KIEAE Journal, Vol. 17, No. 2, Apr. 2017, pp.13-20.

KIEAE Journal

Korea Institute of Ecological Architecture and Environment

84

Extension of Typical Meteorological Data and Energy Demand Analysis for Building Energy Efficiency Rating Certification System

Lee, Sung-Jin* · Kim, Jonghun** · Jeong, Hakgeun*** · Yoo, Seunghwan**** · Lee, Junghun*****

* Energy Saving Laboratory, Energy Efficiency Research Division, Korea Institute of Energy Research, South Korea(sjleeki@kier.re.kr)
** Corresponding author, Energy Saving Laboratory, Korea Institute of Energy Research, South Korea(jonghun@kier.re.kr)
*** Coauthor, Energy ICT Laboratory, Korea Institute of Energy Research, South Korea (hgjeong@kier.re.kr)
**** Coauthor, Energy Saving Laboratory, Korea Institute of Energy Research, South Korea(shyoo@kier.re.kr)
***** Coauthor, Dept. of Architectural Engineering, Sung Kyun Kwan Univ. South Korea(Junghun@kier.re.kr)

ABSTRACT

Meteorological data is one of the important factors in the calculation of building energy demand. The purposes of this study are to review the limitations of the typical meteorological data of ECO2 program and to create the new typical meteorological data and then analyze the building energy demands for additional regions which are not included in the existing 13 region in the ECO2 program. The extended typical meteorological data to a total of 33 regions were based on IWEC(International Weather for Energy Calculations) data files and were created in the form applicable to the building energy efficiency rating certification system. As a result of comparing the heating energy demands of a representative region with the surrounding regions in each of five regions in Korea, the variance of Cv(RMSE) ranged from 36% to 344% and MBE ranged from -32% to 190% for the whole regions. This suggests that the difference of heating energy demand may vary greatly depending on the region where the meteorological data is used and the meteorological data of more detailed regions is needed for reliable calculation of building energy demand

KEYWORD

표준기상데이터
건축물에너지효율등급 인증
직산분리
ISO 13790
건축물에너지 평가

Typical Meteorological data
Builidng Energy efficiency rating certification
ISO 13790
Building Energy Assessment

ACCEPTANCE INFO

Received Dec 21 2016
Final revision received Mar 23, 2017
Accepted Mar 28, 2017

1. Introduction

Meteorological data in building energy simulations is a source of information on annual climate conditions. The 'typical meteorological data' used in the simulation is that of a 'typical year', which is made through statistical processing of the meteorological data for 15 to 30 years [1] .

In Korea, the building energy efficiency rating certification system is implemented [2], and ECO2 is used as a certification program. ECO2 simulation uses the typical meteorological data for 13 major regions in Korea [3]. However, these meteorological data do not reflect the meteorological information of the whole country, and when evaluating the energy efficiency rating of any region other than the 13 major regions, it may be ambiguous which meteorological data should be used.

In the current building energy efficiency rating system, the meteorological data of the nearest surrounding region is used instead when evaluating the energy efficiency rating of any region other than the 13 major regions[4]. For example, Suwon uses the meteorological data of Seoul, but it is also adjacent to Incheon. Pohang adjacent to the coast, which is the closest distance to Daegu, is likely to have problems in using the meteorological data of Daegu which is characteristic of inland climate.

In this study, the limitations of ECO2 typical meteorological data used for the building energy efficiency rating certification are examined and the typical meteorological data of the additional regions not included in the existing 13 major regions are created. Based on the created typical meteorological data, the heating energy demands of the additional regions are also analyzed.

2. Necessity to expand the existing typical meteorological data

In relation to the building energy efficiency rating certification, the necessity to expand the existing typical meteorological data has been mentioned by Hideki Kikumoto et al. [5] and Lee Sung Jin et al. [6]. The operational regulations of the building energy efficiency rating certification system provide only the meteorological data of 13 major regions for energy simulation [3], and thereby there is a limit to obtain the simulation results for any region other than those major regions. Therefore, it is necessary to acquire the meteorological data of additional regions in order to reflect the local characteristics of meteorological data and to

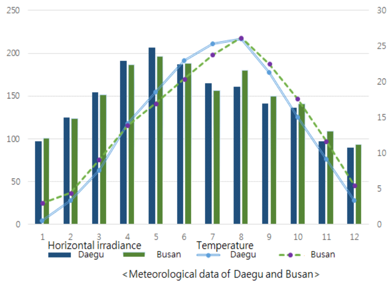
pISSN 2288-968X, eISSN 2288-9698
http://dx.doi.org/10.12813/kieae.2017.17.2.013

improve the reliability of simulation results in building energy evaluation,

The current operational regulations, if any region has no meteorological data, recommend use of the typical meteorological data of the surrounding regions . For example, Pohang uses the meteorological data of Daegu or Busan, and Yeosu uses the meteorological data of the neighboring Gwangju or Mokpo. However, this may have a large influence on energy demand calculation results as well as the meteorological data itself depending on which regions to select.

To verify this problem, the present study takes the cases of Pohang and Yeosu as an example. The energy demands are calculated when the meteorological data of the surrounding major regions (Daegu and Busan in case of Pohang and Gwangju and Mokpo in case of Yeosu) are used, and the difference between the two calculation results are compared. In this calculation, the reference model house and the calculation procedure are based those described in Chapter 4.

Fig. 1 shows the meteorological data and energy demand calculation results of Daegu and Busan, and Fig. 2 shows those of Gwangju and Mokpo.

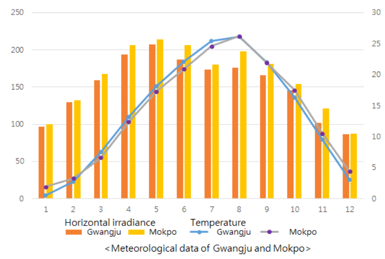


Month	Energy demand [kWh]	
	Daegu	Busan
Jan	356	208
Feb	150	81
Mar	61	30
Apr	0	1
May	0	0
Jun	0	0
Jul	0	0
Aug	0	0
Sep	0	0
Oct	0	0
Nov	20	1
Dec	214	87
TOTAL	802	408

Cv(RMSE)=90%, MBE=-49.2%

<Energy demand of Daegu and Busan>

Fig. 1. Comparison of meteorological data & heating energy demand for Daegu and Busan



Month	Energy demand [kWh]	
	Gwangju	Mokpo
Jan	364	241
Feb	155	132
Mar	59	76
Apr	1	2
May	0	0
Jun	0	0
Jul	0	0
Aug	0	0
Sep	0	0
Oct	0	0
Nov	9	1
Dec	340	228
TOTAL	927	681

Cv(RMSE)=63%, MBE=-26.5%

< Energy demand of Gwangju and Mokpo>

Fig. 2. Comparison of meteorological data & heating energy demand for Gwangju and Mokpo

The statistics, Cv(RMSE)(Coefficient of Variation of the Root Mean Squared Error) and MBE(Mean Bias Error), are defined as follows [7].

$$MBE(\%) = \frac{\sum_{period} (S-M)_{interval}}{\sum_{period} M_{interval}} \times 100 \quad (1)$$

$$RMSE_{period} = \sqrt{\frac{\Sigma (S-M)^2_{interval}}{N_{interval}}} \quad (2)$$

$$A_{period} = \frac{\sum_{period} M_{interval}}{N_{interval}} \quad (3)$$

$$Cv(RMSE_{period}) = \frac{RMSE_{period}}{A_{period}} \times 100 \quad (4)$$

M = simulation result value (kWh)
S = another simulation result value (kWh)
$N_{interval}$ = the number of time intervals

These statistics, which are commonly used to verify the measured value of building energy and the calculated value of model simulation, are used in this study to compare the deviation between simulation results according to different meteorological data. In the case of Pohang, as shown in the figure, it showed a difference of Cv (RMSE) 90%, MBE -49.2% in the heating energy demand of Daegu and Busan, and in the case of Yeosu, it showed a difference of Cv (RMSE) 63% and MBE -26.5% in the heating energy demand Gwangju and Mokpo. This suggests: If there are no typical meteorological data for any region to be evaluated, the use of the meteorological data of the neighboring 13 regions does not reflect the meteorological characteristics of the corresponding region, and thus it may have a large impact on calculation results.

3. Creation of IWEC-based extended typical meteorological data

IWEC (International Weather for Energy Calculations) is the representative meteorological data for building energy calculation which is provided by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) [8]. It was made with the data of National Climatic Data Center (NC) in the USA. For Korea, the IWEC provides 69 kinds of meteorological data including temperature, humidity, solar radiation, wind speed, cloudiness and illumination for 33 regions: Seoul, Busan, Incheon, Daegu, Daejeon, Gangreung, Gwangju, Wonju, Chuncheon, Jeonju, Cheongju, Mokpo, Jeju, Andong, Cheorwon, Chupwolryeong, Daegwallyeong, Gunsan, Jinju, Masan, Pohang, Seogwipo, Seosan, Sokcho, Suwon, Tongyeong, Uljin, Ulleungdo, Ulsan, Wando, Yeongwol , Yeosu, and Donghae) [9].

However, the IWEC meteorological data can't be directly applied to the simulation of building energy efficiency rating certification. To calculate the energy demand, 8,760 hourly raw data should be converted into monthly data, and calculations for solar altitude and total solar irradiance by azimuth are also needed. The solar altitude and azimuth separation are calculated by the method of ASHRAE Fundamental 2013: Calculating clear-sky solar radiation & Transposition to receiving surfaces of various orientations [10].

Fig. 3 shows the solar angles to the vertical and horizontal planes. The solar altitude was calculated using the following equations (5) - (7).

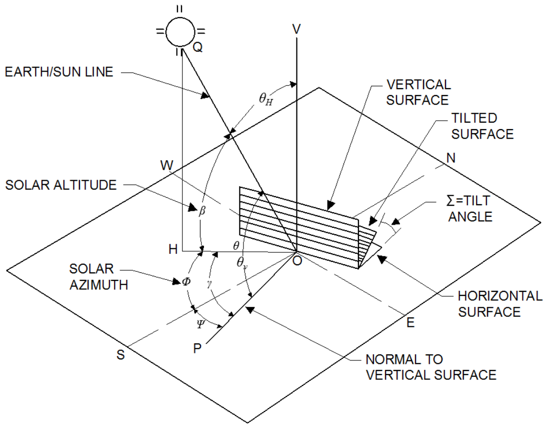


Fig. 3. Solar angles for vertical and horizontal surfaces

$$\sin\beta = \cos L \cos\delta \cos H + \sin L \sin\delta \quad (5)$$

$$\delta = 23.45 \sin(360°(n+284)/365) \quad (6)$$

$$H = 15(AST - 12) \quad (7)$$

where

β = Solar altitude (°)

L = Latitude(°)

n = Day of year

AST = Apparent solar time

The total solar irradiance of horizontal surface, ($E_{t,h}$), and the total solar irradiance by directions, ($E_{t,v}$) are obtained using the solar altitude calculated from the above equations and the following equations (8) to (14).

$$E_{t,h}=E_{b,h} + E_d \quad (8)$$

$$E_{t,v}=E_{b,v} + E_d \quad (9)$$

$$E_{b,h}=E_b \sin\beta \quad (10)$$

$$E_{b,v}=E_b \cos\theta \quad (11)$$

$$\cos\theta = \cos\beta \cos\gamma \quad (12)$$

$$\gamma = \Phi - \Psi \quad (13)$$

$$\sin\Phi = \sin H \cos\delta / \cos\beta \quad (14)$$

where

$E_{t,h}$ = Horizontal surface total solar irradiance (W/m^2)

$E_{t,v}$ = Vertical surface total solar irradiance (W/m^2)

E_d = Diffuse solar irradiance (W/m^2)

$E_{b,h}$ = Horizontal surface direct normal irradiance (W/m^2)

$E_{b,v}$ = Vertical surface direct normal irradiance (W/m^2)

E_b = Direct normal irradiance (Solar radiation received in a collimated beam on a surface normal to the sun (W/m^2)

Φ = Solar azimuth (°)

Ψ = Surface azimuth (°)

Table I shows the temperature and total solar irradiance of 33 regions in Korea provided by IWEC. With these data, the total solar irradiances of horizontal surface and the total solar irradiance by directions were calculated, which showed different values depending on different regions but a similar pattern in the monthly distribution. Fig. 4, as an example of those calculation results, shows the total solar irradiance of horizontal surface and total solar irradiance by the directions of east, west, north, and south for additional representative regions (Suwon, Pohang, Seosan, Yeosu, and Jinju) which are not included in the 13 major regions of ECO2 program and also were selected one by one from the 5 region groups of the whole country.

Fig. 5 is shown in the form of skeletal box-and-whishker plot of the total irradiance of horizontal surface for the additionally selected representative regions and the existing regions around them (Seoul and Incheon in the case of Suwon, Daegu and Busan in case of Pohang, in case of Jinju Daegu and Busan in case of Jinju, Daejeon and Cheongju in case of Seosan, Gwangju and Mokpo in case of Yeosu, which are provided with the meteorological data of ECO2). As shown in the figure, the averaged total solar irradiance of horizontal surface was 149.19 W/m^2, 152.63 W/m^2, 146.27 W/m^2 in the case of Suwon-Seoul-Incheon, respectively; 164.84 W/m^2, 158.40 W/m^2, 165.48 W/m^2 in the case of Pohang-Daegu-Busan, respectively; 167.34 W/m^2, 158.40 W/m^2, 165.48 W/m^2 in the case of Jinju-Daegu-Busan, respectively; 161.12 W/m^2, 161.55 W/m^2, 162.47 W/m^2 in the case of Seosan-Daejeon-Cheongju, respectively, and 144.92 W/m^2, 162.97 W/m^2, 165.95 W/m^2 in the case of Yeosu-Gwangju−Mokpo, respectively. As the Cv(RMSE) deviation of the averaged total solar irradiance of horizontal surface between a representative region in the five region groups and the surrounding regions, Suwon showed 6% and 8% for Seoul and Incheon, respectively; Pohang showed 7% and 5% for Daegu and Busan, respectively; Jinju showed 6% and 9% for Daegu and Busan, respectively; Seosan showed 4% and 7% for Daejeon and Cheongju,

Table 1. Temperature and total solar irradiance for 33 regions in Korea.

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI	TEMP	TSI
Seoul	-2.5	83	0.7	114	5.9	160	13.2	227	18.1	229	21.8	205	24.5	175	26.0	169	21.2	157	15.1	135	7.3	99	0.9	79
Incheon	-2.0	89	0.5	117	4.8	152	10.8	184	16.6	208	21.0	207	24.3	162	25.9	168	20.8	150	15.0	134	8.5	99	1.4	85
Daejeon	-1.2	100	0.9	135	6.2	178	11.7	225	16.7	236	22.1	208	24.6	178	25.9	178	20.9	154	14.2	147	7.5	111	0.2	89
Andong	-2.2	98	-0.9	130	5.7	182	12.4	239	17.1	248	21.7	225	24.6	181	25.1	178	19.8	156	13.8	144	6.4	112	0.1	94
Busan	3.0	112	4.1	143	8.6	169	13.0	204	17.5	218	20.4	205	24.0	194	25.9	196	22.6	166	17.7	150	12.0	119	6.6	109
Cheongju	-1.8	91	1.1	126	4.9	172	13.8	241	17.5	238	22.4	229	25.5	182	26.1	176	20.5	171	14.3	142	6.9	101	1.2	82
Cheorwon	-4.2	91	-2.1	125	3.9	179	10.8	241	16.6	244	20.2	222	23.7	164	24.0	183	18.7	165	11.4	145	3.0	99	-2.3	74
Chuncheon	-5.2	83	-1.3	129	4.2	165	10.6	228	17.6	236	21.6	221	24.9	174	24.7	181	19.5	150	12.8	141	5.6	86	-1.2	72
CPN*	-2.8	97	-0.5	134	6.1	194	11.2	226	17.0	236	20.9	203	24.0	168	24.1	166	19.4	154	13.0	145	6.4	109	0.8	88
Daegu	1.0	108	3.4	141	8.0	170	13.8	209	18.9	214	23.0	211	26.1	177	26.3	168	21.5	149	16.0	146	10.2	109	3.9	100
DGY*	-8.0	104	-2.2	145	0.6	185	7.7	235	11.7	240	15.7	236	19.6	207	19.3	203	14.2	168	8.3	143	3.5	114	-3.1	96
DH-R*	0.8	102	2.2	137	7.2	173	12.3	211	15.8	195	19.1	187	22.6	160	22.9	168	19.3	139	15.4	141	9.5	111	3.7	101
Gangneung	-0.4	106	2.1	135	6.8	176	12.8	217	17.9	241	20.2	220	24.0	198	24.0	184	20.4	161	15.4	148	9.4	109	3.1	98
Gumsam	0.3	97	1.6	132	5.3	169	11.2	221	16.9	226	21.4	215	25.1	191	25.7	191	21.3	162	16.0	148	9.1	112	2.4	89
Gwangju	1.4	99	2.9	131	7.1	171	13.6	218	18.1	226	22.3	208	25.0	181	25.7	191	22.0	175	15.8	149	9.6	114	2.7	93
Jeju	5.6	84	6.3	122	8.6	156	13.4	189	17.6	206	21.4	196	26.0	211	26.7	184	22.3	166	18.5	146	13.0	108	8.3	86
Jeonju	-0.2	103	2.1	136	6.3	179	12.7	228	18.0	243	22.8	221	26.0	187	26.1	186	21.4	173	15.1	152	8.7	111	1.9	89
Jinju	0.2	103	2.1	136	6.9	179	12.7	228	16.9	243	21.9	221	25.4	187	26.0	186	21.2	173	14.7	152	7.9	111	1.6	89
Masan	2.9	110	5.4	141	9.0	174	14.0	196	18.3	204	21.5	177	25.4	156	26.8	168	23.0	158	17.7	142	11.1	115	5.3	101
Mokpo	2.0	102	2.4	130	7.5	165	12.5	218	17.3	232	21.1	203	25.3	197	26.0	210	22.4	170	16.7	159	11.0	116	4.7	91
Pohang	1.9	110	4.3	137	9.2	171	14.2	214	18.9	233	21.5	210	24.5	194	25.4	196	22.1	151	16.6	145	10.2	114	4.7	103
Seogwipo	7.2	99	8.0	125	10.2	164	14.9	203	18.5	203	21.8	184	26.0	184	27.2	186	23.8	165	19.4	152	14.4	116	9.9	95
Seosan	-1.0	95	0.3	132	4.4	178	10.1	216	16.4	225	20.8	212	24.3	183	25.1	188	19.9	164	13.5	148	7.4	107	0.6	86
Sokcho	-0.6	99	1.5	135	6.5	160	11.3	211	16.0	205	19.3	194	23.1	167	22.9	155	20.1	152	15.1	137	9.1	106	2.7	91
Suwan	-2.9	90	-1.2	117	5.9	158	11.9	219	17.5	208	22.0	198	25.1	162	25.4	158	20.7	156	14.5	141	7.0	100	-0.2	82
Tongyeong	2.9	108	4.7	132	7.5	163	13.4	197	17.5	198	20.6	175	24.3	151	25.8	168	22.6	151	17.2	145	11.2	117	5.9	95
Uljin	0.7	105	3.1	136	6.7	160	11.8	208	16.3	225	18.8	201	22.6	187	24.1	187	20.0	160	14.8	142	9.3	109	3.2	101
Ulleungdo	1.6	72	2.4	100	5.6	149	10.4	195	14.9	207	19.2	203	22.8	192	23.6	183	20.2	142	15.6	131	10.8	93	3.6	71
Ulsan	2.0	110	4.3	137	7.9	164	13.5	220	17.9	222	21.4	203	25.4	200	26.0	198	21.7	160	16.2	150	10.3	121	4.6	109
Wando	3.4	103	4.8	133	8.5	164	13.2	205	17.0	218	20.2	194	24.2	183	25.9	196	22.7	163	16.6	158	10.6	114	5.5	97
Wonju	-2.7	86	0.8	126	5.2	167	12.9	237	17.0	247	22.1	216	25.3	168	25.0	166	19.6	155	11.8	137	4.9	97	-0.6	77
Yeongwol	-5.5	93	-1.1	138	4.8	184	11.3	237	16.6	253	21.1	243	23.5	177	24.2	167	19.1	164	12.8	146	5.3	105	-1.5	84
Yeosu	2.6	97	4.5	135	8.3	155	13.4	189	17.5	187	20.4	178	24.0	154	25.6	161	22.4	147	17.4	135	11.7	109	5.6	93

*TEMP(Temperature, ℃), TSI(Total solar irradiance, W/m^2), CPN(Chupungnyeong), DGY(Daegwallyeong), DH-R(Donghae-Radar)

respectively, and Yeosu showed 14% and 17% for Gwangju and Mokpo, respectively. The overall deviation of Cv(RMSE) ranged from minimum 4% to maximum 17%.

4. Energy demand analysis using typical meteorological data

4.1. Calculation method of building energy demand

Since ECO2 simulation cannot directly calculate the building energy demands using the extended meteorological data[11], this study uses ISO 13790: Monthly Calculation Method[12]. Only the heating energy demand is considered in the calculations. The calculation process of the heating energy demands is shown in Fig. 6. The heating energy demand in this calculation method is expressed by the following equation:

$$Q_{H,nd} = Q_{H,ht} - \eta_{H,gn} Q_{H,gn} \tag{15}$$

where

$Q_{H,nd}$ = *Heating energy demand (MJ)*

$Q_{H,ht}$ = *Total heat transfer in heating mode (MJ)*

$\eta_{H,gn}$ = *Effective gain factor in heating mode*

$Q_{H,gn}$ = *Total heat gain in heating mode (MJ)*

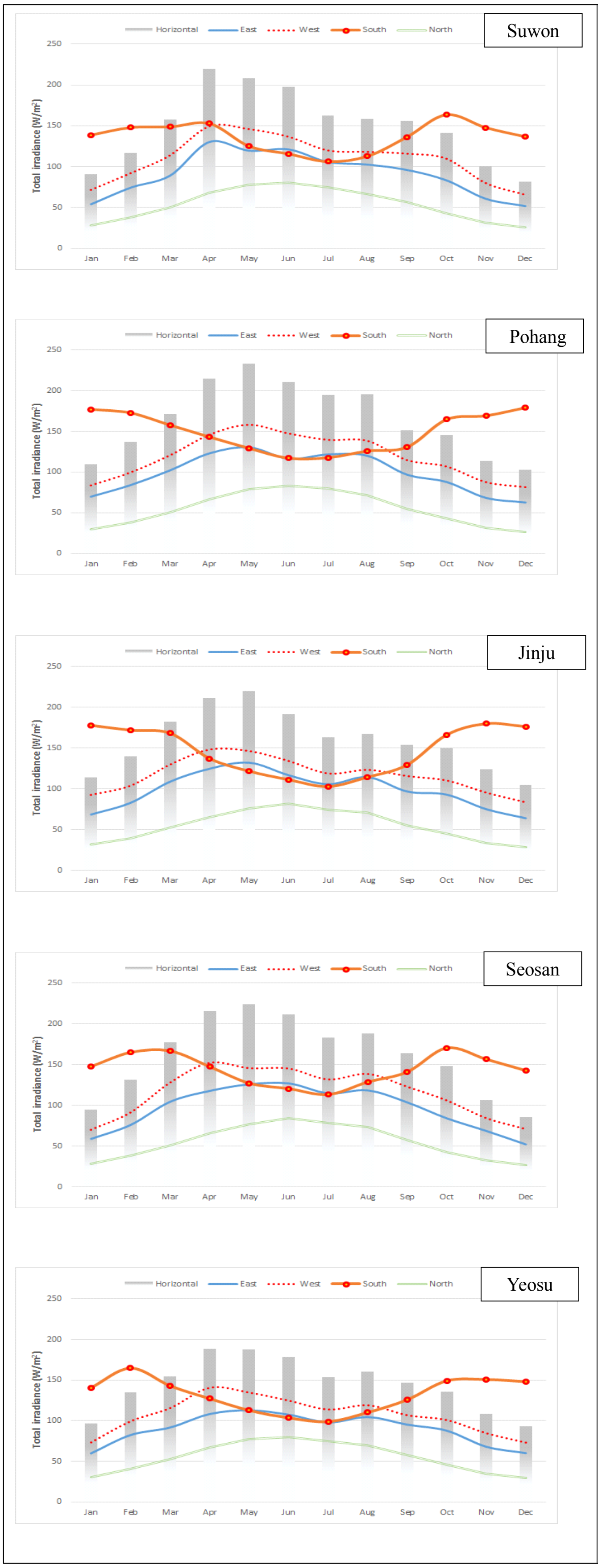


Fig. 4. Solar irradiance of additional regions in Korea

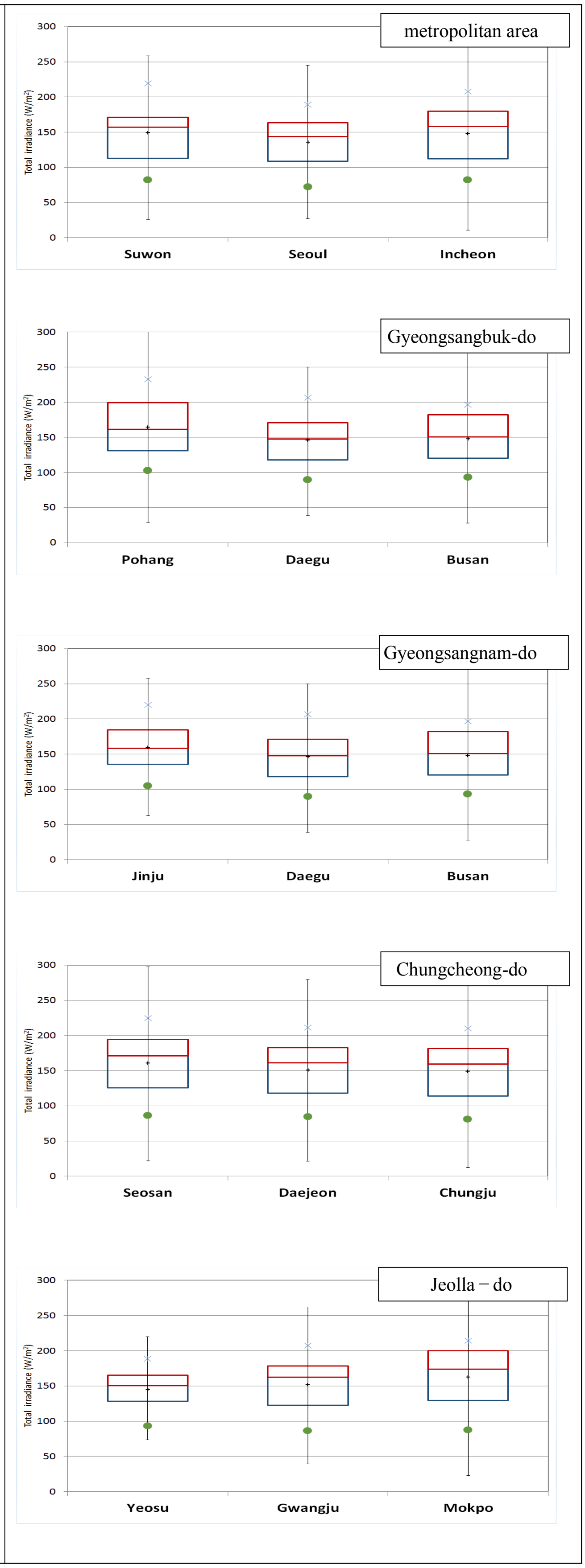


Fig. 5. Comparison of the irradiances of additional regions and the surrounding regions in each of 5 regions

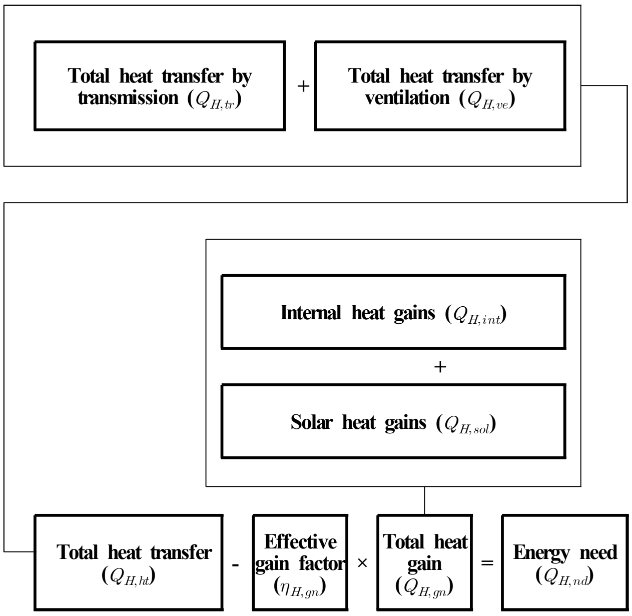


Fig. 6. Flow chart of ISO 13790 monthly calculation method in heating condition.

In the equation (15), the total heat transfer ($Q_{H,ht}$) in the heating mode refers to the heat transfer by transmission and ventilation, and the total heat gain ($Q_{H,gn}$) in the heating mode refers to the internal heat gains and solar heat gains. The effective gain factor ($\eta_{H,gn}$) is a coefficient indicating the degree to which the amount of heat obtained in the heating mode is utilized to reduce the amount of heat loss, and it is calculated by reflecting the heat-balance ratio and the heat capacity of structure.

The total heat transfer ($Q_{H,ht}$) and the total heat gain ($Q_{H,gn}$) in the heating mode are as written in equations (16) and (17), and the total heat transfer ($Q_{H,ht}$) is determined by the heating set-point temperature ($\theta_{int,set}$) and the monthly averaged outside temperature (θ_e)

$$Q_{H,ht} = Q_{H,tr} + Q_{H,ve} \tag{16}$$

$$Q_{H,gn} = Q_{H,int} + Q_{H,sol} \tag{17}$$

$$Q_{H,tr} = H_{tr}(\theta_{int,set} - \theta_e)t \tag{18}$$

$$Q_{H,ve} = H_{ve}(\theta_{int,set} - \theta_e)t \tag{19}$$

where

$Q_{H,tr}$ = *Heat transfer by transmission in heating mode (MJ)*

$Q_{H,ve}$ = *Heat transfer by ventilation in heating mode (MJ)*

H_{tr} = *Heat transfer coefficient by transmission (W/K)*

H_{ve} = *Heat transfer coefficient by ventilation (W/K)*

$\theta_{int,set}$ = *Set-point temperature (℃)*

t = *period of time (Mega seconds)*

The effective gain factor ($\eta_{H,gn}$) in the equation (15) for calculating the heating energy demand is calculated by the following equations (20) to (26).

$$\gamma_H = \frac{Q_{H,gn}}{Q_{H,ht}} \tag{20}$$

$$\text{if} \quad \gamma_H > 0 \text{ and } \gamma_H \neq 1 : \eta_{H,gn} = \frac{1-\gamma_H^{a_H}}{1-\gamma_H^{a_H+1}} \tag{21}$$

$$\text{if} \quad \gamma_H = 1 : \eta_{H,gn} = \frac{a_H}{a_H+1} \tag{22}$$

$$\text{if} \quad \gamma_H < 0 : \eta_{H,gn} = \frac{1}{\gamma_H} \tag{23}$$

$$a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}} \tag{24}$$

$$\tau = \frac{C_m/3,600}{H_{tr} + H_{ve}} \tag{25}$$

$$C_m = \sum(\kappa_j \times A_j) \tag{26}$$

where

γ_H : *Heat-balance Ratio in heating mode*

a_H : *Numerical parameter dependimg on the time constant(τ_H)*

$a_{H,0}$: *Reference numerical parameter*

τ : *Time constant of the building zone (h)*

$\tau_{H,0}$: *Reference time constant (h)*

C_m : *The sum of heat capacity of the building* (J/K)

κ_j : *The heat capacityof factor* (J/ (m^2K))

A_j : *Area of building factor j* (m^2)

The reference numerical parameter ($a_{H,0}$) and the reference time constant ($\tau_{H,0}$) in the equation (24) are presented in the table of ISO 13790. Each country uses its own values according to the situation, but if there are no available values, the values of Table. 2 are used [12].

Table 2. Values of numerical parameter, $a_{H,0}$ and reference time constant,$\tau_{H,0}$.

Method	$a_{H,0}$	$\tau_{H,0}$
Monthly calculation method	1.0	15
Seasonal calculation method	0.8	30
Values of $a_{H,0}$ and $\tau_{H,0}$may also be provided at national level.		

4.2. Reference model

A unit area plane of the reference model house has a specific area of 85㎡ (Fig. 7). The extended plane on 3Bay was selected as the plane configuration of the evaluation model, and the input conditions [4] for the calculation of the energy demand are shown in Table. 3.

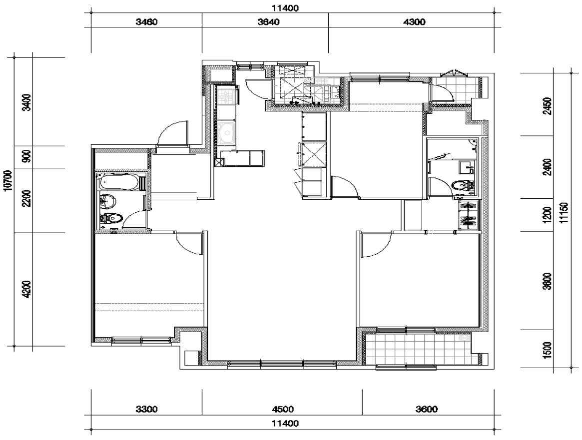


Fig. 7. Reference model for calculation

Table 3. Input data for reference model

Division	Sector	Parameters
General information	Building type	Apartment
	Direction	South
	Height	2.3 m
	Floor area	84.85㎡
	Window to wall area	22%
Internal condition	Heating set point	20℃
	Cooling set point	26℃
	Hours of use	24 hours
	Infiltration	1.0 ACH
	Occupancy	53 Wh/(m^2d)
	Equipment	52 Wh/(m^2d)
	Lighting	4 W/㎡
Surface information	Wall	0.210 W/(m^2K)
	Roof	0.150 W/(m^2K)
	Floor	0.180 W/(m^2K)
	Window	2.400 W/(m^2K)
	SHGC	0.774
	Door	2.700 W/(m^2K)

4.3. Energy demand analysis and application of the extended typical meteorological data

The annual heating energy demand per unit area calculated for the reference model is shown in Fig. 8. The annual heating energy demand per unit area of Suwon, Seoul, and Incheon located in the metropolitan area was 24.01 kWh/(m^2·a), 30.32 kWh/(m^2·a), 22.00 kWh/(m^2·a), respectively, while the Cv(RMSE) of Seoul and Incheon based on Suwon was 49% and 36%, respectively, and MBE showed the difference of 26% and −8%, respectively. In Gyeongsangbuk-do, the heating energy demand of Pohang, Daegu and Busan was 3.26 kWh/(m^2·a), 9.45 kWh/(m^2·a), 4.80 kWh/(m^2·a), and the Cv (RMSE) of Daegu and Busan based on Pohang was 344% and 84%, respectively, and the MBE was 190% and 47%. In Gyeongsangnam-do, the heating energy demand of Jinju, Daegu and Busan was 7.03 kWh/(m^2·a), 9.45 kWh/(m^2·a), 4.80 kWh/(m^2·a) and the Cv (RMSE) of Daegu and Busan based on Jinju was 61%, and 69%, and the MBE was 34% and -32%. In Chungcheong-do, the heating energy demand of Seosan, Daejeon and Cheongju was 16.43 kWh/(m^2·a), 19.13 kWh/(m^2·a), 13.93 kWh/(m^2·a), and the Cv (RMSE) of Daejeon and Cheongju based on Seosan was 38%, 37%, and the MBE was 16% and -15%. Finally, in Jeolla−do, the heating energy demand of Yeosu, Gwangju and Mokpo was 5.76 kWh/(m^2·a), 10.93 kWh/(m^2·a), 8.03 kWh/(m^2·a), respectively, and the Cv (RMSE) of Gwangju and Mokpo based on Yeosu was 196%, 130%, respectively, and the MBE showed a deviation of 90%, 39% respectively. The results are summarized in Table. 4.

As a result of calculation, the heating energy demand of the additional region and the surrounding regions showed a great difference. In addition, the statistical analysis showed a variation of 36%~344% Cv (RMSE) and -32%~190% MBE, which indicates that the heating energy calculation result significantly varies depending on the meteorological data of the corresponding region.

Table 4. Comparison of additional regions with the surrounding regions for heating energy demand and statistical analysis.

Region	City	*Heating energy demand	Cv(RMSE) (%)	MBE (%)
Metropolitan area	Suwon	24.01	-	-
	Seoul	30.32	49	26
	Incheon	22.00	36	-8
Gyeongsangbuk-do	Pohang	3.26	-	-
	Daegu	9.45	344	190
	Busan	4.80	84	47
GyeongSangNam-do	Jinju	7.03	-	-
	Daegu	9.45	61	34
	Busan	4.80	69	-32
Chungcheongn-do	Seosan	16.43	-	-
	Daejeon	19.13	38	16
	Cheongju	13.93	37	-15
Jeollanam-do	Yeosu	5.76	-	-
	Gwangju	10.93	196	90
	Mokpo	8.03	130	39

*Unit: kWh/(m^2·a,)

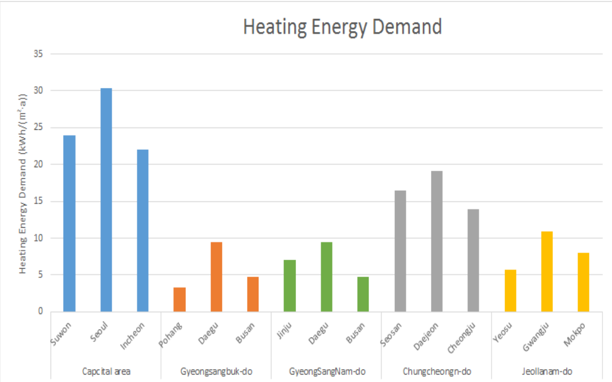


Fig. 8. Results of heating energy demand for each region

5. Conclusion

This study newly created the typical meteorological data of 33 regions in Korea using the meteorological data provided by IWEC. With these typical meteorological data, the heating energy demands of an additional region and the surrounding ECO2 regions for the five region groups were also analyzed. As a result of the analysis, the heating energy demand of the additional region and the surrounding ECO2 regions varied by 36%~344% in Cv (RMSE) and －32%~190% in MBE. This suggests that the ECO2 typical meteorological data has a limit to apply to any region far from the existing 13 major regions and the typical meteorological data of more regions are needed in order to evaluate more reliable building energy demands. However, since the typical meteorological data cannot be expanded indefinitely, further study should be carried out to identify valid territory when evaluating the surrounding region using the meteorological data of a representative region and to quantify the number of typical meteorological data needed in Korea.

Acknowledgements

“This work was conducted under framework of the research and development program of the Korea Institute of Energy Research(B7-9302-01) and (B6-2462)”

Reference

[1] Seo Dong Hyun, "Standard meteorological data of domestic and international meteorological data and status and utilization of standard building model" The Korean Society for Environmental Ecology Facility Journal 2015.07

[2] Kim, Ji-Yeon, "Overview and Status of Energy Efficiency Rating Certification System for Buildings," Korea Institute of Machinery and Materials Equipment Journal 2010.10

[3] (Chun, Jung-Gil, Evaluation of Building Energy Efficiency Rating of the Business Buildings : A Case Study, Conference Jounal of The Society of Air-Conditionong And Refrigerating Engineers of Korea, 2011.7

[4] Korea Energy Corporation, "Operational regulations on Energy Efficiency Rating for Buildings". 2013.9

[5] Hideki kikumoto, Study on the future weather data considering the global and localclimate change for building energy simulation, Jounal of Sustainable Cities and Society, 2014

[6] Lee, Sung Jin, Analysis and Extendability Review of Typical Weather Data for Building Energy Efficiency Rating System, Conference Jounal of The Korean Solar Energy Society, 2016.10

[7] U.S. DEPARTMENT OF ENERGY, M&V Guidelines: Measurement and Verification for Federal Energy Projects version 4.0, 2015

[8] ASHRAE, ASHRAE International Weatehr Files For Energy Calculations 2.0 (IWEC2), https://www.ashrae.org/, 2016

[9] ASHRAE,, IWEC2 User Manual and Final Report, 2011.10

[10] ASHRAE , ASHRAE Fundamental Chapter 14 Climate Design Information, ASHRAE Handbook, 2013

[11] Jeon, Jiwoon, A study on the energy-saving design for public office buildings using ECO2 program, Jungang Univ thesis, 2013.8