Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 14	No. 1	pp. 33-40	2015

Original Research Paper

Scenario Analysis of New Buildings' Energy Conservation and Emission Reduction in Chongqing China (2016-2035)

Liu Huabing*, Ren Hong*, Cai Weiguang*† and Qin Beibei**
*School of Construction Management and Real Estate, Chongqing University, Chongqing 400045, P. R. China
**School of Construction Management and Engineering, University of Reading, Reading, RG6 6AB, UK
†Corresponding Author: Cai Weiguang

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 14-1-2015
Accepted: 12-2-2015

Key Words:
Building energy conservation
Green buildings
Emission reduction
Energy conservation potential

ABSTRACT

This paper puts the Twelfth Five-year (2011-2015) Plan as baseline scenario, and sets up optimism scenario and pessimistic scenario. Under the above scenarios, the paper explores the potential of energy conservation and emission reduction of new green buildings and non-green buildings in Chongqing. The results show great potential for energy conservation of new buildings in Chongqing. In optimism scenario, with reasonable policy and market intensify, CO_2 reduced by energy saving will be equal to that produced by 47% new population in urbanization in Chongqing. New green residential building is the key to promote building energy conservation. As the improvement of energy efficiency standards, new non-green residential buildings should be an important issue in long term.

INTRODUCTION

In the world, buildings consume 40% of total energy consumption, which contributes to almost 1/3 greenhouse gas (GHG) at the same time. However, building area can provide largest GHG emission potential and 30%-80% energy saving, both in developing countries and developed countries (UNEP 2009).

With rapid urbanization and huge population, China has the largest construction market. Up to 2000 million m^2 buildings are built every year, and, more important, this trend will not decline in coming years. Without changing development model, Chinese building energy consumption will account 25% of the world's total current energy consumption (Jiang 2011). Following China's continuous development of industrialization and urbanization, the environment and resources have been challenged by the increasing energy demand (Cai et al. 2014). By promoting energy saving in new buildings and new environmental industries, a new economic growth area could be developed. Besides, with improved energy efficiency, building users can enjoy more comfortable, healthy environment, as well as sustainable energy supply and environment.

From 1986, three national new building energy saving standards have been developed, which divided Chinese building energy saving into three phases. In the first phase (1986-1995), when new residential buildings were designed, energy consumption should decrease 30% than that the standard in 1980/1981. The second phase started from 1996, in which new residential buildings should be designed to consume 30% less energy than that required in the first phase. From 2005, new standard required that the new residential buildings energy consumption should decrease another 30% of that in the second phase. In 2012, Beijing issued its local new building standard, which required all new residential buildings should reduce 30% energy consumption of that in the third phase, which is the highest energy saving goal in China. However, Chongqing has not fully met the requirements in the third phase, especially in counties, some of which are still in the second phase (Zhang 2013).

To promote the new energy saving standard in Chongqing is urgent. Therefore, in order to provide scientific basis for work arrangement in Chongqing, it is essential to analyse energy-saving potential of new buildings in medium and long-term.

METHODOLOGY

Energy conservation potential analysis: According to the 12th Five-year Plan of Energy Saving in Chongqing in terms of new buildings, Chongqing will focus on improving relevant standards and promoting green buildings (Chongqing Municipal Construction of Urban-Rural Development 2011). This paper classifies new buildings to green residential buildings, green commercial buildings, non-green residential buildings and non-green commercial buildings. Based on the current policies, energy saving potential, energy saved by implementing new standards, is estimated every five years of every type of new buildings. This estimation method is as follows.

$$E = \sum_{i=1}^{4} E_i = \sum_{i=1}^{4}\sum_{j=1}^{5} E_{ij} \quad (i=1,2,3,4:j=1,2,3,4,5) \qquad ...(1)$$

$$E_{ij} = EI_{ij} \times s_{ij} \times \xi_{ij} \times \delta_{ij} \quad (i=1,2,3,4:j=1,2,3,4,5) \qquad ...(2)$$

E is the total energy saving potential, while E_1 is energy saving potential of new green residential buildings, and E_2 is energy saving potential of new green commercial buildings, E_3 is energy saving potential of new non-green residential buildings, and E_4 is energy saving potential of new non-green commercial buildings. Besides, E_{ij} is the energy saving potential of the i^{th} type of buildings in j^{th} year. What is more, EI_{ij} is the energy intensity per square meter of the i^{th} type of buildings. ξ_{ij} is energy efficiency ratio, which is the ratio of energy intensification improved by new standards implemented and that before new standards implementation. s_{ij} is the square meters of energy saving. δ_{ij} is executable rate of new energy saving standards.

Scenario analysis: Scenario analysis is the method constructing reasonable scenarios, which makes reasonable assumptions of changing influencing factors in different conditions to predict possible situations or consequences in the future. According to possible changes, scenario analysis can present different occurrences and outcomes, which is the main difference between scenario analysis and traditional prediction. The decision-making model can help policy maker to avoid unreasonable estimate of possible changes and outcomes.

This paper constructs three scenarios with different reconstructed area and fractional energy saving, baseline scenario (S_1), pessimistic scenario (S_2) and optimistic scenario (S_3). In baseline scenario (S_1), the strength of policies is the same as that in twelfth five-year plan. With raising energy-saving awareness and gradually improving market mechanism, energy saving rate and executable rate increase. In pessimistic scenario (S_2), the strength of policies and market demand has weakened, leading to reducing energy saving rate and executable rate. In optimistic scenario (S_3), the strength of policies and market demand has increased, leading to more market demand, higher energy saving rate and executable rate than that in S_1.

ENERGY CONSERVATION POTENTIAL

To avoid the influence of conversion ratio in long time span of prediction, this paper adopts equivalent value to calculate the energy conservation potential. The conversion ratio of electricity and standard coal is 0.1229kgce/kwh. According to the law of urbanization development and current situation in China, urbanization will be nearing to completion in 2035. Building energy intensity in China will be the same as or near to that in developed countries. Current green building rate in America is used as the upper limit of that in Chongqing in 2035 to calculate the future energy consumption of new buildings each year in Chongqing, combined with the current green buildings rate in Chongqing.

During the 10th Five-year, Chongqing adopted the standard of 50% energy saving ratio. This paper choses the existing building in 2005 as the reference building, whose energy intensity works as the reference energy intensity. According to the Statistic Yearbook of 2006 of Chongqing, urban residents, living in 28.066 million square meters, consumed 1.5983 million tons of standard coal. Thus, the residential buildings' energy intensify in Chongqing in 2005 was 46.36kwh/m^2·a (Dong et al. 2008). According to the survey data of commercial buildings in Chongqing, the commercial buildings' energy intensification was 142kwh/m^2·a in 2005 (Dong et al. 2008).

Sum of New Buildings

Sum of new residential buildings: According to Chongqing Statistic Yearbook (2006-2013), the annual increase rate is 0.7%. There are 29.45 million people living in Chongqing in 2012. And, this number would be 34.58 million in 2035. The annual urbanization increase ratio is 1.5%. Based on the law of urbanization, the annual increase rate will be 1.5% from 2013 to 2020, while it would be 1% from 2021 to 2035. Chongqing's urbanization ratio could be 84% in 2035. Based on historical data in Chongqing and developed countries, the per-capita living space will increase 1% every year, which means the living space per capita will be 40.44 m^2.

Total urban population can be calculated as follows,

$$TUP_i = TP_i \times R_i \quad (i=2016, 2017……2035) \qquad ...(3)$$

TUP is the total urban population in Chongqing, while TP is the total population in Chongqing and R is urbanization ratio.

Urban living space can be calculated as follows,

$$URFA_i = URFAP_i \times TUP_i \quad (i=2016, 2017…2035) \qquad ...(4)$$

URFA is the sum of urban residential floor area, while URFAP is urban residential floor area per capita.

New urban residential floor area in Chongqing can be estimated as follows,

$$NURFA_i = URFA_i - URFA_{i-1} \quad (i=2016, 2017.….2035) \qquad ...(5)$$

NURFA is the sum of new urban residential floor area.

There are 21 districts, 9 of which are in the main urban area, and 17 counties in Chongqing. According to the statistic of real estate development in Chongqing, 47% of new buildings are in main urban area, 29% in other districts and

24% in counties. Therefore, sum of new residential buildings in different areas can be calculated as follows,

$$NURFA_1 = NURFA_i \times P_j \quad (i, j=1, 2, 3) \qquad ...(6)$$

$NURFA_1$ is sum of new residential buildings in 9 districts in main urban areas, $NURFA_2$ is sum of new residential buildings in 12 districts outside the main urban area, $NURFA_3$ is sum of new residential buildings in 17 counties. P_i is the proportion of new residential buildings in *i* area. Sum of new residential buildings in different years in different areas are listed in Table 1.

Sum of new commercial buildings: According to Chongqing's Statistic Yearbook (2007-2012), commercial buildings account for 20% of the total buildings, while residential buildings for 80%. Therefore, the new commercial buildings are 1/4 of new residential buildings in Chongqing. New commercial buildings in different areas are estimated based on Table 1.

Sum of new green buildings: According to the 12th Five-year Plan on energy efficiency, the proportion of green buildings in new buildings should not be lower than 20% by 2015 (Department of Building Energy Efficiency and Technology 2012). To promote green buildings, the Ministry of Housing and Urban-Rural Construction issued the Guidance to Promote Green Building in China, which set the goal of 30% (Ministry of Finance, Ministry of Housing and Urban-Rural Development 2011). At present, this proportion in America is 47%.

Thus, this paper supposes that the new green residential buildings can account for 30% of new residential buildings during 13th Five-year. This proportion will increase 5% every five year, which means it will be 45% in 16th Five-year. Sum of new green residential buildings is calculated based on data in Table 1. The proportion of new green commercial buildings in new commercial buildings is the same as that of residential buildings.

Sum of new non-green buildings: The number of new non-green buildings, both residential and commercial, is calculated by subtracting new green buildings from total new buildings.

Energy Conservation Potential of New Green Buildings

Energy saving potential of new green residential buildings: The sum of new green residential buildings, in above, is calculated in the baseline scenario (S_1). Suppose the new green residential buildings in pessimistic scenario (S_2) is 80% of that in S_1, while this number in optimistic scenario (S_3) is 120% (Ren 2014). Compared to reference building, the average energy saving ratio of green buildings is 58 % (Department of Building Energy Efficiency and Technology 2012). In Chongqing, at present, new buildings are required to meet one star green building standards, and are encouraged to perform the two stars or higher (Chongqing Municipal People's Government 2013). By promotion of energy saving, high stars green buildings will flourish, leading to higher energy efficiency rate. For instance, the energy efficiency rate of three stars is 20% higher than that of current energy efficiency standards. If the standards require 75% energy efficiency, three stars green building can save 80% of energy, which means its energy efficiency ratio will be 60%. Sixty percent is the upper limit for energy efficiency ratio of green buildings.

Therefore, in S_1, average energy efficiency ratio of green buildings will be 58% in 13th Five-year, 59% from 2021 to 2030, and up to 60% in 16th Five-year. In pessimistic scenario (S_2), the energy efficiency ratio will be 58% from 2016 to 2025, and then keep at 59%. In optimistic scenario (S_3), the ratio will be 59% from 2016 to 2025, and keep at 60% since 2026.

While calculating the average energy efficiency ratio, two cases, under or over assumed ratio, were considered. To avoid double counting, the implementation rate was designed to be 100%. Parameters in different scenarios are listed in Table 2.

Energy saving potential of new green residential buildings in urban area in different scenarios are calculated by putting these parameters into Formula (2). The results are given in Table 3.

Energy saving potential of new green commercial buildings: Area of new green commercial buildings mentioned above is that in baseline scenario (S_1). In pessimistic scenario (S_2), the area of new green commercial buildings is 80% of that in S_1, while this proportion is 120% in optimistic scenario (S_3) (Ren et al. 2014). Energy efficiency ratio and implementation rate are the same as that in residential buildings. Parameters in different scenarios are listed in Table 4.

Energy saving potentials of new green commercial buildings in urban area in different scenarios are calculated by putting these parameters into Formula (2). The results are given in Table 5.

Energy Conservation Potential of New Non-green Buildings

Energy saving potential of new non-green residential buildings: Area of new non-green residential buildings mentioned above is that in baseline scenario (S_1). In pessimistic scenario (S_2), the area of new green commercial buildings is 80% of that in S_1, while this proportion is 120% in optimistic scenario (S_3) (Ren et al. 2014).

According to the 12th Five-year Plan of Energy Efficiency in Chongqing, energy efficiency ratio of new residential buildings in districts should achieve 65%, which is 50% in countries (Chongqing Municipal Construction of

Table 1: Sum of new residential buildings in different years in different areas in Chongqing.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Total population (10,000)	3028	3050	3071	3092	3114	3136	3158	3180	3202	3225	3247	3270	3293	3316	3339	3362	3386	3410	3433	3458
Urbanization ratio (%)	63.0	64.5	66.0	67.5	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0
Population in urban (10,000)	1908	1967	2027	2087	2149	2195	2242	2290	2338	2386	2435	2485	2535	2586	2638	2690	2743	2796	2850	2904
Urban residential floor area per capita (m^2)	33.48	33.81	34.15	34.49	34.84	35.18	35.54	35.89	36.25	36.61	36.98	37.35	37.72	38.10	38.48	38.86	39.25	39.65	40.04	40.44
Sum of buildings (10,000 m^2)	63868	66504	69213	71994	74850	77231	79672	82173	84736	87363	90055	92814	95640	98536	101503	104542	107656	110845	114112	117459
New buildings (10,000 m^2)	2567	2637	2708	2781	2856	2381	2440	2501	2563	2627	2692	2758	2826	2896	2967	3039	3114	3189	3267	3346
Main urban area (10,000 m^2)	1207	1239	1273	1307	1342	1119	1147	1176	1205	1235	1265	1296	1328	1361	1395	1429	1464	1499	1536	1573
Other districts (10,000 m^2)	744	765	785	807	828	691	707	725	743	762	781	800	820	840	860	881	903	925	947	970
Counties (10,000 m^2)	616	633	650	667	686	571	586	600	615	630	646	662	678	695	712	729	747	765	784	803

Note: The figures in the table are rounded to the nearest number.

Urban-Rural Development 2011). Thus, this paper assumes that in baseline scenario (S_1), the required energy efficiency ratio in 13th Five-year and 14th Five-year is the same as that in 12th Five-year. From 2025 to 2035, the energy efficiency ratio will be 75% in districts and 65% in counties. In pessimistic scenario (S_2), the energy efficiency ratio will not improve until the 16th Five-year. In optimistic scenario (S_3), the energy efficiency ratio will improve from the 14th Five-year, and will be 75% for all new buildings in the 16th Five-year.

When buildings achieved 50% energy saving, the energy efficiency ratio is 0 relative to the reference buildings. The energy efficiency ratio is 30% by achieving 65% energy saving, while it is 50% when energy conservation is 75%.

It will take no less than 3 years for realizing the implementation rate of new standards to improve to 80% (Liang 2011). Therefore, in baseline scenario (S_1), the implementation rate will be 90%, which is 80% in pessimistic scenario (S_2), in the first Five-year after the new standards issued, and will be 100% since the second Five-year. In optimistic scenario (S_3), new standards can be fully executed in the first Five-year. Parameters in different scenarios are listed in Table 6.

Energy saving potential of new non-green residential buildings in districts and counties in different scenarios are calculated by putting these parameters into Formula (2). When the implement rate is not 100%, the potential is calculated by corresponding energy efficiency ratio. The results are depicted in Table 7.

Energy saving potential of new non-green commercial buildings: Area of new non-green commercial buildings mentioned above is that in baseline scenario (S_1). In pessimistic scenario (S_2), the area of new green commercial buildings is 80% of that in S_1, while this proportion is 120% in optimistic scenario (S_3) (Ren et al. 2014).

According to the 12th Five-year Plan of Energy Efficiency in Chongqing, energy efficiency ratio of new commercial buildings in districts in main urban area should achieve 65%, which is 50% in other districts and counties. The energy efficiency ratio and implement rate of new non-green commercial buildings will change as that of new non-green residential buildings. Parameters in different scenarios are listed in Table 8.

Energy saving potentials of new non-green commercial buildings in districts and counties in different scenarios are calculated by putting these parameters into Formula (2). The results are given in Table 9.

ANALYSIS OF ENERGY CONSERVATION POTENTIAL

By putting these energy saving potentials into Formula (1),

Table 2: Parameters in different scenarios of new green residential buildings in Chongqing.

		2016-2020	2021-2025	2026-2030	2031-2035
S_1	Reference energy intensify (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	4065	4379	5656	7180
	Energy efficiency ratio (%)	58	59	59	60
	Implementation rate (%)	100	100	100	100
S_2	Reference energy intensify (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	3252	3503	4525	5744
	Energy efficiency ratio (%)	58	58	59	59
	Implementation rate (%)	100	100	100	100
S_3	Reference energy intensify (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	4878	5255	6787	8616
	Energy efficiency ratio (%)	59	59	60	60
	Implementation rate (%)	100	100	100	100

Table 3: Energy saving potentials of new green residential buildings in urban area of Chongqing. (Unit: 10,000 tons standard coals).

	2016-2020	2021-2025	2026-2030	2031-2035
S_1	13.33	14.61	18.87	24.35
S_2	10.66	11.49	15.09	19.16
S_3	16.27	17.53	23.02	29.23

Table 4: Parameters in different scenarios of new green commercial buildings in Chongqing.

		2016-2020	2021-2025	2026-2030	2031-2035
s_1	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1016	1095	1414	1795
	Energy efficiency ratio (%)	58	59	59	60
	Implementation rate (%)	100	100	100	100
S_2	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	813	876	1131	1436
	Energy efficiency ratio (%)	58	58	59	59
	Implementation rate (%)	100	100	100	100
S_3	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1219	1314	1697	2154
	Energy efficiency ratio (%)	59	59	60	60
	Implementation rate (%)	100	100	100	100

Table 5: Energy saving potentials of new green commercial buildings in urban area of Chongqing (Unit: 10,000 tons standard coals).

	2016-2020	2021-2025	2026-2030	2031-2035
S_1	10.28	11.27	14.56	18.80
S_2	8.23	8.87	11.65	14.79
S_3	12.34	13.53	17.77	22.55

we can get the total energy conservation potential and corresponding contribution rates. The results are given in Table 10. Huge energy saving potential lies in new buildings in Chongqing

During the 13th Five-year (2016-2020), in baseline scenario (S_1), the energy saving potential of new buildings is 416.6 thousand tons standards coal, which is 333.4 thousand tons standards coal in pessimistic scenario (S_2), and 502.8 thousand tons standards coal in optimistic scenario (S_3). From 2031 to 2035, Chongqing can achieve 806.5 thousand tons standards coal saved in S_1, which is 606.2 thousand tons standards coal in S_2, and 1045.1 thousand tons standards coal in S_3. Energy saved in the 16th five-year is twice to triple of that in the 12th Five-year. There is huge energy saving potential in Chongqing.

In energy conservation calculation, 1 kg coke goes to 0.9714 kg standard coal. There are 0.8 kg carbon in 1 kg coke, while 0.8236 kg carbon in 1 kg standard coal. According to the molecular weight of C and CO_2, 0.8236 kg carbon will produce 3.02kg CO_2 (Ren et al. 2014). Carbon emission reducing potential of new buildings in Chongqing in mid-term and long-term is shown in Fig. 1. At present, each resident in Chongqing produces 3.7 tons CO_2 every year. In optimistic scenario, there will be 3,160,000 tons CO_2, which is equal to that produced by 170,000 residents in current level. In addition, by reducing processing and conversion loss, this

Table 6: Parameters in different scenarios of new non-green residential buildings in Chongqing.

		2016-2020	2021-2025	2026-2030	2031-2035
Districts					
S_1	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	7208	6182	6447	6670
	Energy efficiency ratio (standard) (%)	30(65)	30(65)	50(75)	50(75)
	Implementation rate (%)	100	100	90	100
S_2	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	5766	4946	5158	5336
	Energy efficiency ratio (standard) (%)	30(65)	30(65)	30(65)	50(75)
	Implementation rate (%)	100	100	100	80
S_3	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	8650	7418	7736	8004
	Energy efficiency ratio (standard) (%)	30(65)	50(75)	50(75)	50(75)
	Implementation rate (%)	100	100	100	100
Counties					
S_1	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	2276	1951	2035	2105
	Energy efficiency ratio (standard) (%)	0(50)	0(50)	30(65)	30(65)
	Implementation rate (%)	100	100	90	100
S_2	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	1821	1561	1628	1684
	Energy efficiency ratio (standard) (%)	0(50)	0(50)	0(50)	30(65)
	Implementation rate (%)	100	100	100	80
S_3	Reference energy intensity (kwh/m^2·a)	46	46	46	46
	Area of new buildings (10000m^2)	2731	2341	2442	2526
	Energy efficiency ratio (standard) (%)	0(50)	30(65)	30(65)	50(75)
	Implementation rate (%)	100	100	100	100

Table 7: Energy saving potentials of new non-green residential buildings in Chongqing (Unitÿ10,000 tons standard coals).

	2016-2020	2021-2025	2026-2030	2031-2035
S_1	12.22	10.48	20.60	22.42
S_2	9.78	8.39	8.75	16.16
S_3	14.67	24.94	26.01	29.77

number will increase.

In baseline scenario, new green residential buildings contribute most from 2016 to 2025 (Fig. 2). Though less than new non-green residential buildings in the 15th Five-year, new green residential building is the biggest contributor in the 16th Five-year. In pessimistic scenario, new green residential building is always the biggest contributor. Besides, in optimistic scenario, new green residential buildings provide the largest contribution in the 13th Five-year. From 2021 to 2030, new non-green residential buildings will exceed new green residential buildings. However, in the 16th Five-year, contributions from these two types of buildings are similar. Therefore, green residential buildings should be the key emphasis in next years. It would be necessary to promote

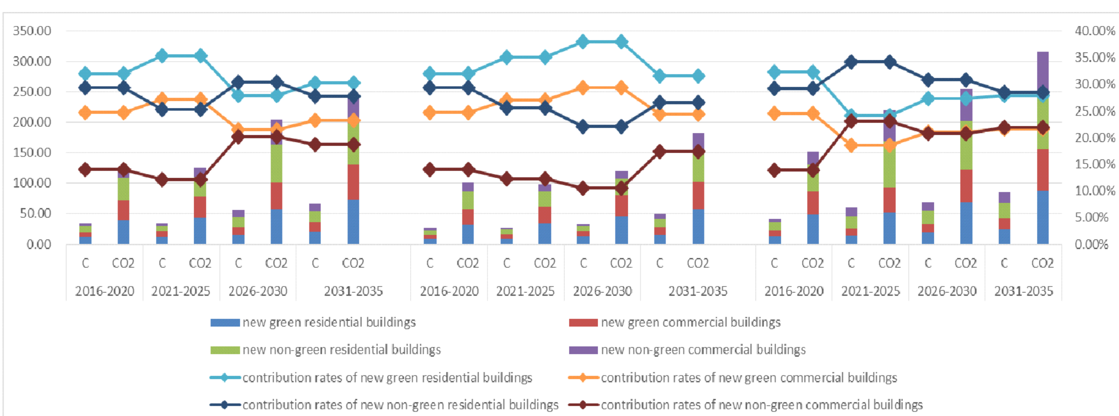

Fig. 1: Potential of GHG reduction from different types of buildings in different scenarios in Chongqing (Left: S_1, Right: S_2, Mid: S_3; Unit: 10,000 tons standard coal)

Table 8: Parameters in different scenarios of new non-green commercial buildings in Chongqing.

		2016-2020	2021-2025	2026-2030	2031-2035
Main urban area					
S_1	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1114	956	997	1031
	Energy efficiency ratio (standard) (%)	30(65)	30(65)	50(75)	50(75)
	Implementation rate (%)	100	100	90	100
S_2	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	891	765	798	825
	Energy efficiency ratio (standard) (%)	30(65)	30(65)	30(65)	50(75)
	Implementation rate (%)	100	100	100	80
S_3	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1337	1147	1196	1237
	Energy efficiency ratio (standard) (%)	30(65)	50(75)	50(75)	50(75)
	Implementation rate (%)	100	100	100	100
Other areas					
S_1	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1257	1077	1124	1162
	Energy efficiency ratio (standard) (%)	0(50)	0(50)	30(65)	30(65)
	Implementation rate (%)	100	100	90	100
S_2	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1006	862	899	930
	Energy efficiency ratio (standard) (%)	0(50)	0(50)	0(50)	30(65)
	Implementation rate (%)	100	100	100	80
S_3	Reference energy intensify (kwh/m^2·a)	142	142	142	142
	Area of new buildings (10000m^2)	1508	1292	1349	1394
	Energy efficiency ratio (standard) (%)	0(50)	30(65)	30(65)	50(75)
	Implementation rate (%)	100	100	100	100

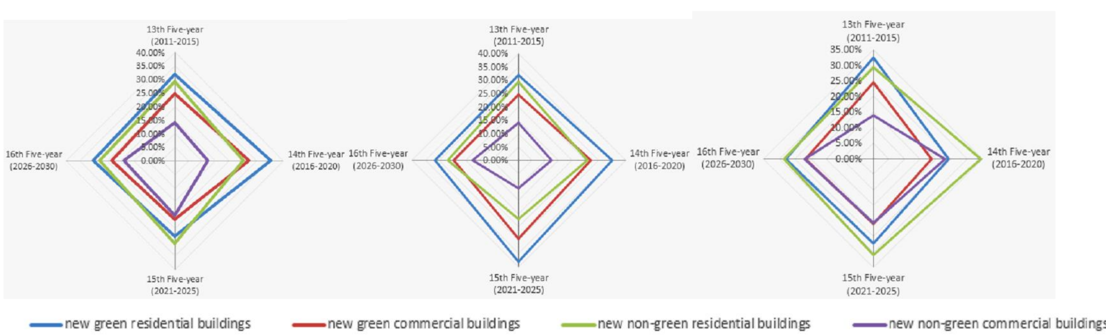

Fig. 2. Radar maps of contributions from different types of buildings in different scenarios (Left: S_1, Right: S_2, Mid: S_3).

Table 9: Energy saving potentials of new non-green commercial buildings in Chongqing (Unit:10,000 tons standard coals).

	2016-2020	2021-2025	2026-2030	2031-2035
S_1	5.83	5.01	13.65	15.08
S_2	4.67	4.00	4.18	10.51
S_3	7.00	16.78	17.50	22.96

higher stars green buildings and improve proportion of green buildings in new residential buildings. In next stage, Chongqing should focus on improvement of energy efficiency standards for non-green residential buildings.

In baseline scenario, as the area of non-green residential buildings is larger than that of green commercial buildings, non-green residential buildings make more contribution in the 13th five-year. Because of the slower speed of urbanization, the contribution of non-green residential buildings will decrease from 2021 to 2025. With higher energy efficiency ratio and energy intensification, green commercial buildings will contribute more than non-green residential buildings. However, as the large area, non-green residential buildings can exceed green commercial buildings by improving energy efficiency ratio.

In pessimistic scenario, non-green residential buildings will contribute more than green commercial buildings in the 13th Five-year. Thanks to higher energy efficiency ratio and energy intensification, green commercial buildings will ex-

Table10: Energy saving potentials from 2016 to 2035 in Chongqing (Unit: 10,000 tons standard coals).

		2016-2020		2021-2025		2026-2030		2031-2035	
		P	C'	P	C'	P	C'	P	C'
Baseline scenario S_1									
New green buildings	R	13.33	32.00%	14.61	35.32%	18.87	27.88%	24.35	30.19%
	C	10.28	24.68%	11.27	27.24%	14.56	21.51%	18.80	23.31%
New non-green buildings	R	12.22	29.33%	10.48	25.33%	20.60	30.44%	22.42	27.80%
	C	5.83	13.99%	5.01	12.11%	13.65	20.17%	15.08	18.70%
Total		41.66	100%	41.37	100%	67.68	100%	80.65	100%
Pessimistic scenario S_2									
New green buildings	R	10.66	31.97%	11.49	35.08%	15.09	38.04%	19.16	31.61%
	C	8.23	24.69%	8.87	27.08%	11.65	29.37%	14.79	24.40%
New non-green buildings	R	9.78	29.33%	8.39	25.62%	8.75	22.06%	16.16	26.66%
	C	4.67	14.01%	4.00	12.21%	4.18	10.54%	10.51	17.34%
Total		33.34	100%	32.75	100%	39.67	100%	60.62	100%
Optimistic scenario S_3									
New green buildings	R	16.27	32.36%	17.53	24.09%	23.02	27.31%	29.23	27.97%
	C	12.34	24.54%	13.53	18.59%	17.77	21.08%	22.55	21.58%
New non-green buildings	R	14.67	29.18%	24.94	34.27%	26.01	30.85%	29.77	28.49%
	C	7.00	13.92%	16.78	23.06%	17.50	20.76%	22.96	21.97%
Total		50.28	100%	72.78	100%	84.30	100%	104.51	100%

Note: R = Residential buildings, C = Commercial buildings, P = Energy saving potentials, C' = Contribution rates

ceed non-green residential buildings from 2021 to 2030. However, once the energy efficiency standard was improved, this trend would not continue.

In optimistic scenario, although the growth rate of area will reduce since the 14th Five-year, non-green residential buildings will always contribute most for improved energy efficiency ratio.

Therefore, Chongqing should focus on improving the energy efficiency standards to promote more contribution from non-green buildings.

CONCLUSION

Half of new buildings in the world are located in China. It is vital for China, even the whole world, to reduce energy consumption and GHG production. There is huge potential of energy conservation in new buildings in Chongqing. Green residential buildings should be the key emphasis in next stage. With the energy efficiency ratio improving, new non-green residential buildings should be the focus in the future. Policymakers in Chongqing can benefit from this paper to make a reasonable plan to promote energy efficiency.

ACKNOWLEDGEMENTS

The authors would like to thank the Energy Foundation for their support.

REFERENCES

Cai Weiguang, Ren Hong and Cao Shuangping 2014. Decomposition analysis of driving factors for building energy consumption in China. Nature Environment and Pollution Technology, 13(1): 1-8.

Chongqing Municipal Construction of Urban-Rural Development 2011. The 12th Five-year Plan of Building Energy Efficiency in Chongqing. Available from:http://www.ccc.gov.cn/xygl/jzjn/jndt/2011-04-06-142921.html, Accessed on 28th July, 2014.

Chongqing Municipal People's Government 2013. Action Plan of Green Building in Chongqing (2013-2020). Available from: http://www.ccc.gov.cn/xxgk/wjtz/2014-01-07-4335045.html, Accessed on 20th July, 2014.

Department of Building Energy Efficiency and Technology 2012. The 12th Five-year Plan on Building Energy Efficiency. Available from: http://www.gov.cn/zwgk/2012-05/31/content_2149889.html, Accessed on 29th July, 2014.

Dong Mengneng, Ding Xiaoqiu and Jiang Han 2008. Analysis of building energy efficiency contribution ratio of Chongqing in 11th Five-year Plan. Journal of Chongqing Jianzhu University, 30(3): 108-111.

Jiang Bo 2011. Research on the Management Institution of New Residential Building Energy Efficiency. PhD. Thesis, Beijing Jiaotong University, Beijing, China.

Liang Chuanzhi 2011. Research on Features of Commercial Building Energy Consumption in Hot Summer and Warm Winter Zone. Master Thesis, Tianjin University, Tianjin, China.

Ministry of Finance, Ministry of Housing and Urban-Rural Development, 2011. Notice to Promote Commercial Buildings Retrofit. Available from: http://www.gov.cn/zwgk/2011-05/11/content_1861716.html, Accessed on 28th July, 2014.

Ren Hong, Liu Huabing and Cai Weiguang 2014. Potential analysis of energy conservation and emission reduction of existing buildings retrofit in Chongqing in medium and long-term. Nature Environment and Pollution Technology, 13(04): 737-742.

UNEP (United Nations Environment Programme) SBCI 2009. Buildings and Climate Change: A Summary for Decision-Makers. Available from:http://www.unep.org/sbci/AboutSBCI/Background.asp. Accessed on 11th July, 2014.

Zhang Weihua 2013. Basic Research on Standard System of Residential Building Energy Consumption Index Classification. Ph.D. Thesis, Chongqing University, Chongqing, China.