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SUSTAINABLE WIND-CATCHER FOR HOUSES IN HOT DRY AREAS

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ABSTRACT

In contemporary architecture, the use of wind-catchers is neglected because of the relatively small amount of air provided by this system in traditional architecture and the emergence of modern ventilators and cooling equipment, which have impressed the people.

Due to the belief of the importance and impact of natural ventilation on human health, the author has studied for more than 25 years all problems that have led architects to neglect the use of wind-catchers in their designs. On the bases of this study, new types and relatively large wind-catchers, with at least $2m^2$ in section, are proposed and applied in his designs. They have been accepted and appreciated aesthetically by owners of houses and succeeded in reducing air and houses inner walls temperatures during spring, autumn and summer nights. The wind catchers, however, prove to be incapable during summer day to provide inhabitants with suitable thermal comfort, since they just carry external hot air without any treatments. Thus, the authors thought of adopting the phenomenon of controlled evaporation as a way to lower the air temperature in order to achieve the possibility of making the wind-catcher a cooling radiator and transport cool air. The validity of this idea was tested by constructing a wind-catcher of $2.5*1.8\ m^2$ in cross section for a one-story guest house building of 60 m2. The wind-catcher walls were lined with regular capillary porcelain material (brick

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burned at temperatures 750-1150°C) and connected with water drop system that was placed on the upper wind-catcher nozzle. Wooden air guides were designed and placed on the wind-catcher upper nozzle to increase contact between the external hot air and the cooled lining porcelain walls. The results during the summer of 2014 showed that the process of moisturizing wind-catcher lowered air temperature about 17 degree Celsius in the day of outside temperature of 48.7 degrees.

Key words: Wind catchers, Sustainable architecture, Environmental design, Ventilation

Introduction

Wind-catchers are considered as one of the healthy and climatically features of the traditional old houses in Iraq at a time when there were no artificial means for ventilation and cooling to provide thermal comfort for house users. After the appearance of artificial ventilation equipment, wind-catchers disappeared from the designs in contemporary housing. This is due to their small sizes, for the largest one does not exceed 0.2 m^2 which could not provide suitable amount of air to fit the thermal comfort for a modern man. Wind-catchers were, therefore, replaced by mechanical systems that respond to new human thermal comfort limits. These devices, however, have affected the environment, for they are thermal and noise polluters. They have, moreover, affected the quality of indoor air through air drying in air conditioners or raising up air moisture contents in the evaporative air coolers. In both cases, they have influenced the increase of positive ions in the air causing drowsiness and depressions [1]. They have turned a number of residential buildings into sick buildings, which led to increase the calls for the provision of data that help designers to make their buildings healthy.

Due to the belief of the importance of this concept, we started in a previous research [2] some applications in our designs to revive the use of wind-catchers, but with large size to be able to create air movements suitable for contemporary human comfort limits. They were presented in forms and dimensions capable to encourage designers to rely on them and to benefit from their diversities, in addition to making them greatly acceptable by people.

These wind-catchers have proved through implementation and thermal measurements carried out and published worldwide [2] to be successful in providing adequate natural ventilation and reducing the temperature of the air inside residential spaces in the spring, autumn and summer nights. The new wind-catcher is still unable to fulfill summer day thermal comfort requirements, as it is considered as a catching and air directing device without addressing the heat of summer air. Thus, the idea of reducing the temperature of air passing through a wind-catcher is introduced by relying on the classical wind-catcher, which was wet as a result of the contact of its brick components to groundwater. This study was carried out to discover the effect of moisturizing wind-catcher walls in developing its work to lower summer air temperature, especially because the air movement increases at noon causing a subconsciously drop in air temperature that is conventionally called the effective temperature degree.

Modern Wind-Catchers

After studying the architectural and environmental problems of conventional a wind-catcher, the researchers have found out that its small sectional area makes it difficult to plaster its walls, and therefore its rough walls become suitable homes for ants and insects, and for the transmission of mice between houses. The conical shape of its upper air inlet, moreover, makes it produce undesired sounds for modern humans especially in bedrooms. Due to its small size, furthermore, it is a dark slot disliked by housewives. Consequently, homeowners started to dislike using it after the provision of artificial ventilation devices [3].

Due to the belief of the importance of natural ventilation, we propose a number of large wind-catcher forms with characteristics that overcome the problems of old wind-catchers. They can represent beautiful architectural pieces. A wind-catcher's openings can be controlled by sealed doors and windows. A theoretical and applied study was carried out for each type. Figure 1 [4], shows that although the one with covered ceiling is more efficient in inletting large air amount, by the increasing external wind speed it produces noises and whistles that may annoy the residential and bedrooms user. It cannot be healthy due to darkness and lack of exposition to sterilized solar radiation [5]. Consequently, it was decided to choose a wind-catcher form No. 7 for experiment. It has been used and implemented in our house designs in Baghdad and Mosul city in Iraq since 1988, and it is used in the present study [2].

Experimental Study

To discover the effect of moisturizing wind-catchers experimentally, an existing passenger guest house, which was built on the road that linked the Provinces Karbala and Najaf, was used to examine cooling the building by the selected moisturized wind-catcher with the following characters.

General Description of the Guest House

The guest house consists of 6*10 meters with an open hall with a height of 4.3 meters, a kitchen, store and bathroom (Figure. 2).

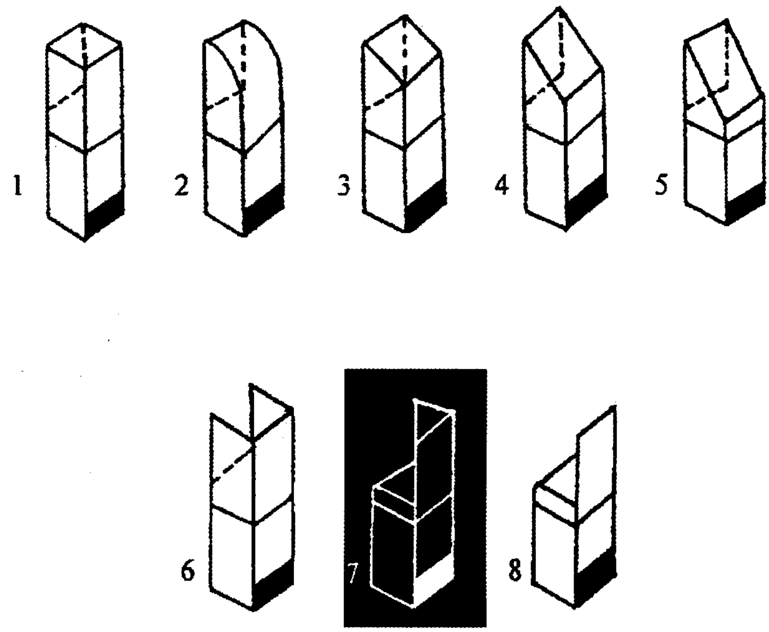


Figure 1 : Types of wind-catcher ceiling covers conducted in experiments

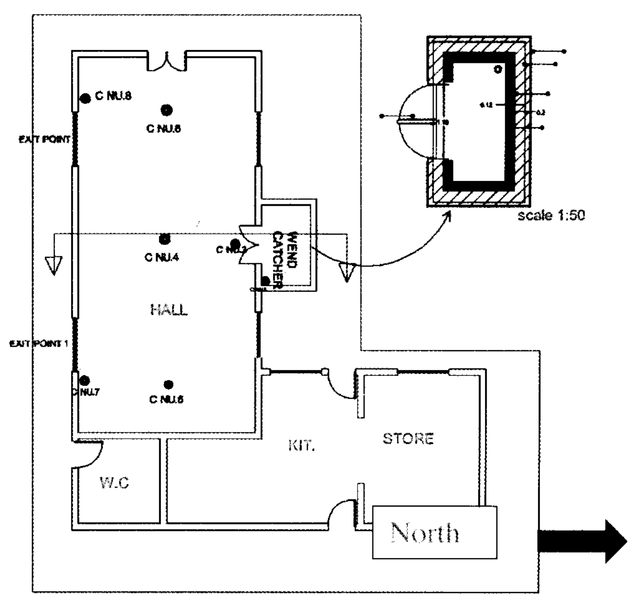


Figure 2 : Guest house plan showing the wind-catcher and thermal sensors places

Construction Material

- The wall is built with hollow concrete blocks, plastered and rendered from external face with white cement, and with gypsum plaster for inner side.
- The slab of the guest house is constructed with the vault method using brick and I-bam steel section, roofed and paved with brick tiles, and covered from inside with gypsum falls ceiling
- Windows used in the hall are four of 2.5 * 2 meters in dimension. Two of them are in the northern facade and two in the southern facade. Figure (2).
- The guest house has single door of 1.2 with 2.4 m. height.
- The floor is concrete tiles.

The Added Wind-Catcher

According to previous studies in Iraq, the best wind-catcher form for most climatic and environmental balance has been chosen is form No.7 in figure (3), with 2.5*1.75 meter in dimension, which will be adopted in this study [4].

According to the directions of most prevailing winds in the study area, which is North West, North and West, the north side wall of the guest house has been chosen to build the wind-catcher No. 7. The height of north and west wind-catcher walls were built flush with the building roof height, while the south and east wind-catcher walls were build three meters higher than building roof level to snip the air and redirect as much of it towered the wind-catcher duct and the connected hall, figure (3) and (9). A port of entry was opened like a door that consisted of two leaves and each leave had a movable window on its upper half that is used to control and allow the desired air quantity (Figure 4).

The foundation of the established wind-catcher was built in a basin shape with a dimension of 3.25 * 2.5 meters with sulfate resistance concrete, (5). The wind-catcher walls were built from thermal insulation blocks (Thermoston blocks with 20 centimeters in thickness) with two different heights, 4.5 m. in height for North and West walls and 7.5 m. in height for East and South walls (Figure 3 & 6). A wind-catcher wall surface was plastered with smooth cement mortar from external and internal sides, to be ready for water proofing process on inner surface. Three layers of Cold Asphalt paint to the height of 4.5 meters were applied to ensure cutting any water leakage from the wet brick lining.

Lining wall was built with perforated light yellow brick with high capillary property (burned with temperature between 1150-750°C), in which capillary property completed. It is recommended to use neither the rocky non-porous green bricks nor the red low-porous bricks which crumble if they absorb water.

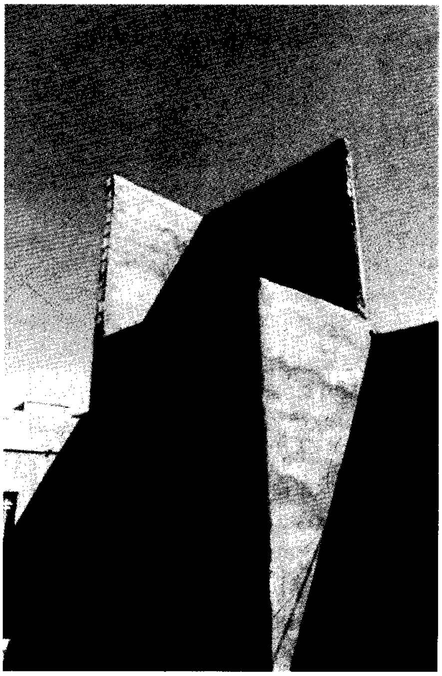
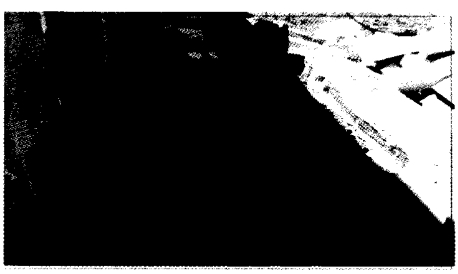


Figure 3 : The constructed wind-catcher (left)
Figure 4 : Air gate with four openings (right)



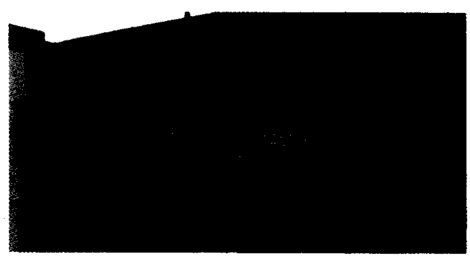


Figure 5: Wind-Catcher lower basin (left)
Figure 6 : Wind-Catcher external walls (right)

The lining process with brick was conducted to the height of 4.3 m., which is 20 cm. under water proofing upper-level to avoid any dissipation of water to the main wind-catcher walls.

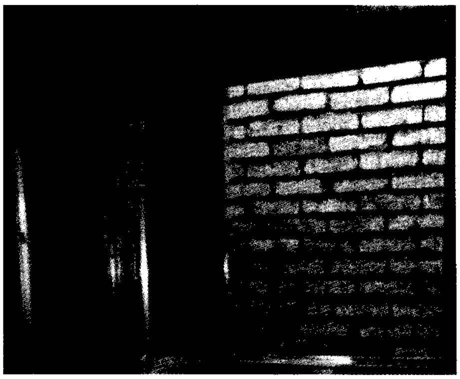



Figure 7 : Showing brick lining from inner side (left)
Figure 8 : Showing brick lining from external side (right)

A water spraying system with perforated pipes (for moistening) was installed to the upper side of the perforated brick wall. It was composed of reinforced plastic pipes, 12mm. in diameter, with 4mm. holes per each 10 cm. connected to a (500 liters) water tank linked to a feeder tank of (2,000 liters) provided with water descending controller (Figure 9) that operated naturally by gravity. A water pump was placed in the bottom of the wind-catcher basin to control any increase of water that may occur as a result of the spraying operation (Figure 9).

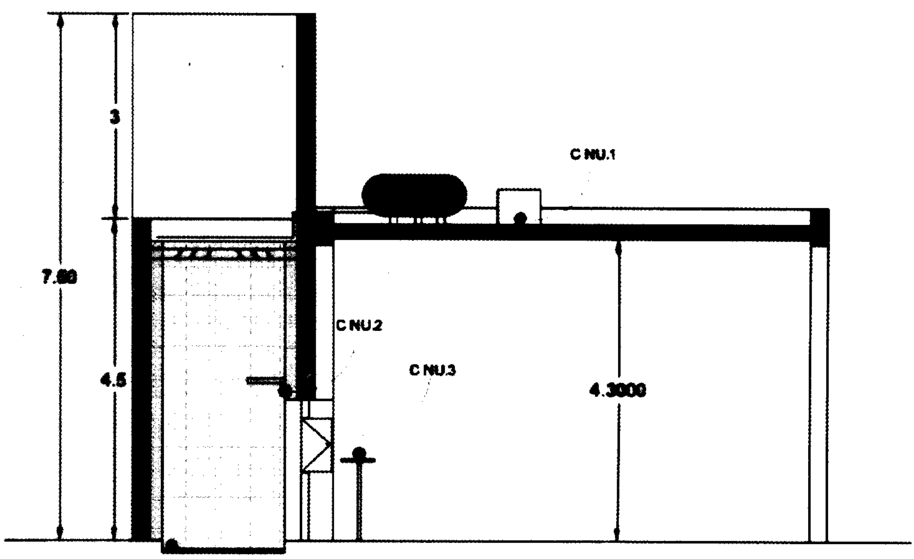


Figure 9 : Vertical section showing spraying water system

Practical Study

A sprinkler system was kept running for a full day before taking measurements in order to ensure completely moisturizing the lining of the wind-catcher.

Eight temperature and humidity sensors were used for this study, six of them were placed in the guest house hall at 4m height from floor level. The seventh was imbedded in moisturizing the lining brick wall, and the eighth was fixed under the shade on the roof of the hall (Figure 1).

The measurements were recorded for each hour of the day for 15 days in June, July and September, where external temperatures range varied between 48.7 and 41°C. The number of readings per day for each thermal and relative humidity sensors was 192 records and 24 records for air speed at wind-catcher inner air hall entrance.

Results

The results of air temperature measurements on 05/07/2014 showed that the moisturized wind-catcher lowered the external air temperature, which was around 48.7 at 3p.m., by 17°C to make the guest house's inner temperature around 31°C. They showed that the temperature of the moisturized brick lining was almost constant during day and night, which ranged between 8 to 9°C.

The relative humidity fluctuated within the space between 20 to 26% at a time when the relative humidity outside space was 15% and the relative humidity inside the wind-catcher lining was 97% (Table 1).

The air speed inside the hall ranged between (0.9 m/s) at night and 4.1 m/s at noon on the day when the external air speed was around 4 m/s at noon. These results could be considered a good indication for the validity of the calculation of the cross-sectional area of the wind-catcher in relation to the area of the guest house hall for providing adequate air movement (Figure 10).

Comparison between Results and Thermal Comfort Limits

In summer, July 05/07/2014, the mean air temperature measured by dry air bulb thermometer inside the guest house hall was 31°C. The mean relative humidity was about 20%. The air temperature found for wet bulb thermometer was 17.7 [6].
The rate of air movement inside the hall was around 1.5 m/s. Therefore, the temperature felt by a human wearing normal clothes of (1 Clo.), as shown in Figure 11, would be as 23.3°C, which is within the limits of thermal comfort [7].

Table 1 : Air temperature, relative humidity, air movements measurements

air speed	C.NU.8	C.NU.7	C.NU.6	C.NU.5	C.NU.4	C.NU.3	C.NU.2	C.NU.1	Saturday 5\7\2014
1.5 m/s	22.2 RH 26	21.5 RH 28	22 RH 31	20.4 RH 31	20.2 RH 33	20 RH 34	8 RH 98	28.1 RH 32	7 am
0.9 m/s	22.8 RH 24	22.5 RH 26	22 RH 32.8	21.8 RH 32	21.5 RH 33	20.1 RH 33	8 RH 98	29.9 RH 30	8 am
1.3 m/s	23.7 RH 24	23.9 RH 24	23.7 RH 25	22.4 RH 28	22.1 RH 28	21.2 RH 33	8 RH 98	33.5 RH 30	9 am
1.1 m/s	25.1 RH 22	25 RH 22	24.9 RH 24	24.1 RH 27	23.9 RH 28	23.1 RH 30	8 RH 98	36.6 RH 27	10 am
0.9 m/s	29.2 RH 28	29.1 RH 26	28.2 RH 28	27.1 RH 28	27.1 RH 27	26.8 RH 27	8 RH 98	40.1 RH 22	11 am
1.7 m/s	29.5 RH 28	29.5 RH 28	28.5 RH 25	28.1 RH 25	28 RH 24	27.9 RH 26	8 RH 98	42.5 RH 19	12 pm
2.1 m/s	30.1 RH 24	30 RH 23	30.8 RH 24	30.2 RH 24	30.1 RH 22	29.1 RH 24	9 RH 97	45.7 RH 17	1 pm
3.8 m/s	32.2 RH 23	32 RH 24	31.7 RH 23	30.5 RH 22	30.3 RH 22	30 RH 28	9 RH 97	47.5 RH 15	2 pm
2.7 m/s	31.6 RH 21	31.9 RH 20	31.9 RH 20	31.9 RH 21	31.6 RH 20	31.5 RH 26	9 RH 97	48.7 RH 15	3 pm
3.6 m/s	31.6 RH 24	31.5 RH 22	32 RH 24	31.3 RH 23	31.3 RH 25	31.2 RH 27	8 RH 98	47.2 RH 17	4 pm
4.1 m/s	31.2 RH 25	30.8 RH 25	31.2 RH 26	30.5 RH 20	31.1 RH 21	30.6 RH 29	8 RH 97	44.5 RH 19	5 pm
2.6 m/s	31 RH 22	31.2 RH 22	31 RH 21	31.1 RH 23	30.1 RH 24	29.2 RH 30	9 RH 97	42.7 RH 21	6 pm
2.1 m/s	29.1 RH 18	29.5 RH 20	29.9 RH 18	29.4 RH 22	29 RH 22	29 RH 28	9 RH 97	40.2 RH 22	7 pm
1.9 m/s	29.5 RH 24	29.5 RH 24	29.5 RH 27	29.1 RH 30	29.2 RH 28	28.4 RH 30	8 RH 97	39.4 RH 23	8 pm
1.7 m/s	27.9 RH 21	28.8 RH 22	28.2 RH 20	28.1 RH 26	27.9 RH 26	27.3 RH 31	8 RH 97	38.4 RH 23	9 pm
1.6 m/s	29.1 RH 22	29.1 RH 20	30.1 RH 21	29.1 RH 27	28.8 RH 26	28.2 RH 30	8 RH 97	36.2 RH 24	10 pm
2 m/s	29.2 RH 20	29 RH 20	29.1 RH 18	28.4 RH 30	28.4 RH 26	28 RH 30	8 RH 97	34.4 RH 26	11 pm
1.8 m/s	28.6 RH 20	28.5 RH 18	28.4 RH 19	28.5 RH 29	28.3 RH 29	27.8 RH 31	8 RH 98	31.5 RH 29	12 pm
2.1 m/s	28.1 RH 22	26.8 RH 21	28.6 RH 19	28.1 RH 28	28.2 RH 30	27.7 RH 31	8 RH 98	28.4 RH 31	1 am
1.3 m/s	27.1 RH 18	27 RH 19	28 RH 18	27 RH 29	27.6 RH 31	27.1 RH 30	8 RH 98	27.4 RH 31	2 am
1.2 m/s	26.9 RH 20	27.1 RH 21	28 RH 21	27.5 RH 30	27.1 RH 29	26.3 RH 31	8 RH 98	25.4 RH 32	3 am
1.5 m/s	25 RH 24	26.5 RH 22	25.8 RH 28	26.8 RH 30	26.3 RH 30	25.8 RH 32	8 RH 98	25.1 RH 32	4 am
1.6 m/s	25.4 RH 26	24.4 RH 24	25.3 RH 24	25.3 RH 31	25.1 RH 30	24.5 RH 31	8 RH 98	26.3 RH 33	5 am
1.9 m/s	25.8 RH 27.8	26 RH 28	26.1 RH 29	26 RH 28	25.9 RH 28	25.1 RH 33	9 RH 97	27.1 RH 32	6 am

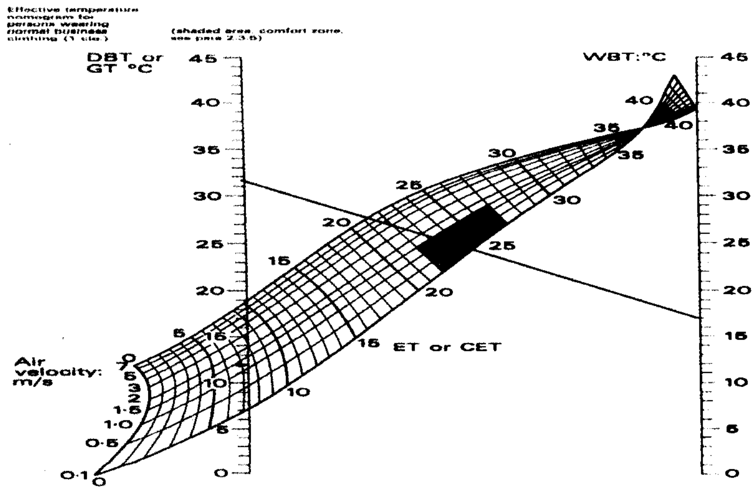


Figure 10 : Effective temperature nomogram for thermal comfort limits for people wearing normal clothes, represented by relationship between air temperature, humidity and air velocity

Conclusions

The process of lining a wind-catcher with moisturized brick reduces air temperature inside the space for about 17 degrees Celsius, which is about 35% of its external air temperature and it reduces about 40°C of the lining temperature, which becomes the source to reduce the air temperature.

The cross-sectional area of the proposed wind-catcher is adequate to change the air of the guest house hall in a period between (1-8) minutes (Figure 2).

The relative humidity inside the space, which varies between 20-26%, confirms that the use of bricks burned to a degree between 750 to 1050°C in which the capillary property is completed, does not raise much the relative humidity of the air passing through due to the lack of accumulation of water on its outer surface. It can be considered as moisture self-control material.

The thermal comfort nomogram in Figure 10 shows that the effective temperature achieved within the space for person wearing normal clothes is 24.3°C, which is within the required comfort limits even when air speed is 0.1 m/s. It becomes less than 23.3 if we adopted the mean rate of air speed 1.5 m/s. This makes the proposed wind-catcher with moisturized brick lining succeed in improving thermal environment within architectural spaces in hot dry countries of low relative humidity and high air temperature like Iraq.

Due to the fact that the proposed wind-catcher helps in reducing internal air temperature to a modern human thermal comfort limits, is shining and can be considered as a lighting source for overlooking space, is easy to maintain, can control indoor air quantity or completely closed according to season, this kind of wind-catcher can be considered sustainable to provide comfort for houses' users and help in reducing the use of polluting energy in the city.

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