RESEARCH HIGHLIGHT

September 2012 Technical Series 12-104

Summer Shading Performance of Awnings at the CCHT

INTRODUCTION

A project to directly measure reduced air conditioner energy due to awnings (*see* figure 1) was conducted at the Canadian Centre for Housing Technology (CCHT).[1] Significant passive heating can be provided by solar energy entering the windows of a house. Management of these solar gains in all seasons can minimize energy use for space heating and cooling. In the heating season, maximizing solar gains minimizes energy use, but can also cause occasional overheating, especially in very energy-efficient houses with large areas of south- or west-facing windows. In the cooling season, solar gains should be minimized to reduce cooling loads and to avoid overheating.

Blinds, shades and curtains are found in most houses, and can be easily adjusted by occupants. However, a study at the CCHT showed that "typical interior blinds…are not particularly energy-efficient nor cost-effective compared to unshaded windows."[2] The same study also shows that exterior rollshutters and close-weave screens are the most effective devices for reducing house heating and cooling energy, and have other benefits. However, rollshutters and screens are unconventional in appearance (*see* figure 2), and block some or all daylight and views when used to block solar gains.

Awnings, which were common on houses in the past, are more conventional in appearance, and may be more acceptable to occupants (*see* figure 1). Retractable awnings should be able to reduce cooling energy and overheating during the heating season, and maximize useful solar gains. Retractable awnings will not reduce heating loads, and they can allow for the design and installation of larger south-facing windows as they can reduce the associated risk of overheating. This project directly measured reduced cooling energy attributed to awnings on south windows. It also compared temperatures and light levels in the home, with and without the awnings.

Figure 1 The awnings on the experimental house, photographed close to solar noon.

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[1] The Canadian Centre for Housing Technology is jointly operated by the National Research Council, Natural Resources Canada and Canada Mortgage and Housing Corporation. This research and demonstration facility features two highly instrumented, identical, two-storey houses with simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. For more information about the CCHT facilities, please visit http://www.ccht-cctr.gc.ca.

[2] Laouadi, A., Guidelines for Effective Residential Solar Shading Devices, IRC-RR-300, Institute for Research in Construction, National Research Council Canada, Ottawa, 2010, www.ccht-cctr.gc.ca/eng/reports.html, p. 13.

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BACKGROUND AND METHODOLOGY

The awning evaluation was carried out at the CCHT's twin-house research facility in Ottawa, Canada, in the spring and summer of 2010. The twin-house facility has been in operation since 1998, and has been the site of many side-by-side comparisons of energy saving technologies. The unique nature of the facility allows researchers to not only evaluate energy savings, but also the whole house effects including temperatures and humidity. Data from over 250 sensors are monitored continuously, and special-purpose sensors and data loggers are installed for particular projects.

The awnings

This project tested standard commercially available retractable canvas awnings. They were mounted on the three largest south-facing windows of one of the CCHT twin houses, the experimental house, as shown in figure 1. These windows are very close to true south-facing. The awnings are manually operated, so users can deploy them when shading is desired, and retract them to allow maximum daylighting and solar gains at other times. Figure 3 shows the profile of the awning deployed on the ground floor window.

Data collection

The permanent CCHT data collection system was used to measure energy use by the air conditioner (A/C) in each house, as well as room temperatures. Data collected every five minutes in each house included:

- electricity (kWh) used by the external A/C units (fans and compressors);
- electricity (kWh) used by the furnace fans that distributed the air throughout the houses;
- temperatures in each of the rooms;
- outdoor temperature; and
- solar radiation, both global and on the south side of the houses.

Light levels in the living rooms were also measured every five minutes by photometric sensors, instruments with approximately the same sensitivity to light of various wavelengths as the human eye.

Figure 2 Rollshutters on the north side of a CCHT house.

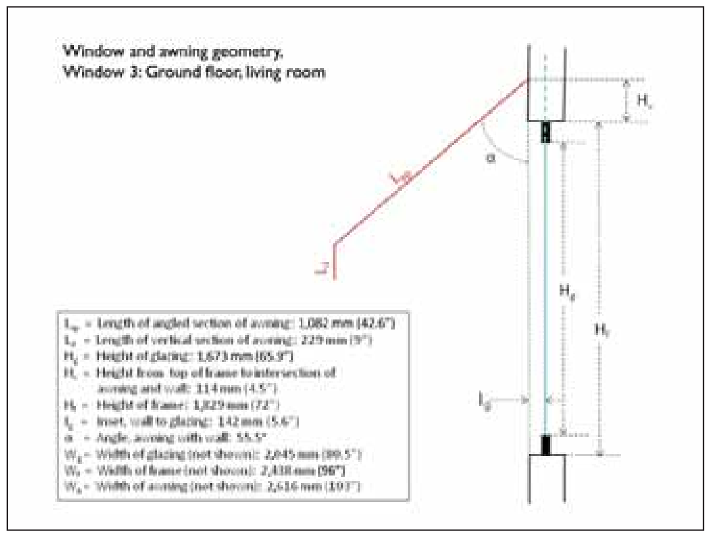

Figure 3 Profile of the living room window and awning, NTS.

Benchmarking and experiment

As with all side-by-side testing at the CCHT, the project consisted of two phases. The first was benchmarking, in which the two houses were run with identical internal conditions, and no awnings on either house. This determined how similar temperatures, light levels, and the amounts of energy used for air conditioning were under a range of weather conditions, and provided the basis of comparison. The second phase was the experiment, in which the awnings were installed on the experimental house, while the control house continued to operate without awnings.

The venetian blinds (mini-blinds) in both houses were kept in their standard position throughout the benchmarking and experiment: blinds down, slats open. Internal conditions in both houses were the same as during benchmarking, and are shown in table 1.

Table 1 Operating conditions for benchmark and experiment, both houses.

	System	Setting
1	Air circulation	The fan of a high efficiency condensing gas furnace provides low speed continuous circulation and high speed airflow for cooling
2	Air conditioner	2 ton (7.03 kW), 13 SEER
3	Thermostat setpoint	24°C
4	HRV	Low speed continuous (30.7 L/s, 65 cfm)
5	Windows	Closed and locked
6	Simulated occupancy	Standard schedule
7	Humidifier	Off

Simulated occupancy includes light bulbs that simulate the heat from humans in various locations, operation of lights and major appliances, and hot water draws.

Benchmarking took place on 35 days between May 18 and August 15, 2010. Outdoor temperature varied from 11.6°C to 36.8°C. Daily amounts of global (horizontal) solar radiation varied from 5,081 kJ/m^2 to 28,325 kJ/m^2. Testing took place on 24 days between August 21 and September 19, 2010. Outdoor temperature varied from 7.1°C to 33.6°C. Global solar radiation ranged from 3,689 kJ/m^2 to 22,505 kJ/m^2. Thus, the benchmark and testing days included similar ranges of temperature and solar radiation.

FINDINGS

Energy savings

The average measured saving in cooling energy due to the awnings was 3.19 kWh/day, or 17% of the cooling energy without awnings. The results for individual days were projected to the entire 127-day CCHT cooling season for 2010, based on a two-factor regression of daily savings versus vertical solar radiation on the south wall of the houses, and average outdoor temperature. The result is a total seasonal saving of 401 kWh, or 15% of the total amount used in the control house for the season.

The CCHT houses had their windows closed and the A/C under thermostat control for the entire cooling season. Occupants of similar houses may open and close windows to control temperatures, only using the A/C when necessary. They would incur smaller cooling loads that may lead to smaller savings. On the other hand, when the A/C is not in use, the awnings would keep indoor temperatures lower, so the A/C might be used less often. Then, awnings should still save cooling energy, although it is not possible to estimate the amount here.

Temperatures

The awnings caused room temperatures to be lower, both in rooms with awnings and those without. For example, the master bedroom on the second floor had an awning during the experiment. During benchmarking, most of the maximum daily temperatures were above the 24°C setpoint. With awnings on the experimental house, only 7 of 24 daily maximums were above 24°C, while in the control house 19 of them were. Results are similar for another bedroom on the north side of the house that did not have awnings. In the living room, on the ground floor near the thermostat, the daily maximums are closer to the setpoint, but its awning still produced significantly cooler temperatures. Other rooms on the ground floor (north side, no awnings) show smaller reductions. Cooler temperatures due to the awning are also shown by analysis of temperature bins and probabilities, which are based on all hourly temperatures, rather than daily maximums. Cooler temperatures in rooms without awnings may be due to continuous circulation of air by the furnace fan, or to reduction of the cooling load, which would allow the A/C to better cool the entire house.

The fact that temperatures on the second floor are higher is probably due to the buoyancy of warm air, and to the difficulty of blowing denser cold air to the upstairs. This is generally believed to be common in multi-storey houses with one thermostat (one zone); basements are generally cooler, while the upstairs tends to be warmer.

In summary, awnings significantly reduced temperatures in rooms with awnings, and in most of the rooms without them. Without awnings, maximum temperatures were often higher than the setpoint. This indicates that in houses with enough cooling and circulation capacity, for example, zoned houses, the awnings could further reduce cooling energy. As mentioned, the CCHT house is probably typical of most houses, in that the second floor is often warmer. Therefore, occupants of most (unzoned) houses that install awnings on south-facing windows can expect to benefit from both lower cooling bills and lower temperatures. Houses with zoned heating and cooling systems could expect further reductions in cooling bills.

Light levels

Light levels are measured as illuminance, the unit of which is the lux (lx), which is equal to one lumen/m^2, or 0.0929 footcandles. Typical levels are:[3]

Condition	Illumination (lx)
Sunlight	108,000
Full daylight	10,800
Overcast day	1,080
Twilight	10.8
Full moon	0.108
Starlight	0.0011

Recommended light levels for residences vary from 50 to 500 lx, depending on the age of the occupants, and the reflectivity of the surroundings. The central recommendations are 75 lx for general activities, and 300 lx for reading magazines.[4]

With no awnings, the living room in the experiment house received more light than the control on both sunny and cloudy days as shown in figure 4.

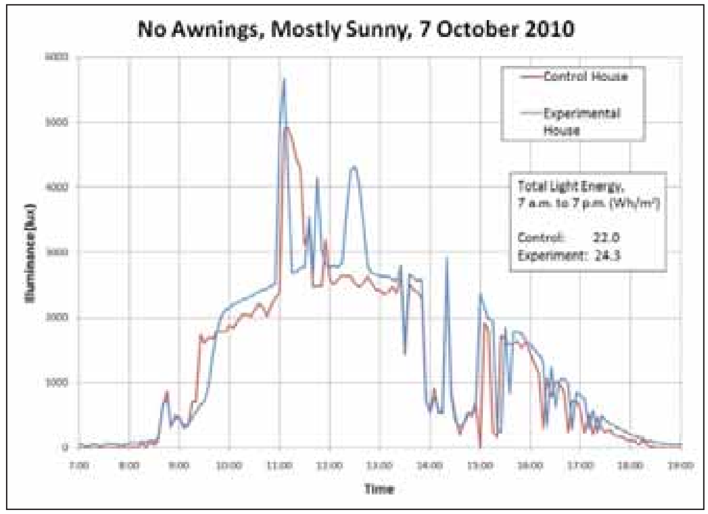

Figure 4 Light levels on a mostly sunny day with no awnings.

However, the awning generally reduced the light level significantly. On a typical sunny day, both the control and experiment houses were above the 75 lx level for the same amount of time, but the house with the awning was above 300 lx for three hours less (*see* figure 5). On a typical cloudy day, the differences were even greater.

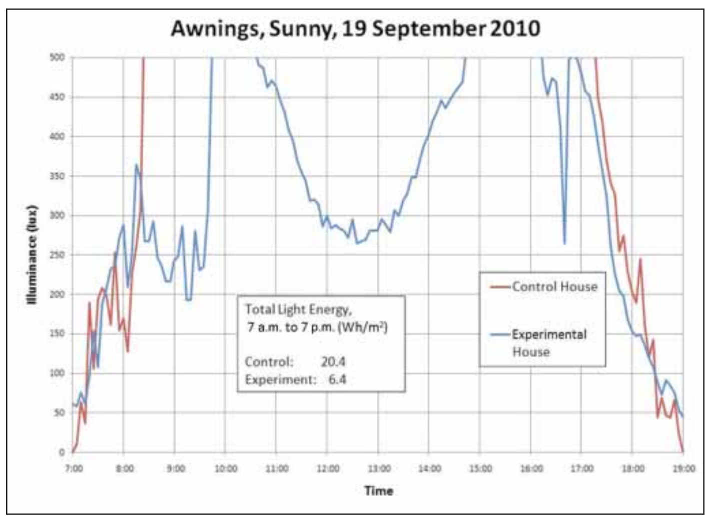

Figure 5 Light levels on a sunny day with awnings on the experimental house.

[3] Engineering Toolbox. www.engineeringtoolbox.com/light-level-rooms-d_708.html

[4] IESNA. Illuminating Engineering Society of North America. *Lighting Handbook*, 8th Edition, New York. 1993.

The control house received more than twice the total light energy, with forty-five minutes more above 75 lx, and five hours more above 300 lx as compared to the experimental house. In fact, the experimental house never reached 300 lx (*see* figure 6).

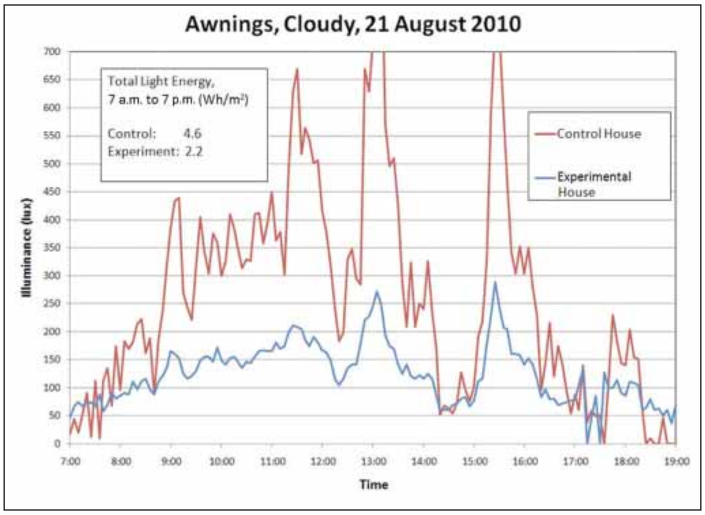

Figure 6 Light levels on a cloudy day with awnings on the experimental house.

Thus, awnings significantly reduce light levels, and significantly increase the amounts of time that illuminance is below recommended levels. The effects this will have on occupants will depend on factors that cannot be predicted. These include whether occupants are in the rooms during times of low light, what activities they are engaged in, and their subjective reactions to the light levels. It is likely that some will find the reduced light unacceptable, and will turn on lights, thus negating some of the energy savings. More lighting will increase energy use directly, and also by increasing cooling loads. However, since savings due to awnings are around three kWh per day, it is unlikely that occasional extra lighting would negate a significant amount of the energy savings, especially in energy-efficient houses with energy-efficient lighting. It should also be noted that other shading devices will probably block light, and also views of the outside, more than awnings do, although light levels with other devices, such as rollshutters, were not measured.

LIMITATIONS OF THIS STUDY

Savings from awnings will vary depending on the house, types of windows, number of windows shaded, and awning geometry. Care should be taken in applying these results to other houses, due to some of the specific attributes and features of the CCHT facility. These include the following:

- The CCHT houses were designed to maximize the southern exposure of windows, and thereby solar gains. This reduces winter heating loads, but also increases summer cooling requirements. Houses with smaller south window areas are likely to get less benefit from awnings.
- All the windows of the CCHT twin houses are double-pane, argon-filled, with a low-emissivity coating on the exterior face of the interior pane of glass (surface three). The effects of awnings on other types of windows can be expected to be different.
- The CCHT houses were built to the R-2000 standard. Therefore, they prevent heat gains and losses better than most houses. In older, less insulated and less airtight construction, solar heat gains through windows may be less significant, compared to heat gains due to outdoor temperatures.
- Only three south-facing windows had awnings in this study. Shading the remaining south window, east and especially west windows could also have a significant effect on cooling loads.
- The CCHT houses are not furnished. With no furnishings, the interiors have less thermal mass than typical inhabited houses. Thus, the CCHT houses would respond more quickly to changes in solar gains and outdoor temperatures.
- As mentioned, the CCHT houses were operated in air conditioning mode for the entire cooling season. Many occupants shut off the cooling system periodically, and open windows on cool nights or days. In such cases, actual seasonal savings could be lower than projections from this study.

CONCLUSIONS

This study showed that retractable canvas awnings can provide significant reductions in energy use for cooling, while also lowering temperatures in rooms with and without the awnings. On the other hand, awnings significantly lower light levels in the room with awnings.

IMPLICATIONS FOR THE HOUSING INDUSTRY

As houses become more energy-efficient, the hardware and technologies required to achieve further savings tend to suffer from diminishing returns. For example, additional thicknesses of insulation cost the same as previous ones, while producing smaller energy savings. Generally, active renewable energy systems are only cost-effective when other measures are well past their points of diminishing returns, and can be very limited by available space, exposure and orientation. Therefore, maximizing free passive solar space heating should be a major objective in any building project. If a house is well exposed, and can be built with a southern orientation, then the main limiting factor on passive solar is overheating, especially during the cooling season.

Interior blinds, shades and curtains have been shown to be ineffective at reducing cooling loads. Fixed overhangs do not provide any net benefit to annual heating and cooling loads.

Other studies have found that exterior rollshutters and close-weave screens reduce cooling loads more than awnings, and have other benefits. However, they are unconventional, and probably reduce light levels more than awnings do.
For these reasons, awnings may be the best choice for many homeowners to reduce cooling loads in summer.

The main implication of this study is that houses can be designed to receive significant passive solar gains and the associated risks of overheating can be mitigated by the use of retractable exterior awnings. Retractable awnings allow full solar gains through windows in the heating season and prevent the heat gains in the cooling season. Awnings have a good chance of being accepted by homeowners because of their conventional appearance.

For more information about the CCHT twin-house research facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca.

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