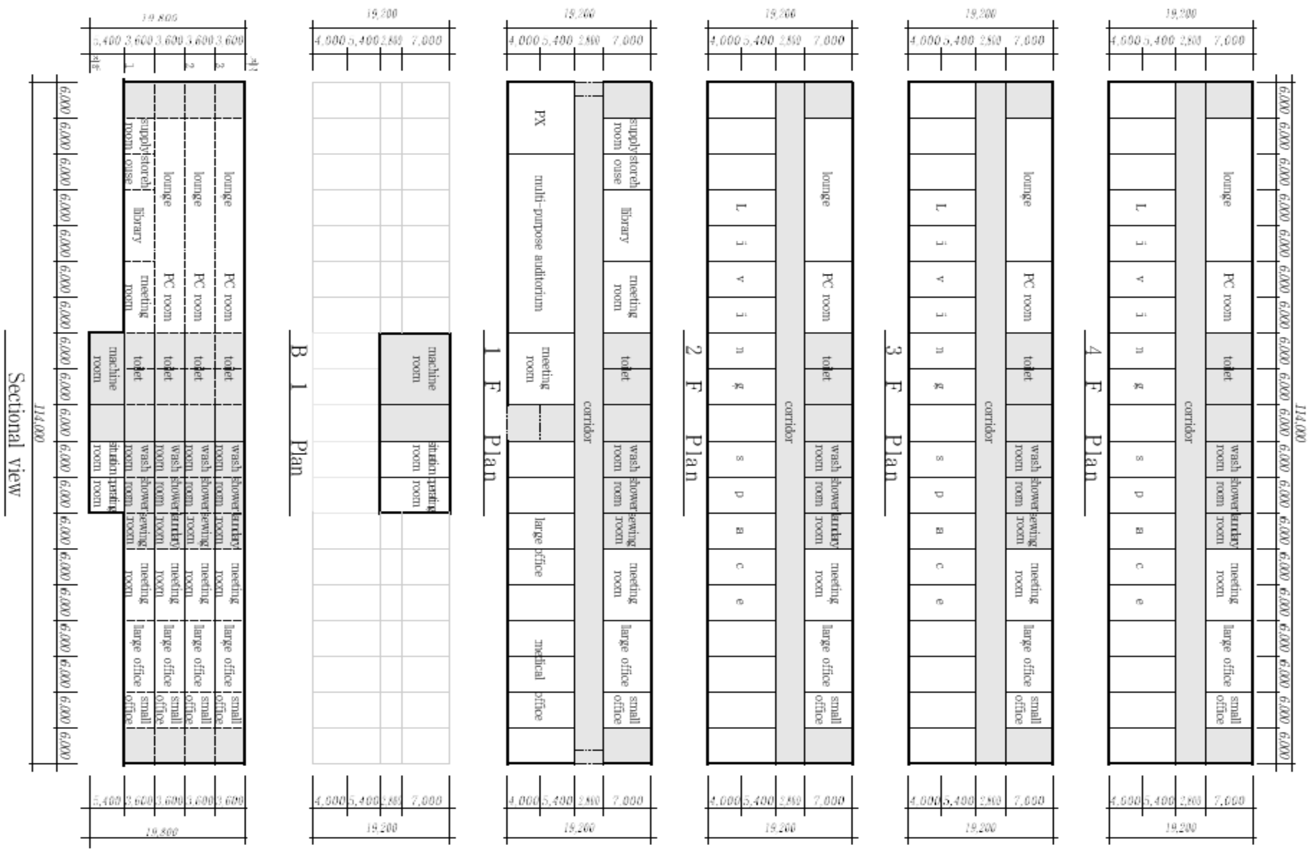


Fig. 2. Floor plan & cross-sectional drawing for a barracks standard model

Table 3. Zoning plan for a barracks standard model by use

Division	Total (㎡)	B1 (㎡)	1F (㎡)	2F (㎡)	3F (㎡)	4F (㎡)
Living space	3,440		226	1,072	1,072	1,072
Small office	168		42	42	42	42
Large office	618		366	84	84	84
Meeting room	902	118	281	168	168	168
Reading room (library)	84		84			
Toilet, Shower room, etc.	840		210	210	210	210
Lounge, Gym, etc.	899		395	168	168	168
Hall, Lobby, Corridor, Stair hall, etc.	1,896	59	502	445	445	445
Storehouse, Machine Room, etc.	202	118	84			
Total	9,049	294	2,189	2,189	2,189	2,189

The intensity of illumination set for each zoning[6] is shown in Table 4. Ventilation has not been considered, however, as the standard[7] on defense and military facilities is the same for barracks.

6) Ministry of National Defense, National defense & Military Facility Standard DMFC 4-40-40 Lighting & Electric Heat Equipment Design Criteria(2013.7.25., revised), Ministry of National Defense, 2014

7) Ministry of National Defense, National defense & Military Facility Standard DMFC 4-30-10 Air-conditioning Equipment Design Criteria(2014.1.2., revised), Ministry of National Defense, 2014

Table 4. Illumination applied to a barrack by use

Division	Illumination standard (Lx)	Illumination plan (Lx)
Living space	200 ~ 300	250
Small office	300 ~ 500	400
Large office	300 ~ 500	400
Meeting room	300 ~ 500	400
Reading room (library)	300 ~ 500	400
Toilet, Shower room, etc.	100 ~ 200	150
Lounge, Gym, etc.	150 ~ 300	200
Hall, Lobby, Corridor, Stair hall, etc.	100 ~ 200	150
Storehouse, Machine Room, etc.	100 ~ 150	150

Table 5 and Fig. 2 show architectural surface area, floor plan and cross-sectional plan of the selected standard model.

Table 5. Architectural surface area for a barracks standard model

Division	Area(㎡)
Window	832
Roof of the top floor	2,189
Lowest floor	2,189
Exterior wall (Case of directly facing the open air)	3,005
Underground Wall (Case of indirectly facing the open air)	430

4. Results of Analysis

This study uses ECO2 by considering calculation of energy consumption and total load, possibility of simulation in locations where barracks are located, provision and compatibility of climate data and use of easy of military officials.

We selected five central regions (Seoul, Incheon, Wonju, Chuncheon and Cheongju), seven southern regions (Busan, Daegu, Daejeon, Gwangju, Gangneung, Jeonju and Mokpo) and Jeju for which climate data is provided as specified in the Operational Rule of Building Energy Efficiency Certification System as the regions for analysis.

4.1. Results of Analysis on Annual Energy Consumption According to Regions

Energy consumption simulation was performed for the regional, standard barracks model according to the change of insulation standards.

Among heating, cooling, hot water and lighting, energy consumptions for hot water and lighting were calculated to be 20.6kWh/m²·y and 22.7kWh/m²·y, respectively. It is the result from the analysis of simulation modeling according to use zoning where residence type of barracks and use characteristics of each room such as administrative facilities and support facilities are reflected.

Energy consumptions of each region were changed by heating and cooling and Table 6 shows the results.

According to the results from analysis of energy consumptions of the standard model by applying the standard as of 2000, the barracks model of Chuncheon showed the highest vale (126.6kWh/m²·y) and that of Incheon showed the lowest value (114.6kWh/m²·y) in the central region. The barracks model of Daejeon showed the highest value (120.0kWh/m²·y) and that of Busan showed the lowest value (97.2kWh/m²·y) in the southern region. Barracks model of Jeju resulted in 109.5kWh/m²·y.

According to the results from analysis of energy consumptions of the standard model by applying the standard as of 2005, the barracks model of Chuncheon showed the highest vale (125.7kWh/m²·y) and that of Incheon showed the lowest value (113.8kWh/m²·y) in the central region. The barracks model of Daejeon showed the highest value (119.4kWh/m²·y) and that of Busan showed the lowest value (96.9kWh/m²·y) in the southern region. Barracks model of Jeju resulted in 100.3kWh/m²·y.

According to the results from analysis of energy consumptions of the standard model by applying the standard as of 2008, the barracks model of Chuncheon showed the highest vale (123.6kWh/m²·y) and that of Incheon showed the lowest value (112.1kWh/m²·y) in the central region. The barracks model of Daejeon showed the highest value (106.5kWh/m²·y) and that of Busan showed the lowest value (95.9kWh/m²·y) in the southern region. Barracks model of Jeju resulted in 98.3kWh/m²·y.

According to the results from analysis of energy consumptions of the standard model by applying the standard as of 2010, the barracks model of Chuncheon showed the highest vale (115.8kWh/m²·y) and that of Incheon showed the lowest value (105.6kWh/m²·y) in the central region. The barracks model of Daejeon showed the highest value (109.9kWh/m²·y) and that of Busan showed the lowest value (91.1kWh/m²·y) in the southern region. Barracks model of Jeju resulted in 92.9kWh/m²·y.

According to the results from analysis of energy consumptions of the standard model by applying the standard as of 2015, the barracks model of Chuncheon showed the highest vale (111.4kWh/m²·y) and that of Incheon showed the lowest value (102.1kWh/m²·y) in the central region. The barracks model of Daejeon showed the highest value (106.5kWh/m²·y) and that of Busan showed the lowest value (88.8kWh/m²·y) in the southern region. Barracks model of Jeju resulted in 90.9kWh/m²·y.

The results of regional energy consumption simulation indicate that Chuncheon has the highest energy consumption and Busan has the lowest energy consumption. Jeju-do showed higher energy consumption than Busan although it is located in a region with lower latitude.

4.2. Results of Analysis on Monthly Energy Consumption According to Regions

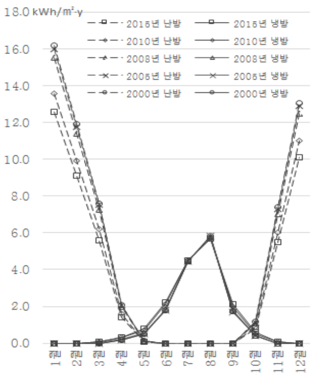
As energy consumptions for how water and lighting are found to be identical, monthly energy consumptions for heating and cooling of each region are calculated and shown in Fig. 3.

According to the results, energy consumptions for heating of each region tend to decrease 24% and 43% on average in the central and southern region, respectively as insulation conditions are reinforced from 2000 to 2015. On the contrary, energy consumptions for cooling increased 13%, 5% and 12% on average in the central and southern regions and Jeju-do, respectively.

Based on the buildings completed in 2015, energy consumptions for cooling and heating decreased 21%, 17% and 28% on average in the central and southern regions and Jeju-do, respectively compared with those in 2000 and if lighting and hot water loads are considered, 11%, 10% and 17% of energy consumptions decreased on average in the central and southern regions and Jeju-do, respectively.

Table 6. Analysis result of regional energy consumption consequent on change in thermal insulation standard(kWh/㎡·y)

Region		2000					2005					2008					2010					2015				
		Heating	Cooling	Hot water	lighting	Total	Heating	Cooling	Hot water	lighting	Total	Heating	Cooling	Hot water	lighting	Total	Heating	Cooling	Hot water	lighting	Total	Heating	Cooling	Hot water	lighting	Total
Central region	Seoul	59.6	14.9	20.6	22.7	117.8	58.9	14.8	20.6	22.7	117.0	56.8	15.1	20.6	22.7	115.2	49.4	15.9	20.6	22.7	108.6	45.2	16.4	20.6	22.7	104.9
	Incheon	59.6	11.7	20.6	22.7	114.6	58.9	11.6	20.6	22.7	113.8	56.9	11.9	20.6	22.7	112.1	49.3	13.0	20.6	22.7	105.6	45.1	13.7	20.6	22.7	102.1
	Wonju	68.1	12.8	20.6	22.7	124.2	67.3	12.7	20.6	22.7	123.2	65.0	12.9	20.6	22.7	121.2	56.6	13.9	20.6	22.7	113.8	51.9	14.5	20.6	22.7	109.7
	Chuncheon	70.9	12.5	20.6	22.7	126.6	70.0	12.3	20.6	22.7	125.7	67.7	12.6	20.6	22.7	123.6	59.0	13.5	20.6	22.7	115.8	54.0	14.1	20.6	22.7	111.4
	Cheongju	58.6	15.7	20.6	22.7	117.6	57.9	15.6	20.6	22.7	116.7	55.8	15.8	20.6	22.7	114.9	48.4	16.7	20.6	22.7	108.4	44.2	17.3	20.6	22.7	104.8
Southern region	Busan	39.2	14.8	20.6	22.7	97.2	38.8	14.8	20.6	22.7	96.9	37.6	15.1	20.6	22.7	95.9	31.4	16.4	20.6	22.7	91.1	29.7	15.8	20.6	22.7	88.8
	Daegu	48.6	16.8	20.6	22.7	108.7	48.2	16.7	20.6	22.7	108.2	46.7	17.0	20.6	22.7	107.0	39.4	18.1	20.6	22.7	100.8	37.1	17.4	20.6	22.7	97.8
	Daejeon	60.4	16.3	20.6	22.7	120.0	59.9	16.2	20.6	22.7	119.4	58.1	16.4	20.6	22.7	117.9	49.3	17.4	20.6	22.7	109.9	46.5	16.7	20.6	22.7	106.5
	Gwangju	49.3	17.3	20.6	22.7	109.9	48.9	17.3	20.6	22.7	109.5	47.4	17.5	20.6	22.7	108.2	40.0	18.7	20.6	22.7	101.9	37.7	17.9	20.6	22.7	98.9
	Gangneung	51.9	11.6	20.6	22.7	106.8	51.5	11.6	20.6	22.7	106.4	49.9	11.9	20.6	22.7	105.1	42.1	13.4	20.6	22.7	98.8	39.8	12.9	20.6	22.7	96.0
	Jeonju	57.0	17.8	20.6	22.7	118.2	56.5	17.8	20.6	22.7	117.6	54.9	18.0	20.6	22.7	116.1	46.5	18.9	20.6	22.7	108.7	43.8	18.1	20.6	22.7	105.2
	Mokpo	46.1	16.5	20.6	22.7	105.8	45.7	16.4	20.6	22.7	105.4	44.2	16.7	20.6	22.7	104.2	37.3	18.0	20.6	22.7	98.6	35.2	17.2	20.6	22.7	95.7
Jeju	Jeju	48.3	17.9	20.6	22.7	109.5	38.7	18.3	20.6	22.7	100.3	36.3	18.7	20.6	22.7	98.3	30.1	19.5	20.6	22.7	92.9	27.5	20.1	20.6	22.7	90.9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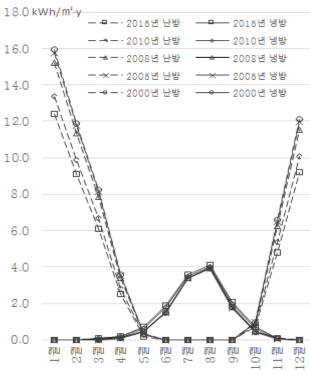
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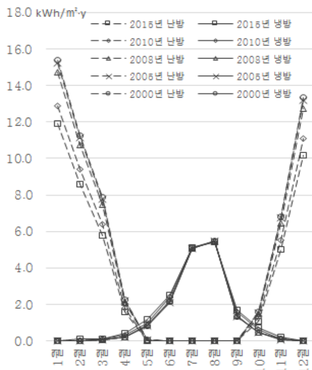
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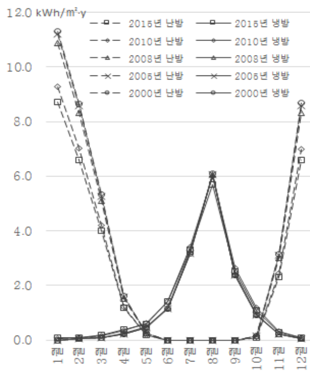
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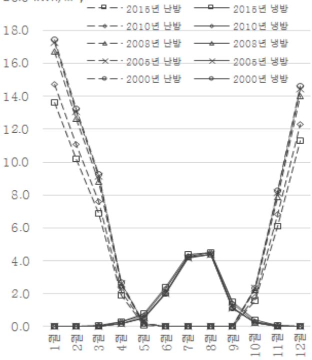
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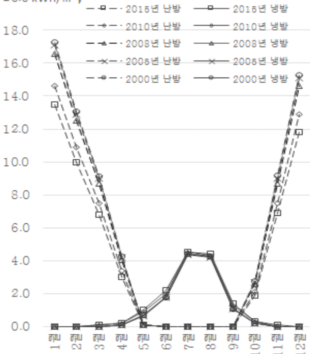
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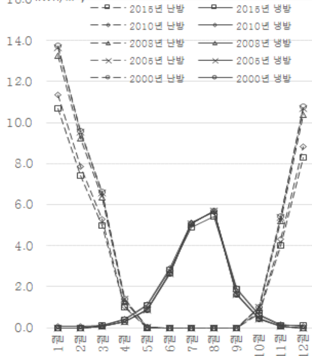
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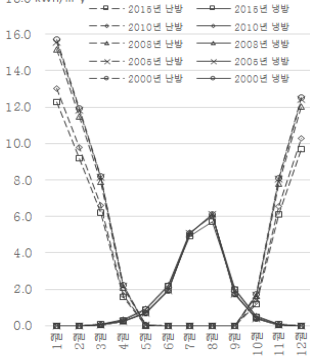
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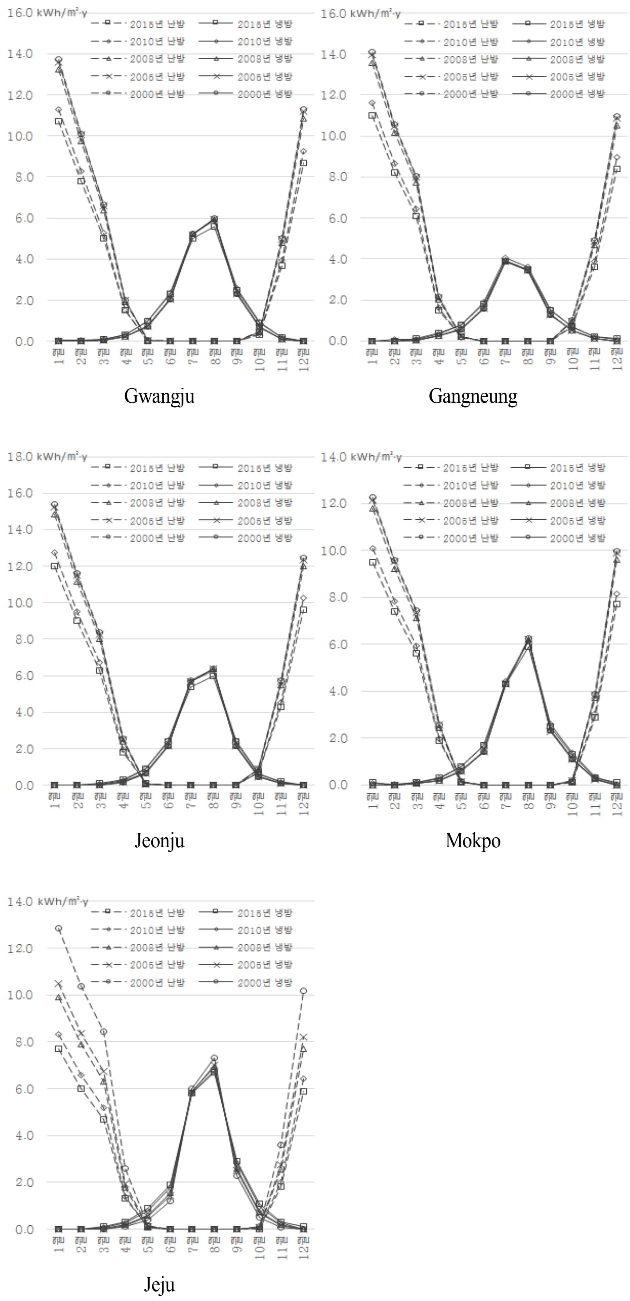

Fig. 3. Monthly energy consumption for heating & air-conditioning

5. Conclusion

This study analyzed and quantified the change of energy consumptions according to the reinforcement of insulation conditions from early 2000s where the modernization of large barracks started until now.

The results of this study are summarized as follows.

1) Based on the standard model, insulation conditions from 2000 to 2015 were applied and simulation program (ECO2) was used to calculate energy consumptions of five central regions (Seoul, Incheon, Wonju, Chuncheon and Cheongju), seven southern regions (Busan, Daegu, Daejeon, Gwangju, Gangneung, Jeonju and Mokpo) and Jeju-do. Energy consumptions for hot water and lighting of each region were calculated to be 20.6kWh/㎡·y and 22.7kWh/㎡·y, respectively, according to energy consumptions for cooling and heating, Chuncheon showed the highest value and Busan had the lowest value. Jeju-do showed higher energy consumptions than Busan although it is located in a region with lower latitude.

2) Based on the buildings completed in 2015, energy consumptions for cooling and heating decreased 21%, 17% and 28% on average in the central and southern regions and Jeju-do, respectively compared with those in 2000 and if lighting and hot water loads are considered, 11%, 10% and 17% of energy consumptions decreased on average in the central and southern regions and Jeju-do, respectively.

This study was performed to provide basic data for energy remodeling study according to completion years as the time arrives to repair large barracks which have been constructed since early 2000s. Further study will be performed on optimum energy remodeling in consideration of economy and environment friendliness based on this study.

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