IJE TRANSACTIONS C: Aspects Vol. 26, No. 9, (September 2013) 955-962

International Journal of Engineering

Journal Homepage: www.ije.ir

Estimation and Prediction of Residential Building Energy Consumption in Rural Areas of Chongqing

M. U. Hossain[a,b,*], L. Meng[a,b], S. Farzana[a], A. L. Thengolose[a]

[a] *Faculty of Urban Construction and Environmental Engineering, Chongqing University, Chongqing, 400030, China*
[b] *The Key Laboratory of Eco-environments in Three Gorges Reservoir Region (Ministry of Education), Chongqing University, 400030, Chongqing, China*

PAPER INFO

Paper history:
Received 12 March 2013
Received in revised form 10 April 2013
Accepted 18 April 2013

Keywords:
Rural Area
Residential Energy
Simulation
Grey Model
Forecasting

A B S T R A C T

Energy simulation is a vital part of energy policy of a country, especially for a developing country like China where energy consumption is growing very rapidly. The present study has been conducted to simulate the total primary energy consumption in residential sector in rural areas in Chongqing by using macro and micro drivers including population size, number of households, persons per household, fuel types, end-use devices and their intensities. The study finds the energy intensity of end-use device in rural areas in Chongqing is 1166.15 kwh/household/year. About 11.02% energy consumes for lighting, 16.53% for space heating and cooling, 58.71% for cooking and water heating, and 13.74% for other end-use devices in the studied areas. The sharing of fuels are LPG 18.15%, coal 23.54%, firewood 21.13% and electricity 37.18% that are used as primary fuel. The study finds the total residential energy consumption is43.940X10^9 kWh/year in rural areas of Chongqing in 2012. The study has also conducted to forecast the energy consumption during 2000-2020 by using two Grey Model such as GM (1, 1) and DGM (2, 1) in Chongqing. The GM (1, 1) uses a first order differential equation to characterize an unknown system in which the irregular data of system can become regular sequences which it can identify the uncertainties of system and predict the variables of it. DGM (2, 1) model is a new grey model which is constructed by grey derivative and second-order grey derivative. The five years average growth rate of total energy consumption in Chongqing during 2011-2015 and 2016-2020 are 51.70% and 195.04% respectively comparing to 2010 by GM (1, 1) model, whereas 70.54% and 330.23% respectively by DGM (2, 1) model during the designated time period. The higher accuracy has been found in GM (1, 1) model than in DGM (2, 1) model.

doi: *10.5829/idosi.ije.2013.26.09c.03*

1. INTRODUCTION

Chongqing is an important growth center in West China, and the municipality directly under the Central Government for harmonized development of rural and urban areas. The total area is 82,400 km^2 with total population of 33 million. Aaround 51% of this population live in rural and 49% in urban areas [1]. Chongqing is an extremely hot and humid region, hence there has been increasing demand for air conditioning equipment as well as heating requirements [2]. Chow [3] discussed the energy consumption in Hong Kong for the period 1984–1997 with particular emphasis on the residential sector. Mohamed and Bodger [4] examined the influence of economic and demographic variables in New Zealand. Ceylan et al. [5] conducted an assessment of future energy, energy production and consumption in Turkey. Sengupta [6] conducted a long-term demand of commercial energy consumption and their long run supply by using regression models in India. Geem and Roper [7] suggested ANN model to estimate competently the energy demand in South Korea. Kaboudan [8] made a non-linear dynamic econometric forecasting model to predict the electricity consumption in Zimbabwe by using a 20 year data. An exponential prediction model developed by Tamimi and Kodah to predict the Jordan's energy consumption [9]. Yumurtaci and Asmaz [10] suggested an approach to calculate the future energy demand of Turkey. Michalik et al. [11] applied linguistic variables and fuzzy logic approach for the development of mathematical model to forecast the

*Corresponding Author Email: uzzal_esrm@yahoo.com (M. U. Hossain)

energy demand in the household area. Saab et al. [12] explored different univariate-modeling to predict monthly electric energy consumption in Lebanon. Akay and Atak [13] suggested Grey prediction with rolling mechanism (GPRM) to forecast the total and industrial electricity consumption in Turkey. Ediger and Tatlldil [14] used semi-statistical technique to formulate the prediction model to forecast the primary energy demand in Turkey. Aydinalp et al. [15] built up a neural network based energy consumption model for household sector in Canada.

Many studies has been carried out on energy simulation in induatrial and commercial sectors, but still exists a gap of residential energy consumption estimation in rural areas. The energy consumption in residential areas has been increasing rapidly with the economic development of the residents in China. For example, rural residents have significantly used HVAC systems and other home appliances. So, the present study has been conducted to simulate the rural residential energy consumption in Chongqing by using macro and micro drivers. A comparative study that has also been conducted to estimate the total energy consumption in Chongqing, and to predict the future energy demand and change of pattern in rural areas by using GM (1, 1) and DGM (2, 1) models. Specific features such as total energy consumption and total residential electricity trends from 2000 to 2009 have been used to forecast electricity consumption up to 2020.

2. MODELING METHODOLOGY

2.1. Energy Simulation in Rural Areas in Chongqing Residential sector contains very complex pattern of energy consumption associated with household living, such as water heating, cooking, space cooling and heating, lighting and use of other appliances. The energy consumption in different regions can be simulated by using Equation (1) [16]. In addition of space heating, the Equation (2) has been adopted to simulate the total energy consumption in rural areas in Chongqing. In this model, growth factors such as economic and population growth is not considered because it is very complex to include all drivers into one system, and numerous models still exist to include this drivers. The present study emphasizeson the present energy consumption simulation in rural residential sector, and prediction has been made based on previous 10 years statistical data.

$$E_{CR} = \sum_{m}^{OPTION} \frac{P_m}{F_m} \times \left[\left(\sum_j S_{j,m} \times UEC_{j,m} + E_m \sum_{i}^{OPTION} L_{i,m} \times Ca_{i,m} \times H_{i,m}\right) + \sum_{z}^{OPTION}\left(CW_{m,z} + LK_{m,z}\right)\right] \quad (1)$$

where:

m=Locale type (*urban, rural*),
P_m =population in locale m,
F_m =number of persons per household (*family*) in locale m,
E_m = electrification rate (%) in locale m,
j =type of appliance or end-use device,
$S_{j,m}$ = penetration of appliance or device j in percent appliance owned by household (*values in excess of 100% would indicate more than one device per household on average*),
UEC_j = energy intensity of appliance j in MJ or kWh/year,
i= type of lighting bulb (*incandescent, fluorescent*),
$L_{i,m}$= number of lighting bulb of type i per household in locale m,
$Ca_{i,m}$ = power of bulb of type i in locale m,
$H_{i,m}$ = hours of use of bulb of type i in locale m,
Z = fuel type
$CW_{m,z}$ = cooking and water heating energy use of fuel k per household per year in locale m in MJ/household/year, and
$LK_{m,z}$ = Lighting energy use of fuel Z in locale m in MJ/household/year.

In addition, for space heating in this region, the equation can be written as:

$$E_{CR} = \sum_{m}^{OPTION} \frac{P_m}{F_m} \times \left[\left(\sum_j S_{j,m} \times UEC_{j,m} + E_m \sum_{i}^{OPTION} L_{i,m} \times Ca_{i,m} \times H_{i,m}\right) + \sum_{z}^{OPTION}\left(CW_{m,z} + LK_{m,z} + SH_{m,z}\right)\right] \quad (2)$$

where:
$SH_{m,z}$ = Space heating and cooling energy use of fuel Z in locale m in MJ/household/year.

2.2. Forecasting Modeling In this study, grey models GM (1, 1) and DGM (2, 1) were adopted for forecasting the total energy consumption in Chongqing. The GM (1, 1) uses a first order differential equation to characterize an unknown system. At present, grey forecast has been more widely used because it has advantages of a small sample data, computing convenience and short time forecast of high accuracy [17]. Therefore, according to the grey theory, through the generating method, the irregular data of system can become regular sequences which can identify the uncertainties of system and predict its variables [18]. DGM (2, 1) model is a new grey model which is constructed by grey derivative and second-order grey derivative [19, 20].

2.2. 1. GM (1, 1) Model for Forecasting the Energy Consumption in Chongqing

Step 1: Assume $X^{(0)}$ as original discrete time variable

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \cdots\cdots, x^{(0)}(v), \cdots\cdots, x^{(0)}(n)\right\} \quad (3)$$

where $X^{(0)}$ (v) the time series data at time v, n must be equal to or be larger than 4.

Step 2: On the basis of the initial sequence $X^{(0)}$, a new sequence $X^{(1)}$ is set up through the accumulated generating operation in order to provide the middle message of building a model and to weaken the variation tendency, i.e.

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots\cdots, x^{(1)}(v), \cdots\cdots, x^{(1)}(n)\} \tag{4}$$

Where

$$x^{(1)}(k) = \sum_{v=1}^{k} x^{(0)}(v) \qquad k = 1, 2, \cdots\cdots, n \tag{5}$$

Step 3: The first-order differential equation of grey model GM(1, 1) then becomes:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b \tag{6}$$

and its difference equation is:

$$X^{(0)}(k) + aZ^{(1)}(k) = b \qquad k = 2, 3, \cdots\cdots, n \tag{7}$$

and from Equation (7), it is easy to get

$$\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \\ -Z^{(1)}(n) & 1 \end{bmatrix} \times \begin{bmatrix} a \\ b \end{bmatrix} \tag{8}$$

where a and b are the coefficients to be identified.

Let

$$Y_n = [x^{(0)}(2), x^{(0)}(3), \cdots\cdots, x^{(0)}(n)]^T \tag{9}$$

$$B = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \\ -Z^{(1)}(n) & 1 \end{bmatrix} \tag{10}$$

Also take

$$Z^{(1)}(k+1) = \frac{1}{2}\left(x^{(1)}(k) + x^{(1)}(k+1)\right) \qquad k = 1, 2, \cdots\cdots, (n-1) \tag{11}$$

and

$$A = [a, b]^T \tag{12}$$

where Yn and B are the constant vector and the accumulated matrix respectively. $Z^{(1)}$ (k +1) is the (k+1)[th] background value. Applying ordinary least-square method to Equation (8) on the basis of Equations (9) – (12), coefficient A becomes

$$A = \left(B^T B\right)^{-1} B^T Y_n \tag{13}$$

Step 4: Substituting A in Equation (7) with Equation (13), the approximate equation becomes:

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - b/a\right) \times e^{-ak} + b/a \tag{14}$$

where $\hat{x}^{(1)}(k+1)$ is the predicted value of $x^{(1)}$ (k +1) at time (k +1). After the completion of an inverse-accumulated generating operation on Equation (14), $\hat{x}^{(1)}(k+1)$, the predicted value of $x^{(0)}$ (k +1) at time (k +1) becomes available and therefore:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \tag{15}$$

where $k = 0, 1, 2, 3, \cdots\cdots$

Equation (15) is the total electricity consumption for GM (1, 1) of mathematical expressions. K is one time variable.

Step 5: Mean relative percentage error (MRPE), which measures the percent of prediction accuracy can be found by the following equation:

$$MRPE = \frac{1}{n}\sum_{k=1}^{n}\left[\left|x^{(0)}(k) - X^{(0)}(k)\right| \Big/ x^{(0)}(k)\right] \tag{16}$$

2. 2. 2. The DGM (2, 1) Model The DGM (2, 1) model [21, 22] is a single sequence second-order linear dynamic model and is fitted by differential equations. *Assume an original series to be $X^{(0)}$,*

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots\cdots, x^{(0)}(n)\} \tag{17}$$

A new sequence $X^{(1)}$ is generated by the accumulated generating operation (AGO).

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots\cdots, x^{(1)}(n)\} \tag{18}$$

Where

$$x^{(1)}(k) = \sum_{s=1}^{k} x^{(0)}(s) \quad (k = 1, 2, \cdots\cdots, n) \tag{19}$$

setting up a second-order differential equation:

$$\frac{d^2 X^{(1)}}{dt^2} + a\frac{dX^{(1)}}{dt} = u \tag{20}$$

where

$$\hat{a} = [a, u]^T = \left(B^T B\right)^{-1} B^T Y \tag{21}$$

$$Y = \begin{bmatrix} \left(x^{(0)}(2) - x^{(0)}(1)\right) \\ \left(x^{(0)}(3) - x^{(0)}(2)\right) \\ \vdots \\ \left(x^{(0)}(n) - x^{(0)}(n-1)\right) \end{bmatrix} \tag{22}$$

$$B = \begin{bmatrix} -x^{(0)}(2) & 1 \\ -x^{(0)}(3) & 1 \\ \vdots & \\ -x^{(0)}(n) & 1 \end{bmatrix} \tag{23}$$

According to Equation (20), we have:

$$\hat{x}^{(1)}(k+1)=\left(\frac{u}{a^2}-\frac{x^{(0)}(1)}{a}\right)e^{-ak}+\frac{u}{a}(k+1)+\left(x^{(0)}(1)-\frac{u}{a}\right)\left(\frac{1+a}{a}\right) \quad (24)$$

The prediction values of original sequence can be obtained by applying inverse AGO to $x^{(1)}$. Namely,

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k)\,(k=0,1,2,..,n) \quad (25)$$

$$=\left(\frac{b}{a^2}-\frac{x^{(0)}(1)}{a}\right)\left(1-e^{a}\right)e^{-ak}+\frac{b}{a} \quad (26)$$

3. RESULTS AND DISCUSSION

3.1. Rural Residential Energy Simulation in Chongqing

3. 1. 1. Hypothesis of the Drivers It is extremely complex to simulate the actual residential energy in rural areas. The study hereby, simulates the total primary energy consumption in residential sector in rural areas by using macro and micro drivers. Along with population size, main drivers of energy and demand in rural residential areas in Chongqing are number of households, persons per household, fuel types, end-use devices and their intensities. According to field survey, energy intensity of end-use device in rural areas in Chongqing is 1166.15 kwh/household/Year. The end-use drivers of the residential sector in Chongqing rural areas are shown in Table 1.

3.1.2. End-use Activity The study reviews the cumulative energy intensity on the main residential energy end use sectors (see Table 2). According to the Statistical Yearbook of Chongqing, total population in rural area is 33.0345×10^{6}, average number of people per household is 2.87 and electrification rate is 100%. According to the Chongqing Residential Building Energy Code, the space heating is restricted in Chongqing. However, people use various types of heating devices for space heating in winter due to their economic development. The household uses coal and electricity for space heating in rural areas. The total energy required for space heating and cooling including air-conditioning is 390 kWh/household/year, whereas cooking and water heating intensity in rural area is 1385 kWh/household/year. The annual lighting energy intensity is 260 kWh/household/year. For lighting purpose, most of the household uses incandescent lamps, but some of them use fluorescent and CFL as well. There are 9.38 bulbs per household. The bulbsare 40 W and operate 4~5 hours per day. For energy purposes, generally four types of fuel have been used by the residents such as LPG, coal, electricity and fire wood. The sharing of fuel consumption is shown in Figure 1. The sharing of residential energy consumption by sectors in Chongqing rural area is shown in Figure 2. Finally, the study simulates the total energy consumption in residential sector in rural areas in Chongqing by Stock turn-over Modeling. By applying Equation (2), the study has found that total residential energy consumption is 43.940×10^{9} kWh/year in rural areas of Chongqing in 2012.

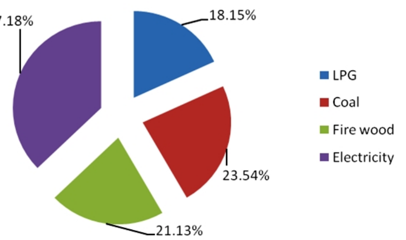

Figure 1. Residential primary energy consumption by fuel in Chongqing rural areas

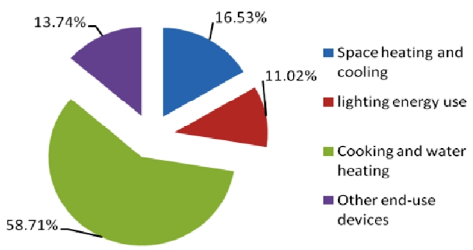

Figure 2. Residential energy consumption by end-use in Chongqing rural areas

TABLE 2. End-use intensities in Chongqing rural areas

Category	End-use intensity/UEC	
	Unit	End use quantity
Space heating and cooling	kWh/household/year	390
Lighting energy use	kWh/household/year	260
Cooking and water heating	kWh/household/year	1385
Other end-use devices	kWh/household/year	323.93

TABLE 1. End-use structure of the residential sector in Chongqing rural areas

End-use	Space heating	Air conditioning	Lighting	Cooking and water heating	Appliances
Technologies	Electric heater	Ordinary	Incandescent	Micro woven	Washing machine
	Stove	Efficient	Florescent	Electric water heater	TV
	Coal stove	Highly efficient	CFL	Rice cooker	Refrigerator
					Computer

TABLE 3. Model values and prediction error of total energy consumption (10^4 tce) in Chongqing

Year	Actual value	GM (1, 1) Model		DGM (2, 1) Model	
		Model value	Relative error (%)	Model value	Relative error (%)
2000	2330.82	2330.82	0	2330.82	0
2001	2463.68	2197.92	10.79	2568.6	-4.26
2002	2563.05	2510.69	2.04	2771.5	-8.13
2003	2737.9	2867.94	-4.75	3020.06	-10.31
2004	3168.41	3276.04	-3.40	3324.58	-4.93
2005	3881.52	3742.2	3.59	3697.63	4.74
2006	4234.61	4274.69	-0.95	4154.64	1.89
2007	4782.36	4882.96	-2.10	4714.52	1.42
2008	5556.78	5577.78	-0.38	5400.4	2.81
2009	6567.6	6371.46	2.99	6240.66	4.98

TABLE 4. Model values and prediction error of total residential electricity consumption (10^8 kWh) in Chongqing

Year	Actual data	GM (1, 1) Model		DGM (2, 1) Model	
		Model value	Relative error (%)	Model value	Relative error (%)
2000	47.91	47.91	0	47.91	0%
2001	51.02	44.91	11.98	49.81	2.37
2002	53.12	49.14	7.49	51.47	3.11
2003	48.44	53.76	-10.98	53.55	-10.55
2004	53.56	58.83	-9.84	56.14	-4.82
2005	60.9	64.37	-5.70	59.37	2.51
2006	76.47	70.43	7.90	63.4	17.09
2007	74.99	77.06	-2.76	68.43	8.75
2008	84.99	84.32	0.79	74.7	12.11
2009	94.41	92.26	2.28	82.53	12.58

3. 2. Forecasting Total Energy Consumption The total energy consumption data from 2000 to 2009 is employed to set up the two grey prediction models, namely GM (1, 1) and DGM (2, 1) to compare the forecasting trends, growth rate and the accuracy of prediction of the two models. The actual and forecasted values are shown in Table 3.

Table 3 demonstrates that GM (1, 1) model has smaller relative error as compared to DGM (2, 1). This means that the accuracy rate is higher in GM (1, 1) than in DGM (2, 1) model. The comparison of forecasted values with actual values of total energy consumption from 2000 to 2020 by GM (1, 1) and DGM (2, 1) model is shown in Figure 3. The fast growing trend has been found in DGM (2, 1) model by comparing in GM (1, 1) model. For accuracy, the GM (1, 1) model is more perfect for forecasting, but for fast growing forecasting, DGM (2, 1) model is more perfect that GM (1, 1) model.

3.3. Forecasting Total Residential Electricity Consumption The total residential electricity consumption data from 2000 to 2009 in Chongqing is used to set up the two grey prediction models GM (1, 1) and DGM (2, 1) to compare the forecasting trends, consumption growth rate and the accuracy of prediction of the two models. The actual and forecasted values are shown in Table 4. The GM (1, 1) model shows smaller relative error as compared to DGM (2, 1) model which shows that the accuracy rate is higher in GM (1, 1) than in DGM (2, 1) model. The comparison of forecasted values of total energy consumption from 2000 to 2020 by GM (1, 1) and DGM (2, 1) model is shown in Figure 4. The GM (1, 1) model shows the constant growth rate of total residential electricity consumption, whereas the DGM (2, 1) shows a lower growth rate of consumption but the tendency was high with time consistency.

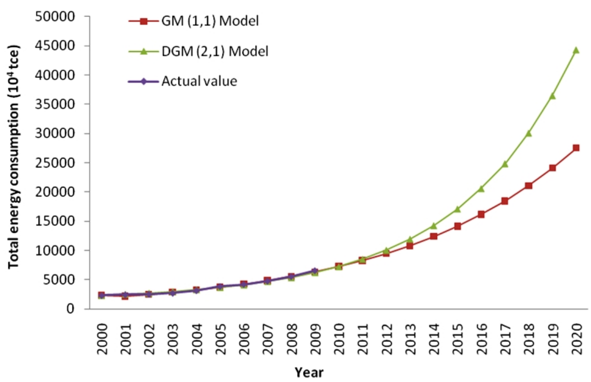

Figure 3. Total energy consumption forecasting in Chongqing by GM (1, 1) and DGM (2, 1) model

TABLE 5. Summary of the MRPE and growth rate in GM (1, 1) and DGM (2, 1) Model

Category	GM (1, 1) Model			DGM (2, 1) Model		
	MRPE (%)	5 years average growth rate than in 2010		MRPE (%)	5 years average growth rate than in 2010	
		2011-2015	2016-2020		2011-2015	2016-2020
Total energy consumption	3.10	51.70%	195.04%	4.35	70.54%	330.23%
Total residential electricity consumption	5.97	32.06%	107.11%	7.39	55.32%	274.95%

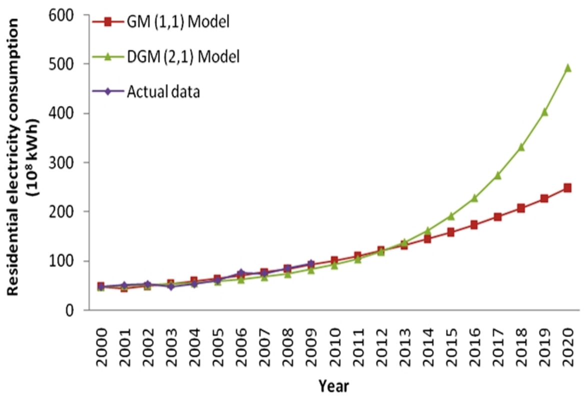

Figure 4. Residential electricity consumption forecasting in Chongqing by using GM (1, 1) and DGM (2, 1) Model

3.4. Comparison of MRPE and Prediction of Consumption by Forecasting Model

The mean relative percentage error (MRPE) and prediction of total energy consumption and residential electricity consumption of Chongqing is shown in Table 5. The MRPE of total energy consumption from 2000 to 2009 are 3.10 and 4.35%, respectively for GM (1, 1) and DGM (2, 1) models. Similarly, the MRPE of total residential electricity consumption is 5.97% for GM (1, 1) model, whereas 7.39% for DGM (2, 1) during the period of 2000-2009.

The five years average growth rate of total energy consumption in Chongqing during 2011-2015 and 2016-2020 are 51.70 and 195.04% of the total energy consumption in 2010 GM (1, 1) model, respectively, whereas it is 70.54% and 330.23% by DGM (2, 1) model during the designated time period. Similarly, the five years average growth rate of total residential electricity consumption in Chongqing during 2011-2015 and 2016-2020 is 32.06% and 107.11% of the consumption in 2010 by GM (1, 1) model, respectively, while it is 55.32% and 274.95% respectively by DGM (2, 1) model for the same time period.

4. CONCLUSION

Chongqing is the only municipality of west China and is considered as a development hub of west China, where energy consumption and demand are increasing rapidly with the development of all sectors especially in residential sector. The study simulates the rural residential energy consumption in Chongqing with the implication of various energy drivers and end-use appliances. The study also forecasts and compares the energy consumption during 2000-2020 by using two Grey Models, namely GM (1, 1) and DGM (2, 1), and their effectiveness. The results show that the total energy and electricity consumption in residential areas of Chongqing has been increasing rapidly. The results also show that the accuracy of GM (1, 1) model is higher than DGM (2, 1) model, because the mean relative percentage error (MRPE) is higher in all the measured sectors in DGM (2, 1) model as compared with GM (1, 1) model. Inversely, for fast growing forecasting, DGM (2, 1) model is more perfect than GM (1, 1) because the predicted values have been increasing rapidly with time consistency in DGM (2, 1) model as compared to GM (1, 1).

5. ACKNOWLEDGEMENT

The authors would like to appreciate the support from China's NSFC Project (No. 51108473) and National Key R&D Project of China's Twelfth Five-year Plan (No. 2013BAJ11B05).

6. REFERENCES

1. Sheng, Z., "Towards china's urban-rural integration: Issues and options", ***International Journal of China Studies***, Vol. 2, No. 2, (2011), 345-367.
2. Dong, S., "Energy demand projections based on an uncertain dynamic system modeling approach", ***Energy sources***, Vol. 22, No. 5, (2000), 443-451.
3. Chow, L. C.-h., "A study of sectoral energy consumption in hong kong (1984–97) with special emphasis on the household sector", ***Energy Policy***, Vol. 29, No. 13, (2001), 1099-1110.
4. Mohamed, Z. and Bodger, P., "Forecasting electricity consumption in new zealand using economic and demographic variables", ***Energy***, Vol. 30, No. 10, (2005), 1833-1843.
5. Ceylan, H., OZTURK, H. K., Hepbasli, A. and Utlu, Z., "Estimating energy and exergy production and consumption values using three different genetic algorithm approaches. Part 2:

Application and scenarios", ***Energy Sources***, Vol. 27, No. 7, (2005), 629-639.

6. Sengupta, R., *Energy modelling for india*. 1993 Govt. of India: New Delhi: Planning Commission, .
7. Geem, Z. W. and Roper, W. E., "Energy demand estimation of south korea using artificial neural network", ***Energy policy***, Vol. 37, No. 10, (2009), 4049-4054.
8. Kaboudan, M. A., "An econometric model for zimbabwe's future electricity consumption", ***Energy***, Vol. 14, No. 2, (1989), 75-85.
9. Tamimi, A. and Kodah, Z., "Retracted: Modeling of energy consumption and projection in jordan", ***Energy Conversion and Management***, Vol. 34, No. 5, (1993), 427-432.
10. Yumurtaci, Z. and Asmaz, E., "Electric energy demand of turkey for the year 2050", ***Energy Sources***, Vol. 26, No. 12, (2004), 1157-1164.
11. Michalik, G., Khan, M., Bonwick, W. and Mielczarski, W., "Structural modelling of energy demand in the residential sector: 1. Development of structural models", ***Energy***, Vol. 22, No. 10, (1997), 937-947.
12. Saab, S., Badr, E. and Nasr, G., "Univariate modeling and forecasting of energy consumption: The case of electricity in lebanon", ***Energy***, Vol. 26, No. 1, (2001), 1-14.
13. Akay, D. and Atak, M., "Grey prediction with rolling mechanism for electricity demand forecasting of turkey", ***Energy***, Vol. 32, No. 9, (2007), 1670-1675.
14. Ediger, V. Ş. and Tatlıdil, H., "Forecasting the primary energy demand in turkey and analysis of cyclic patterns", ***Energy Conversion and Management***, Vol. 43, No. 4, (2002), 473-487.
15. Aydinalp, M., Ismet Ugursal, V. and Fung, A. S., "Modeling of the appliance, lighting, and space-cooling energy consumptions in the residential sector using neural networks", ***Applied Energy***, Vol. 71, No. 2, (2002), 87-110.
16. Zhou, N., "Current status and future scenarios of residential building energy consumption in china", (2010).
17. Talebnejad, A. and Nadaf, A., "The use of grey system theory in predicting the road traffic accident in fars province in iran", ***Australian Journal of Business and Management Research Vol***, Vol. 1, No. 9, (2011), 18-23.
18. Mao, M. and Chirwa, E., "Application of grey model gm (1, 1) to vehicle fatality risk estimation", ***Technological Forecasting and Social Change***, Vol. 73, No. 5, (2006), 588-605.
19. Liu, S., Forrest, J. Y. L. and Lin, Y., "Grey systems: Theory and applications", Springer, Vol. 68, (2010).
20. Xie, N.-m. and Liu, S.-f., "Discrete gm (1, 1) and mechanism of grey forecasting model", ***Systems Engineering-theory & Practice***, Vol. 1, (2005), 014.
21. Shao, Y. and Su, H.-j., "On approximating grey model dgm (2, 1)", ***AASRI Procedia***, Vol. 1, (2012), 8-13.
22. Zhu, X., "Application of composite grey bp neural network forecasting model to motor vehicle fatality risk", in Computer Modeling and Simulation, 2010. ICCMS'10. Second International Conference on, IEEE. Vol. 2, (2010), 236-240.

Estimation and Prediction of Residential Building Energy Consumption in Rural Areas of Chongqing

M. U. Hossain[a,b], L. Meng[a,b], S. Farzana[a], A. L. Thengolose[a]

[a] Faculty of Urban Construction and Environmental Engineering, Chongqing University, Chongqing, 400030, China
[b] The Key Laboratory of Eco-environments in Three Gorges Reservoir Region (Ministry of Education), Chongqing University, 400030, Chongqing, China

PAPER INFO

Paper history:
Received 12 March 2013
Received in revised form 10 April 2013
Accepted 18 April 2013

Keywords:
Rural Area
Residential Energy
Simulation
Grey Model
Forecasting

چکیده

شبیه سازی انرژی بخش مهمی از سیاست انرژی کشور است، به ویژه برای یک کشور در حال توسعه مانند چین که مصرف انرژی با سرعت بسیار در حال رشد است. مطالعه حاضر به منظور شبیه سازی کل مصرف انرژی اولیه در بخش مسکونی در مناطق روستایی چونگ کینگ با استفاده از عوامل موثر کلان و خرد از جمله جمعیت، تعداد خانوار، افراد به ازای هر خانوار، نوع سوخت، استفاده از مصرف‌کننده‌های نهایی و شدت آنها انجام شده است. بر اساس این مطالعه، شدت انرژی مصرف‌کننده‌های نهایی در مناطق روستایی در چونگ کینگ ۱۱٦٦.۱۵ کیلووات ساعت در سال به ازای هر خانوار بوده است. از این مقدار در حدود ۱۱.۰۲٪ انرژی برای روشنایی، ۱٦.۵۳٪ برای گرم کردن و خنک کردن فضا، ۵۸.۷۱٪ برای پخت و پز و گرم کردن آب، و ۱۳.۷٤٪ برای دیگر مصرف‌کننده‌های نهایی در مناطق مورد مطالعه به کار رفته است. سهم انواع سوخت به عنوان سوخت اولیه از این قرار بوده است:LPG ۱۸.۱۵٪، زغال سنگ ۲۳.۵٤٪، هیزم ۲۱.۱۳٪ و برق ۳۷.۱۸٪ . بر این اساس کل مصرف انرژی مسکونی در سال ۲۰۱۲ در مناطق روستایی چونگ کینگ ٤۳/۹٤ تراوات-ساعت است. این مطالعه همچنین مصرف انرژی در چونگ کینگ را در فاصله سال‌های ۲۰۰۰-۲۰۲۰ را با استفاده از دو مدل خاکستری GM(۱،۱) و DGM(۲،۱) در پیش بینی کرده است. GM (۱،۱) می‌تواند با استفاده از یک معادله دیفرانسیل مرتبه اول یک سیستم ناشناخته که در آن داده های نامنظم سیستم به توالی های منظم تبدیل شده و عدم قطعیت سیستم را شناسایی و پیش بینی کند، تبدیل کند. DGM (۲،۱) مدل مدل جدید خاکستری است که توسط مشتق خاکستری و مشتق مرتبه دوم خاکستری ساخته شده است. میانگین پنج سال نرخ رشد مصرف کل انرژی در چونگ کینگ در طی سال‌های ۲۰۱۱-۲۰۱۵ و ۲۰۱٦-۲۰۲۰ توسط مدل GM (۱،۱)به ترتیب۵۱.۷۰٪ و ۱۹۵.۰٤ درصد نسبت به سال ۲۰۱۰ به دست آمده است، در حالی که DGM (۲ ، ۱) این ارقام را ۷۰.۵٤٪ و ۳۳۰.۲۳٪ پیش بینی می‌کند. دقت مدل GM (۱،۱) بالاتر از مدل DGM (۲،۱) است.

doi: *10.5829/idosi.ije.2013.26.09c.03*