energies

MDPI

Article

Field Measurement and Evaluation of the Passive and Active Solar Heating Systems for Residential Building Based on the Qinghai-Tibetan Plateau Case

Zhijian Liu [1,*], Di Wu [1], Miao Jiang [1], Hancheng Yu [2] and Wensheng Ma [3]

1 Department of Power Engineering, North China Electric Power University, Baoding 071003, China; wudisjd@sina.com (D.W.); jm970921@163.com (M.J.)
2 Department of Building Energy Conservation, Qinghai College of Architectural Technology, Xining 810002, China; yhc9008@163.com
3 Institute of Building Environment and Energy, China Academy of Building Research, Beijing 100000, China; mws0509@163.com
* Corresponding: lzj6035@163.com

Received: 28 September 2017; Accepted: 20 October 2017; Published: 26 October 2017

Abstract: Passive and active solar heating systems have drawn much attention and are widely used in residence buildings in the Qinghai-Tibetan plateau due to its high radiation intensity. In fact, there is still lack of quantitative evaluation of the passive and active heating effect, especially for residential building in the Qinghai-Tibetan plateau areas. In this study, three kinds of heating strategies, including reference condition, passive solar heating condition and active solar heating condition, were tested in one demonstration residential building. The hourly air temperatures of each room under different conditions were obtained and analyzed. The results show the indoor air temperature in the living room and bedrooms (core zones) was much higher than that of other rooms under both passive and active solar heating conditions. In addition, the heating effect with different strategies for core zones of the building was evaluated by the ratio of indoor and outdoor degree hour, which indicates that solar heating could effectively reduce the traditional energy consumption and improve the indoor thermal environment. The passive solar heating could contribute 49.8% degree hours for heating under an evaluation criterion of 14 °C and the active solar heating could contribute 75% degree hours for heating under evaluation criterion of 18 °C, which indicated that solar heating could effectively reduce the traditional energy consumption and improve the indoor thermal environment in this area. These findings could provide reference for the design and application of solar heating in similar climate areas.

Keywords: passive solar heating; active solar heating; indoor thermal environment; the ratio of indoor and outdoor degree hour; residential building

1. Introduction

The rapidly growing use of the world's energy has gradually become a worldwide focus of attention, and current predictions show that this growing trend will continue. Energy consumption by buildings and their operations is responsible for 30–40% of primary energy [1–3]. It was estimated that the heating energy requirement in Chinese cold and severe cold zones could reach as high as 75% of total energy consumption, especially for the Qinghai-Tibet plateau areas [4–6]. The conventional fuels could not burn adequately due to the high altitude and low oxygen content in the Qinghai-Tibet plateau. It not only wastes large amounts of conventional energy, but also produces harmful gases, which seriously threatens the fragile atmosphere and ecological environment [7–9]. The solar energy resource in the Qinghai-Tibet plateau is very abundant due to its clean atmosphere, high transparency and low dust content, where the annual sunshine duration is over 3000 h and annual global radiation is 5800–7400 MJ/m^2 [10]. Therefore, a solar heating application could effectively solve the problems surrounding traditional energy consumption and indoor thermal comfort in Qinghai-Tibet, and offer a sustainable and environmentally friendly development.

The solar heating application, as one of clean heating technology, has been drawn much concern and has been widely used in residential buildings around the world in practice because the traditional building energy consumption could be reduced and indoor thermal environment be improved [11,12]. Llovera et al. noted that an important reduction in energy consumption for buildings could be achieved through the careful planning and improvements of control strategy for solar heating system [13]. Shan et al. designed an integrated space heating system including passive sunspace, active solar water heating and an air-source heat pump, which could satisfy the indoor thermal environment and has higher energy efficiency [14]. Rekstad et al. comparatively investigated one solar heating system and one air–water heat pump system of two passive houses respectively. They found that the passive house with solar heating system showed better energy saving performance, due to less auxiliary energy demand than the other with air–water heat pump systems during the monitoring period in Norway [15].

Studies involving thermal parameters for solar heating have drawn much attention [16–18]. Zhai et al. compared the thermal comfort and ventilation effect of the solar house between two different roof collectors, which indicates that a double-pass roof solar collector is superior to the single pass model from the points of view of both space heating and natural ventilation [19]. Zhu and Chen acquired the characteristics of indoor thermal environment parameters varying with outdoor temperature and the wall color [20]. Miller et al. investigated the thermal comfort and heating and cooling characteristics of the passive solar house in India and Australia, and compared the expected and empirical thermal comfort, as well as different solar house design strategies with actual measurement results. Nevertheless, there is a lack of a complete evaluation mechanism and method [21].

Many researchers concentrate on thermal efficiency optimization or thermal response analysis of solar houses and the emphasis has been on the analyses of only one heating strategy [22–24]. However, few studies have been performed on the comparison of different heating strategies. In addition, few investigators are involved in the field of quantitatively evaluation of the effectiveness of solar heating in the Qinghai-Tibet plateau. Therefore, one residential building in the Qinghai-Tibetan plateau is selected as the study object in this research to compare the indoor thermal environment with different heating strategies. Indoor thermal temperature data under reference conditions were compared with that of passive and active solar heating strategies. Hourly air temperatures of each room were measured and analyzed. The ratio of indoor and outdoor degree hour as the evaluation criterion was applied to evaluate the heating effect of different strategies for the improvement of indoor thermal level. These findings could provide some reference for the design and application of solar heating in similar climates area.

2. Object of the Study

One residential building was determined to be the research object, which was built in Wangtun village (latitude 35°97′ N, longitude 101°47′ E, altitude 2367 m), in the Qinghai Tibetan plateau. This village is located in the severe cold climate zone, with a maximum mean monthly temperature of 23 °C in August and minimum mean monthly temperature of −5 °C in January, respectively [5]. It is single-storey house facing the south, with the height of 3.5 m, an east–west length of 12.0 m and north–south length of 6.9 m, according to the Qinghai local design technical specification [25]. Its total floor area is 84.15 m^2. A photo of the residential building appearance is presented in Figure 1. The building layout plan with detailed dimensions are shown in Figure 2. The building contains seven rooms, including room 1 for the toilet, room 2 for the living room, rooms 3 and 5 for the bedrooms, room 4 for the sunspace, room 6 for the kitchen, and room 7 (contains two smaller rooms) for the storage room.

Figure 1. Picture of the residential building appearance.

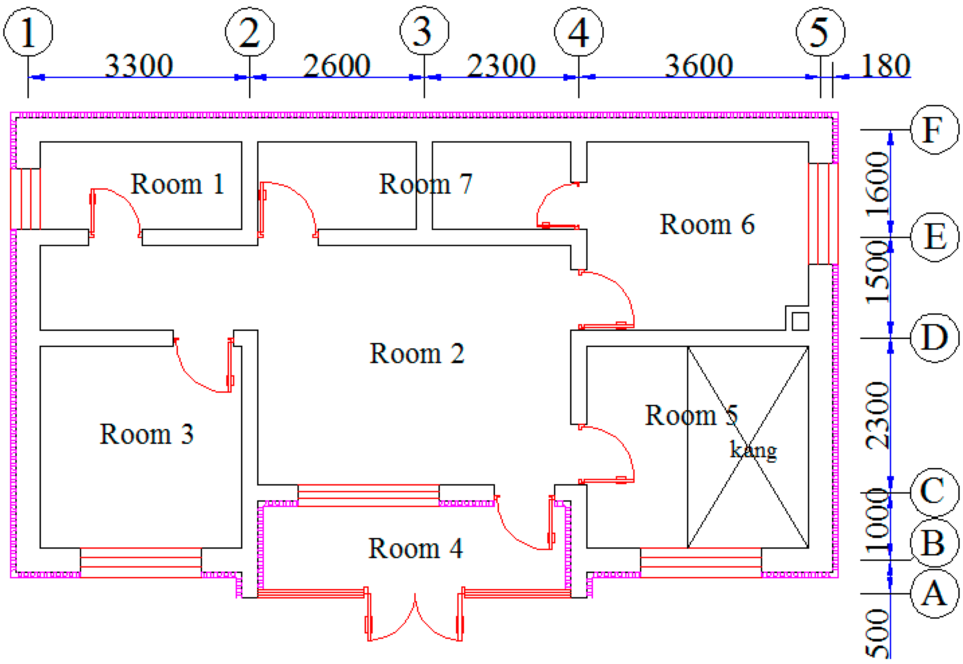


Figure 2. The detailed dimensions and the function of each room.

The structural and thermal parameters of the building are shown in Table 1. The sunspace is made of an aluminum-plastic composite energy saving material (70 series), and the direct gain windows are of swinging casement windows with triplex glass, and the u-value is 1.8 W/(m^2·K). The size of the sunspace is 4660 × 3200 × 1500 mm^3. The storage room connected with the living room is set on the north side of the building to maintain the indoor environment temperature of the core zone rooms (living room and two bedrooms). The storage room could receive more solar radiation through high windows to raise its own temperature.

Table 1. Structural and thermal parameters of building elements.

WWRs	
South direction	0.33
North direction	0
East direction	0.11
West direction	0.04
Roof	0
Area of external wall (including windows)	
South direction	42.70 m^2
North direction	39.37 m^2
East direction	22.91 m^2
West direction	22.91 m^2
Roof	84.15 m^2
Area of external window	
South direction	14.10 m^2
North direction	0 m^2
East direction	2.55 m^2
West direction	0.81 m^2
Building information	
Total floor area of building	84.15 m^2
Volume of building	283.73 m^3
Total area of external wall (including windows)	212.04 m^2
Shape coefficient	0.75
Integrated shading coefficient	SC = 0.68
Solar heat gain coefficient	SHGC = 0.78
Solar radiation correction coefficient of door and window	C_{mci} = 0.41
Total heat transfer coefficient	
External wall	0.29 W/(m^2·K)
Opaque section of roof	0.15 W/(m^2·K)
External window	2.20 W/(m^2·K)
Ground	0.15 W/(m^2·K)
External door	1.70 W/(m^2·K)

The thermal insulation material for the exterior wall of the building is B1-graphite insulating board and colliery wastes brick, and the average heat transfer coefficient is 0.27 W/(m^2·K). The roof and ground are also insulated with B1-graphite insulating board with average heat transfer coefficient about 0.15 W/(m^2·K) and 0.032 W/(m^2·K). A solar-air energy heat pump system and floor radiation heating technologies as active heating methods were adopted in this building. Unlike a traditional solar source like a heat pump and an air source heat pump, this system combined these two systems with high-energy efficiency, which could absorb solar energy and air energy simultaneously when the solar radiation is abundant, and absorb air energy only during the night [26]. The rated power of the system for heating water is 12 kW with R22 as refrigerant. Inlet and outlet water temperature is 55 °C and 60 °C respectively and heat water production is 257 L/h. A floor radiation heating system will operate with a single-circuit water supply when the temperature of the storage tank reach 50 °C. The coil pipes of the floor radiation heating system are laid on the ground of two bedrooms, living rooms and toilet.

3. Methodology

3.1. Heating Strategies

Different heating strategies, i.e., reference condition, passive solar heating condition and active solar heating condition, were carried out in stages and the hourly air temperature of each room was measured in the testing period. The testing period is selected in January, when it is the coldest month. The data obtained in the case of reference condition is used as reference data, which is compared with the data of two solar heating strategies to investigate their effect on indoor thermal environment.

The reference condition could be defined as the building cannot obtain heat from indoor and outside in the measurement period because external door and windows was covered with reflector and the heat pump system stops running. The corresponding test under the reference condition took place during 9:00 (12/1/2017)–8:00 (13/1/2017) for one day. During the period, it could only maintain the indoor temperature level by means of heat preservation. When the building was receiving the solar energy under the passive solar heating condition (9:00 13/1/2017–8:00 16/1/2017, three days), the reflector was removed but heat pump still did not work. It could only receive solar energy through windows, door and sunspace. The test under the active solar heating condition was carried out during 9:00 (16/1/2017)–8:00 (19/1/2017) for three days. The solar-air energy heat pump system started to run for the three days.

3.2. Measuring Locations

In order to evaluate the thermal environment of each room with different strategies, thermocouples covered with aluminum foil are arranged in the center of the room to obtain the hourly air temperature. The indoor average air temperature of each room can be obtained by calculating the average value of each measuring locations. The locations of the indoor measuring points are presented in Figure 3 and Table 2. The technique data for the measuring devices are shown in Table 3. For example, the locations of "2 m 1–1" and "1 m 1–2" identify that the thermocouples were respectively settled at the height 2 m and 1 m from ground in room 1 (toilet). Due to the larger area of room 2, eight thermocouples were settled at the height 2 m and 1 m from ground respectively for avoiding biased evaluation.

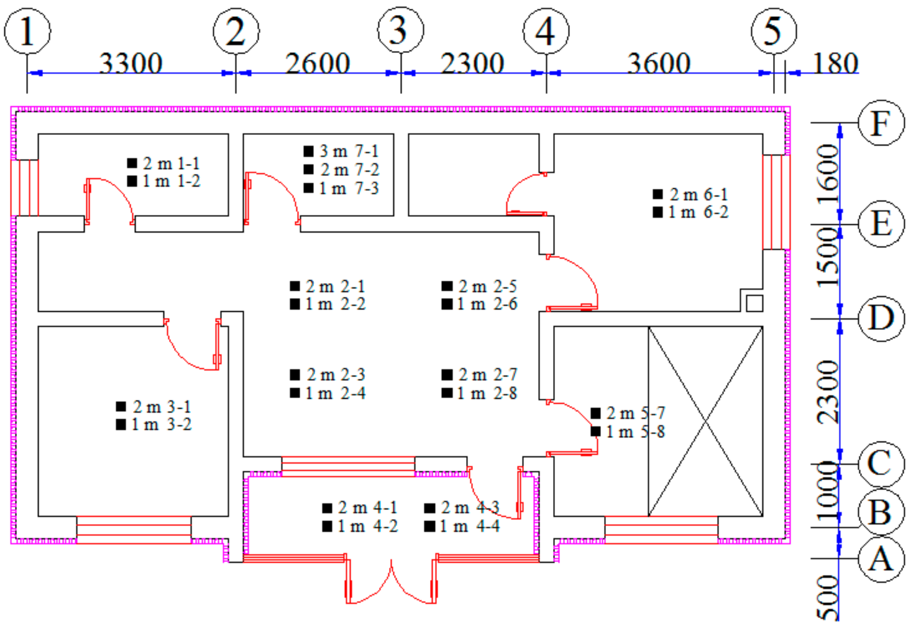


Figure 3. Floor plan of indoor measuring points.

Table 2. Locations of indoor measuring points.

Rooms	Points	Locations
Toilet (Room 1)	1–1	2 m from the ground of the room center
	1–2	1 m from the ground of the room center
Living room (Room 2)	2–1	2 m from the ground (north-west)
	2–2	1 m from the ground (north-west)
	2–3	2 m from the ground (south-west)
	2–4	1 m from the ground (south-west)
	2–5	2 m from the ground (north-east)
	2–6	1 m from the ground (north-east)
	2–7	2 m from the ground (south-east)
	2–8	1 m from the ground (south-east)
Bedroom (Room 3)	3–1	2 m from the ground of the room center
	3–2	1 m from the ground of the room center
Sunspace (Room 4)	4–1	2 m from the ground (west)
	4–2	1 m from the ground (west)
	4–3	2 m from the ground (east)
	4–4	1 m from the ground (east)
Bedroom (Room 5)	5–1	2 m from the ground of the room center
	5–2	1 m from the ground of the room center
Kitchen (Room 6)	6–1	2 m from the ground of the room center
	6–2	1 m from the ground of the room center
Storage room (Room 7)	7–1	3 m from the ground of the room center (west)
	7–2	2 m from the ground of the room center (west)
	7–3	1 m from the ground of the room center (west)

Table 3. The technique data for the measuring devices.

Measuring Devices	Model	Range	Resolution	Accuracy	Manufacturers
Thermocouple	T-Type	−200–320 °C	0.2 °C	0.4%	PTR (China)
Pyranometer	Survey100	0–1500 W/m^2	0.1 W/m^2	0.5%	Seaward (Britain)
Temperature Data Logger	LR8401-21	−120–350 °C	0.1 °C	0.5%	HIOKI (Japan)

Hourly outdoor temperatures and solar radiation intensity were measured by T-type thermocouples and a pyranometer. The T-type thermocouple was settled on the roof, while the pyranometer was positioned parallel to the south wall of the studied residential building. It should be noted that the thermocouples needed protection against direct solar radiation when it was used for measurement.

3.3. Evaluation Criterion

The ratio of indoor and outdoor degree hour is proposed to assess the heating effect of different strategies for the improvement of indoor thermal level. The ratio of the indoor and outdoor degree hour is defined as the ratio of the difference between indoor temperature and outdoor temperature to the difference between outdoor temperature and reference temperature, which can be expressed as:

$$DH = \frac{t_{\text{indoor}} - t_{\text{outdoor}}}{t_{\text{re}} - t_{\text{outdoor}}} \tag{1}$$

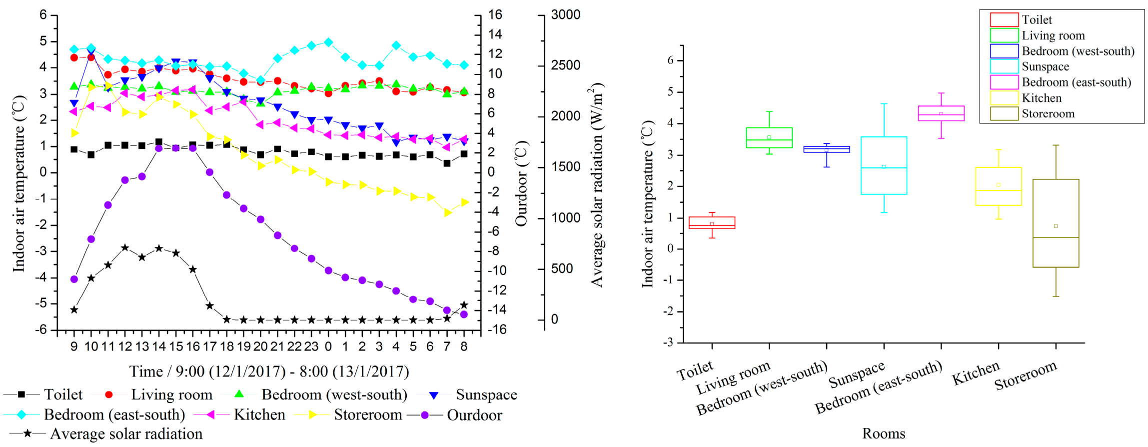
where t_{indoor} and t_{outdoor} are respectively indoor and outdoor temperature, [°C], t_{re} represents reference temperature, [°C]. The ratio value of indoor and outdoor degree hour could reflect how much weight of required indoor heating effect could be achieved by the heating strategy.

In addition, according to the Technical Specification for Passive Solar Heating in Qinghai Province (DB63/T 1527-2016) [25], indoor average temperature of passive and active solar house should reach 14 °C and 18 °C, respectively, during the heating season and these two temperature values were determined as the reference temperature (t_{re}).

4. Results and Analyses

4.1. Reference Condition

Hourly indoor air temperatures of each room, outdoor temperatures and solar radiation under reference condition are presented in Figure 4. Each room could not obtain heat from outside of building due to the reflector covered. Meanwhile, there was some amount of heat loss because of the lower environment temperature about −6.5 °C, which results in the temperature of each room decreasing slightly after 14:00. It can be seen that the core zone rooms have the highest temperature throughout the day with the average air temperature around 3.6 °C (living room), 3.2 °C (southwest bedroom) and 4.3 °C (southeast bedroom). The temperature of the two bedrooms started to increase at 20:00 due to the personnel activities. There are three people sleeping in the southeast bedroom and one sleeping in southwest bedroom, and the electric blanket operates intermittently, which caused the increase of indoor temperature. The temperature of sunspace is higher when the solar radiation is intense during the day and it sharply drops from 4 °C to 1 °C during the night, which illustrates that the temperature of sunspace affected by the environment temperature greatly. The temperature in the kitchen and storage room is low. The temperature in storage room and sunspace is in the large range of temperature fluctuation. The toilet temperature maintains at the lowest level throughout the day with smaller fluctuation. Under the reference condition, the temperature of each room is listed in Table 4 respectively, which has a lower average air temperature.



(a) (b)

Figure 4. Average air temperature of each room (reference condition); (**a**) Hourly average temperature variation; (**b**) Hourly average temperature histogram.

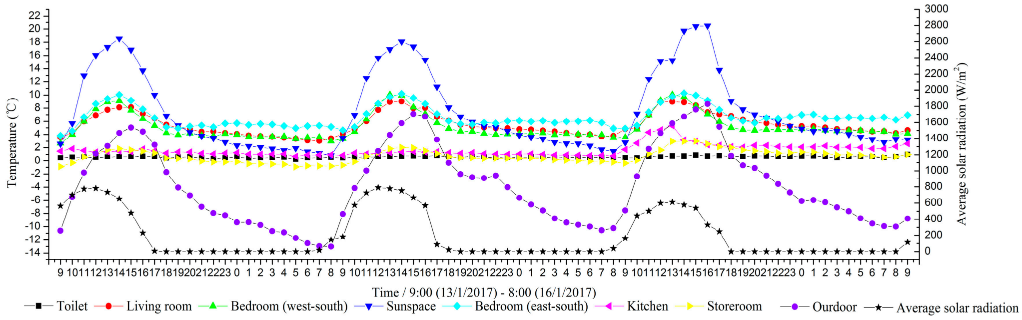
Table 4. Average air temperature of each room with difference conditions.

Conditions	Toilet (°C)	Living Room (°C)	Bedroom (°C)	Sunspace (°C)	Bedroom (°C)	Kitchen (°C)	Storage Room (°C)
Reference	0.8	3.6	3.2	2.6	4.3	2.1	0.7
Passive solar heating	0.6	5.5	5.2	7.4	6.6	1.6	0.7
Active solar heating	4.9	13.9	12.2	9.3	11.1	4.6	2.0

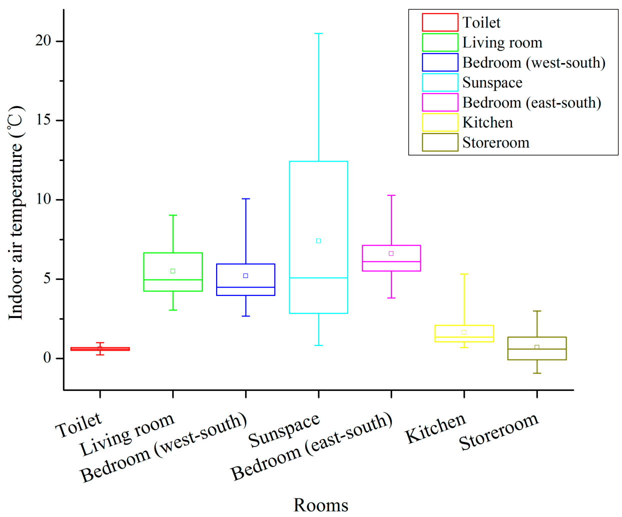
4.2. Passive Solar Heating Condition

The hourly indoor air temperatures of each room under passive solar heating conditions during three days of the test are presented in Figure 5. The average temperature of each room could refer to Table 4. The core zone rooms maintain at a higher level and varies with the outdoor temperature. The toilet, kitchen and storage room have lower temperatures and smaller fluctuation ranges. Sunspace is greatly affected by the environment, which has the highest temperature of around 20 °C and the lowest temperature of around 1 °C. The temperature change trend and average air temperature of rooms are similar in these three days.

Through the analysis of the measuring data, it can be seen that passive solar heating strategy could not reach the average temperature required (14 °C) in this studied case. However, the average temperature of the core zone rooms and sunspace increases by 2 °C–5 °C than that with reference condition, because more heat was received and stored in the building during the day. That reveals the south rooms with direct gain windows and sunspace have a great advantage in receiving solar radiation energy. The temperature in the toilet and kitchen was lower than that under the reference condition due to more heat lost without reflector.



(**a**)



(**b**)

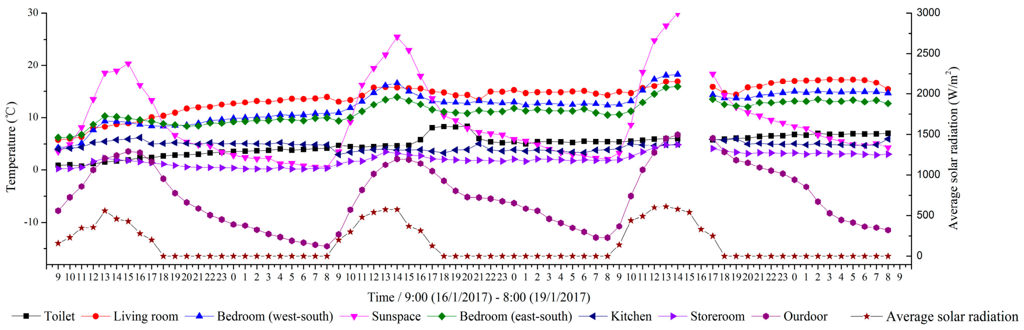
Figure 5. Average air temperature of each room (passive solar heating condition); (**a**) Hourly average temperature variation; (**b**) Hourly average temperature histogram.

4.3. Active Solar Heating Condition

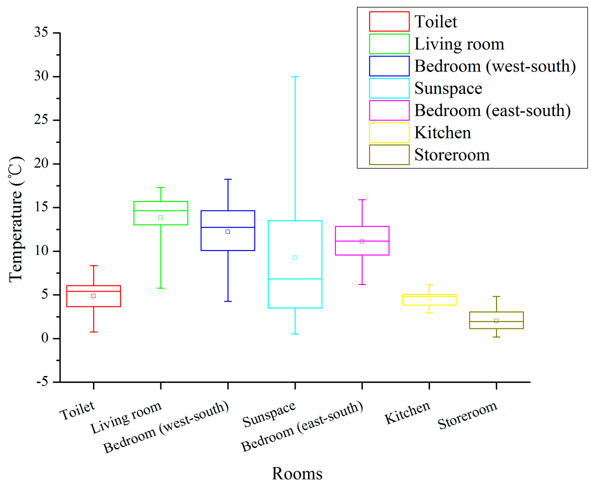
The indoor air temperature in different rooms under the active solar heating condition is higher than that under two conditions mentioned above. The temperature variation trend of each room was consistently increasing, as shown in Figure 6. The data of hourly temperature at 15:00 and

16:00 in the third testing day was not obtained for the breakdown of local power supply equipment, while the temperature trend can be speculated easily. The average air temperature of rooms 1–7 is respectively calculated (Table 4). The core zone rooms have higher temperature level and almost all of hourly temperatures, and are higher than 8 °C. The hourly temperatures of these fluctuate slightly. The sunspace has a large temperature fluctuation range and its temperature varies violently with the outdoor temperature, which has a similar temperature characteristic with the passive solar heating condition. The toilet's air temperature is improved because of floor radiation heating.

Compared with the reference condition and the passive solar heating condition, the average air temperature of core zone rooms are improved about 8 °C and 6 °C, which is higher than the outdoor temperature about 17 °C. Thus, it is verified that using active solar heating strategy is conducive to improve indoor temperature and achieves a better heating effect.



(**a**)

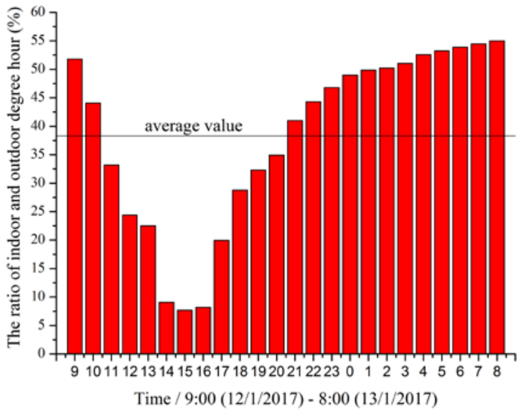


(**b**)

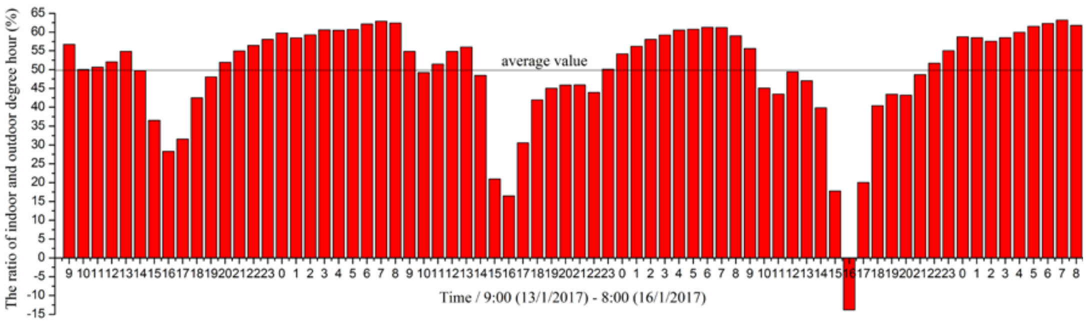
Figure 6. Average air temperature of each room (active solar heating condition); (**a**) Hourly average temperature variation; (**b**) Hourly average temperature histogram.

5. Discussion

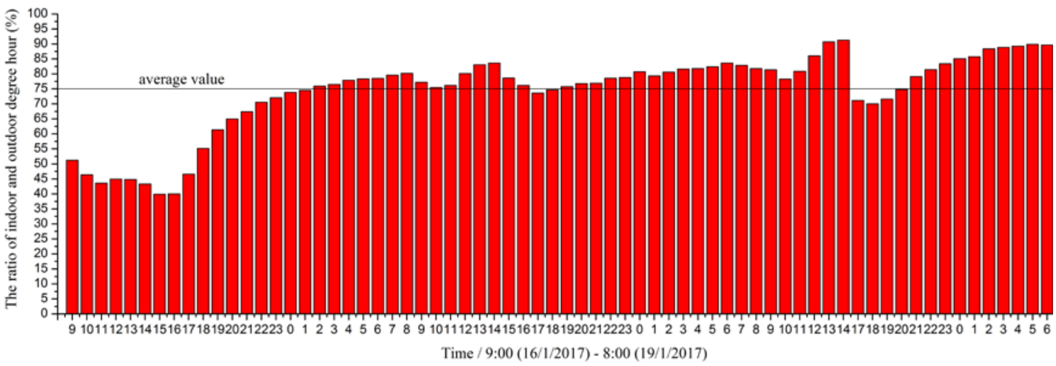
The ratio of indoor and outdoor degree hours in core zone rooms with three heating strategies is shown in Figure 7. The average ratio of indoor and outdoor degree hours is 38.3% under the reference condition with the base temperature of 14 °C, which illustrates that it could achieve 38.3% of the required indoor heating effect under this condition (Figure 7a). During 11:00 to 20:00, the ratio value is lower than the average level and the lowest value is about 8% at 14:00 to 16:00. The higher ratio is appears at 1:00 to 9:00. The ratio is smaller when the outdoor temperature is higher. Because the indoor temperature could reach a relatively higher level when the environment temperature is higher, the contribution of heating strategy to improve the indoor temperature is relatively less. The average ratio of indoor and outdoor degree hour is 49.8% under the passive solar heating condition with a reference temperature of 14 °C (as shown in Figure 7b). The ratio is below 0% at 16:00 on the third day, because the indoor temperature could be higher than the reference temperature in the absence of other heating strategies. The average ratio is 75% with a reference temperature of 18 °C under active solar heating condition, which could satisfy most of the heating energy requirements (Figure 7c). Although the indoor temperature could not reach the required average temperature during the testing period under the active solar condition as described above, it can be found that the average temperature of each room was consistently increasing (Figure 6a), which likely indicates that the active solar heating strategy could achieve the required indoor temperature level to a great extent during the heating season.



(**a**)



(**b**)



(**c**)

Figure 7. The ratio of indoor and outdoor degree hour with different strategies. (**a**) Reference condition; (**b**) Passive solar heating condition; (**c**) Active solar heating condition.

6. Conclusions

In this research, the indoor temperature characteristics of one residential building in the Qinghai-Tibetan plateau were tested with three heating strategies, including a reference condition, a passive solar heating condition and an active solar heating condition. Through the comparison of the heating effect of different strategies, the following conclusions can be obtained.

The indoor air temperature in the living room and bedrooms were much higher than other rooms under passive and active solar heating conditions. Under the passive solar heating condition, their average air temperatures increase by 2 °C–5 °C than that under a reference condition, which reveals the south rooms with direct gain window and sunspace have a great advantage in getting solar radiation. Compared with the other two conditions, the average air temperature of those with an active solar heating condition are improved about 8 °C and 6 °C respectively, which is higher than the outdoor temperature about 17 °C. It is verified that using an active solar heating strategy is conducive to improve indoor temperature and achieves a better heating effect.

The ratio of indoor and outdoor degree hours was used to evaluate heating effect under different conditions. The average ratios are 38.3% and 49.8% under reference and passive solar heating conditions with a base temperature of 14 °C. That average ratio is 75% under active solar heating condition with base temperature of 18 °C. These results illustrate that active solar heating strategy could obtain satisfactory indoor thermal environment during the testing period.

Acknowledgments: This study was supported by the Major Basic Research Development and Transformation Program of Qinghai province, No. 2016-NN-141 and 2014-NN-E03.

Author Contributions: Zhijian Liu, Hancheng Yu and Wensheng Ma conceived and designed the experiments; Di Wu and Miao Jiang wrote the paper and revised the manuscript; Guangya Jin and Qiang Guo participated field measurement and revised the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nejat, P.; Jomehzadeh, F.; Taheri, M.M.; Gohari, M.; Majid, M.Z.A. A Global Review of Energy Consumption, CO_2 Emissions and Policy in the Residential Sector (with an Overview of the Top Ten CO_2 Emitting Countries). *Renew. Sustain. Energy Rev.* **2015**, *43*, 843–862. [CrossRef]
2. Xu, F.; Xie, N.; Zhou, J.; Yin, K.; Wang, B. Study on Developing Status and Appropriate Technologies Analysis of Green Residential Buildings in Hunan Province. *Energy Procedia* **2017**, *121*, 150–157. [CrossRef]
3. Liu, Z.; Xu, W.; Zhai, X.; Qian, C.; Chen, X. Feasibility and Performance Study of the Hybrid Ground-Source Heat Pump System for One Office Building in Chinese Heating Dominated Areas. *Renew. Energy* **2017**, *101*, 1131–1140. [CrossRef]
4. Liu, Z.; Xu, W.; Qian, C.; Chen, X.; Jin, G. Investigation on the Feasibility and Performance of Ground Source Heat Pump (GSHP) in Three Cities in Cold Climate Zone, China. *Renew. Energy* **2015**, *84*, 89–96. [CrossRef]
5. Zhao, D.; Ji, J.; Yu, H.; Wei, W.; Zheng, H. Numerical and Experimental Study of a Combined Solar Chinese Kang and Solar Air Heating System Based on Qinghai Demonstration Building. *Energy Build.* **2017**, *143*, 61–70. [CrossRef]
6. Zhou, X.; Wang, F.; Fan, J.; Ochieng, R.M. Performance of Solar Chimney Power plant in Qinghai-Tibet Plateau. *Renew. Sustain. Energy Rev.* **2010**, *14*, 2249–2255. [CrossRef]
7. Xia, Y.; Xia, K.; Shi, Y. *Eco-Sustainable Architecture (ESA)*; Architecture & Building Press: Beijing, China, 2001; pp. 23–52.
8. Zou, B.; Dong, J.; Yao, Y.; Jiang, Y. An Experimental Investigation on a Small-Sized Parabolic trough Solar Collector for Water Heating in Cold Areas. *Appl. Energy* **2016**, *163*, 396–407. [CrossRef]
9. Lomas, K.J. The UK Applicability Study: An Evaluation of Thermal Simulation Programs for Passive Solar House Design. *Build. Environ.* **1996**, *31*, 197–206. [CrossRef]
10. Liu, Z.; Li, H.; Liu, K.; Yu, H.; Cheng, K. Design of High-Performance Water-in-Glass Evacuated Tube Solar Water Heaters by a High-Throughput Screening Based on Machine Learning: A Combined Modeling and Experimental Study. *Sol. Energy* **2017**, *142*, 61–67. [CrossRef]

11. Li, E.; Liu, J.P.; Yang, L. Research on the Passive Design Optimization of Direct Solar Gain House for Residential Buildings in Lhasa. *Ind. Constr.* **2012**, *42*, 27–32.
12. Wang, W.; Tian, Z.; Ding, Y. Investigation on the Influencing Factors of Energy Consumption and Thermal Comfort for a Passive Solar House with Water Thermal Storage Wall. *Energy Build.* **2013**, *64*, 218–223. [CrossRef]
13. Llovera, J.; Potau, X.; Medrano, M.; Cabeza, L.F. Design and Performance of Energy-Efficient Solar Residential House in Andorra. *Appl. Energy* **2011**, *88*, 1343–1353. [CrossRef]
14. Shan, M.; Yu, T.; Yang, X. Assessment of an Integrated Active Solar and Air-Source Heat Pump Water Heating System Operated within a Passive House in a Cold Climate Zone. *Renew. Energy* **2016**, *87*, 1059–1066. [CrossRef]
15. Rekstad, J.; Meir, M.; Murtnes, E.; Dursun, A. A Comparison of the Energy Consumption in Two Passive Houses, One with a Solar Heating System and One with an Air—Water Heat Pump. *Energy Build.* **2015**, *96*, 149–161. [CrossRef]
16. Zhang, X.F.; Niu, S.-W.; Luo, G.-H.; Yang, L.-N. The Heating Effect of the Additional Solar House to Classroom in the Cold Region—A Case Study of an Elementary School. *Energy Procedia* **2012**, *14*, 1193–1198.
17. Tian, Z.; Perers, B.; Furbo, S.; Fan, J. Annual Measured and Simulated Thermal Performance Analysis of a Hybrid Solar District Heating Plant with Flat Plate Collectors and Parabolic trough Collectors in Series. *Appl. Energy* **2017**, *205*, 417–427. [CrossRef]
18. Chang, H.; Liu, Y.; Shen, J.; Xiang, C.; He, S.; Wan, Z.; Jiang, M.; Duan, C.; Shu, S. Experimental Study on Comprehensive Utilization of Solar Energy and Energy Balance in an Integrated Solar House. *Energy Convers. Manag.* **2015**, *105*, 967–976. [CrossRef]
19. Zhai, X.Q.; Dai, Y.J.; Wang, R.Z. Comparison of Heating and Natural Ventilation in a Solar House Induced by Two Roof Solar Collectors. *Appl. Therm. Eng.* **2005**, *25*, 741–757. [CrossRef]
20. Zhu, J.; Chen, B. Experimental Study on Thermal Response of Passive Solar House with Color Changed. *Renew. Energy* **2015**, *73*, 55–61. [CrossRef]
21. Miller, W.; Buys, L.; Bell, J. Performance Evaluation of Eight Contemporary Passive Solar Homes in Subtropical Australia. *Build. Environ.* **2012**, *56*, 57–68. [CrossRef]
22. Liu, Z.; Li, H.; Cao, G. Quick Estimation Model for the Concentration of Indoor Airborne Culturable Bacteria: An Application of Machine Learning. *Int. J. Environ. Res. Public Health* **2017**, *14*, 857. [CrossRef]
23. Thalfeldt, M.; Pikas, E.; Kurnitski, J.; Voll, H. Facade Design Principles for Nearly Zero Energy Buildings in a Cold Climate. *Energy Build.* **2013**, *67*, 309–321. [CrossRef]
24. Stevanović, S. Parametric Study of a Cost-Optimal, Energy Efficient Office Building in Serbia. *Energy* **2016**, *117*, 492–505. [CrossRef]
25. Yu, H.; Dang, J.; Ma, W.; Zhan, P.; Sun, Z. *Technical Specification for Passive Solar Heating in Qinghai Province, (DB63/T 1527-2016)*; Standard Press: Qinghai, China, 2017.
26. Liu, Y.; Ma, J.; Zhou, G.; Zhang, C.; Wan, W. Performance of a Solar Air Composite Heat Source Heat Pump System. *Renew. Energy* **2016**, *87*, 1053–1058. [CrossRef]